# NFPA® 52

# Vehicular Gaseous Fuel Systems Code

# 2010 Edition

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

## IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA® DOCUMENTS
## NOTICE AND DISCLAIMER OF LIABILITY CONCERNING THE USE OF NFPA DOCUMENTS

NFPA® codes, standards, recommended practices, and guides ("NFPA Documents"), 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 Documents.

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 Documents. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making NFPA Documents 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 Documents. 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.

## IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA DOCUMENTS

## ADDITIONAL NOTICES AND DISCLAIMERS

### Updating of NFPA Documents

Users of NFPA codes, standards, recommended practices, and guides ("NFPA Documents") 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. An official NFPA Document 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 Documents

A statement, written or oral, that is not processed in accordance with Section 6 of the Regulations Governing Committee Projects 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 Document. The users of NFPA Documents 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 Documents.

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 Document 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 Documents 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 Documents are copyrighted by the NFPA. 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 Documents 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 Documents, contact NFPA at the address below.

### For Further Information

All questions or other communications relating to NFPA Documents 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 documents 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.

# NFPA® 52

# Vehicular Gaseous Fuel Systems Code

## 2010 Edition

This edition of NFPA 52, *Vehicular Gaseous Fuel Systems Code*, was prepared by the Technical Committee on Vehicular Alternative Fuel Systems, and acted on by NFPA at its June Association Technical Meeting held June 8-11, 2009, in Chicago, IL. It was issued by the Standards Council on August 6, 2009, with an effective date of August 26, 2009, and supersedes all previous editions.

This edition of NFPA 52 was approved as an American National Standard on August 26, 2009.

## Origin and Development of NFPA 52

While compressed natural gas (CNG) vehicles have been used extensively in other countries since the late 1940s, it was not until the late 1970s that their use in the United States became extensive enough to warrant preparation of a national standard.

Between 1980 and 1982, a committee of the American Gas Association (AGA) developed a draft of a fire safety standard for vehicular fuel systems. This was based on existing worldwide standards and current U.S. practice.

In late 1981, the AGA petitioned the NFPA to establish a technical committee project on the subject. The normal NFPA solicitation of comments revealed sufficient response from various interested parties, and the Committee on Compressed Natural Gas Vehicular Fuel Systems was established by the Standards Council in July 1982.

The first edition of NFPA 52 was issued in 1984, and it was revised in 1988, 1992, 1995, and 1998.

The 2002 edition of NFPA 52 contained minor revisions, most of these in the chapter on engine fuel systems. There also were some changes made to comply with the *Manual of Style for NFPA Technical Committee Documents*. The most significant of these were reordering of chapters and numbering of definitions.

The 2006 edition of NFPA 52 was a complete revision. NFPA 57, *LNG Vehicular Fuel Systems Code*, was incorporated into NFPA 52. Additionally, the scope of the committee was expanded to include hydrogen, and new chapters were added that addressed general gaseous hydrogen requirements and equipment qualifications; service and maintenance of gaseous hydrogen engine fuel systems; gaseous hydrogen compression, gas processing, storage, and dispensing systems; and liquefied hydrogen fueling facilities.

The 2010 edition of NFPA 52 revises the committee scope so that it is better coordinated with the responsibilities of NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, with regard to hydrogen storage systems. A large number of changes have also been made to the chapters concerning hydrogen, to update to current material in NFPA documents, the *Manual of Style for NFPA Technical Committee Documents*, and acceptable performance criteria.

Paragraphs that have been extracted from NFPA 55 are shown with the extract reference in brackets [ ] at the end of the paragraph. In some cases, modifications have been made to the extracted text to use terminology appropriate for this standard, such as the term *cryogenic fluid* instead of *compressed gas*. In those instances, brackets encase the modified terms.

## Technical Committee on Vehicular Alternative Fuel Systems

**Nancy C. Pehrson,** *Chair*
CenterPoint Energy, Inc., MN [U]

**Ronald C. Adcock,** Marsh USA Inc., AZ [I]
**Herbert F. Burnett,** Burnett and Burnette, CA [SE]
**William P. Chernicoff,** U.S. Department of Transportation, DC [E]
**Ronald R. Czischke,** Underwriters Laboratories Inc., IL [RT]
**Steven Dallman,** U.S. Department of Transportation, OK [SE]
**Larry L. Fluer,** Fluer, Inc., CA [IM]
Rep. Compressed Gas Association
**Thomas J. Forsythe,** Hughes Associates, Inc., CA [SE]
**Stan R. Gornick,** American LaFrance, LLC, SC [U]
**Karen I. Hall,** National Hydrogen Association, DC [M]
**Douglas B. Horne,** DBHorne LLC, GA [M]
Rep. Clean Vehicle Education Foundation
**Thomas Joseph,** Air Products and Chemicals, Inc., PA [M]
**Joseph Labonte,** Daimler Chrysler Corporation, Canada [U]
**James P. Lewis,** ICF International, TX [SE]
**Frank E. Lynch,** Hydrogen Components, Inc., CO [M]
**Michael W. Mackey,** General Physics Corporation, CA [SE]
**Gregory A. Milewski,** Shell Oil Company, TX [M]
Rep. American Petroleum Institute
**Cris R. Morgan,** California Highway Patrol, CA [E]
**Robert E. Petsinger,** CNG Services International Inc., PA [IM]
**Gary Pope,** USA PRO & Associates LLC, CA [SE]
**Ralph Rackham,** FuelMaker Corporation, Canada [M]
**Michael F. Short,** UTC Power, CT [M]
**E. Michael Steele,** General Motors Corporation, CA [U]
Rep. Society of Automotive Engineers
**Lurae B. Stuart,** American Public Transportation Association, DC [U]
**Michael R. Swain,** University of Miami, FL [U]
Rep. U.S. Department of Energy

### Alternates

**Mervin E. Bohrer, Jr.,** Bauer Compressors, Inc., VA [M]
(Alt. to R. Rackham)
**William P. Collins,** UTC Power/Fuel Cells, CT [M]
(Alt. to M. F. Short)
**Paul M. Horgan,** California Highway Patrol, CA [E]
(Alt. to C. R. Morgan)
**Prentiss Searles,** American Petroleum Institute, DC [M]
(Alt. to G. A. Milewski)
**Hank Seiff,** Clean Vehicle Education Foundation, VA [M]
(Alt. to D. B. Horne)
**Roger A. Smith,** Compressed Gas Association, Inc., VA [IM]
(Alt. to L. L. Fluer)
**Robert A. Zeman,** Underwriters Laboratories Inc., IL [RT]
(Alt. to R. R. Czischke)

### Nonvoting

**William G. Houf,** Sandia National Laboratories, CA [U]

**Paul May,** 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 fire and explosion hazards associated with compressed natural gas (CNG), liquefied natural gas (LNG) engine fuel systems, compressed hydrogen gas ($GH_2$) engine fuel systems, and liquefied hydrogen gas ($LH_2$) engine fuel systems on vehicles of all types and for refueling stations and associated storage.

The Committee shall coordinate its documents with the Committee on the National Fuel Gas Code with respect to natural gas piping within the scope of that Committee; with the Committees on Industrial Trucks, Fire Safety for Recreational Vehicles, and Marine Fire Protection with respect to engine fuel systems and refueling stations within their scopes; the Liquefied Natural Gas Committee with respect to storage of LNG within its scope, and with the Industrial and Medical Gases Committee with respect to storage of bulk compressed or liquefied hydrogen systems within its scope.

## Contents

## NFPA 52

# Vehicular Gaseous Fuel Systems Code

## 2010 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 Documents." They can also be obtained on request from NFPA or viewed at www.nfpa.org/disclaimers.***

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

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

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 code shall apply to the design, installation, operation, and maintenance of compressed natural gas (CNG) and liquefied natural gas (LNG) engine fuel systems on vehicles of all types and for fueling vehicle (dispensing) systems and associated storage, including the following:

(1) Original equipment manufacturers (OEMs)
(2) Final-stage vehicle integrator/manufacturer (FSVIM)
(3) Vehicle fueling (dispensing) systems

**1.1.2** This code shall apply to the design, installation, operation, and maintenance of liquefied natural gas (LNG) engine fuel systems on vehicles of all types, to their associated fueling (dispensing) facilities, and to LNG to CNG facilities with LNG storage in ASME containers of 70,000 gal (265 $m^3$) or less.

**1.1.3** Vehicles and fuel supply containers complying with federal motor vehicle safety standards (FMVSSs) covering the installation of CNG fuel systems on vehicles and certified by the respective manufacturer as meeting these standards shall not be required to comply with Sections 4.4, 4.8, 4.9, and 4.10 and Chapter 6 (except Sections 6.9, 6.11, 6.12, 6.13, and 6.14).

**1.1.4** This code shall apply to the design, installation, operation, and maintenance of compressed hydrogen ($GH_2$) and liquefied compressed hydrogen ($LH_2$).

•

**1.1.5** This code shall include marine, highway, rail, off-road, and industrial vehicles.

**1.1.6** Vehicles that are required to comply with applicable federal motor vehicle safety standards covering the installation of LNG fuel systems on vehicles and that are certified by the manufacturer as meeting these standards shall not be required to comply with Chapter 11, except 11.12.8.

**1.1.7** This code shall apply to testing, service, and maintenance of $GH_2$ engine fuel systems.

**1.1.8** Vehicles that meet FMVSS requirements for hydrogen-fueled vehicles shall not be subject to this document.

### 1.2 Purpose. (Reserved)

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

**1.3.1** Unless otherwise specified, the provisions of this code are not intended to require upgrading facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the code. Where specified, the provisions of this code shall be retroactive.

**1.3.2** 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 code deemed appropriate.

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

### 1.4 Alternate Provisions.

**1.4.1** Advancements in technology and improvements in system design and equipment can result in equipment fabrication methods, component design requirements, and installation and operating practices that differ from those specified in this code.

**1.4.1.1** Such deviations or improvements can provide equivalent safety and compatible operation that meet the intent of this code.

**1.4.1.2** Such deviations shall be permitted where the authority having jurisdiction has seen evidence that a special investigation of all factors has been made and, based on sound experience and engineering judgment, has concluded that the proposed deviations meet the intent of this code.

**1.4.2** Designers, fabricators, and constructors of LNG or $LH_2$ fueling facilities shall be competent and have expertise in the design, fabrication, and construction of LNG or $LH_2$ containers, cryogenic equipment, loading and unloading systems, fire protection equipment, detection, siting, containment, piping systems, and other components of the facility.

**1.4.3** The installation of $GH_2$, LNG, and $LH_2$ systems shall be supervised by personnel familiar with proper practices with reference to their construction and use.

**1.4.4** LNG, L/CNG, CNG, hydrogen, and other gaseous/cryogenic installations shall be permitted to use alternate site distances, operating requirements, and equipment locations with validation by qualified engineer(s) with proven expertise in mechanical systems, electrical systems, gaseous storage systems, cryogenic storage systems, fire protection, and gas detection.

**1.4.4.1** The validation shall at a minimum include the following:

(1) Process safety analysis and hazard and operability studies (HAZOPS)
(2) Mitigating fire protection measures such as suppression systems
(3) Aboveground or belowground systems or vaults for the containers
(4) Fire and gas detection systems designed to interface with an emergency shutdown device (ESD)
(5) Ventilation and other facility features
(6) Drainage and impounding for the individual site as administered by qualified engineer(s) with proven expertise in these fields

**1.4.5** Vehicles compliant with FMVSS for on-road use are compliant with this code at the point in time of original manufacture.

**1.5 Units.**

**1.5.1** Metric units in this code are based on ANSI SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System.*

**1.5.2** All pressures in this document are gauge pressures, unless otherwise indicated.

**1.6 Enforcement.** This code shall be administered and enforced by the authority having jurisdiction designated by the governing authority. *(See Annex B for sample wording for enabling legislation.)*

**1.7 Training.** Persons engaged in the handling and storage of LNG, CNG, $GH_2$, $LH_2$, and L/CNG shall be trained in the hazards and properties of these materials.

## Chapter 2 Referenced Publications

**2.1 General.** The documents or portions thereof listed in this chapter are referenced within this code 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 1, *Fire Code,* 2009 edition.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2007 edition.

NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages,* 2008 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines,* 2006 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2009 edition.

NFPA 54, *National Fuel Gas Code,* 2009 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2010 edition.

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG),* 2009 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2008 edition.

*NFPA 70®, National Electrical Code®,* 2008 edition.

*NFPA 72®, National Fire Alarm and Signaling Code,* 2010 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2010 edition.

NFPA *101®*, *Life Safety Code®*, 2009 edition.

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

NFPA 259, *Standard Test Method for Potential Heat of Building Materials,* 2008 edition.

NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft,* 2010 edition.

NFPA 303, *Fire Protection Standard for Marinas and Boatyards,* 2006 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2008 edition.

NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas,* 2008 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2007 edition.

*NFPA 5000®, Building Construction and Safety Code®,* 2009 edition.

**2.3 Other Publications.**

**2.3.1 ANSI Publications.** American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/ISA PRD-1, *Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers*, 1998.

ANSI SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System*, 1997.

ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, 1979.

ANSI Z89.1, *Personal Protection — Protective Headwear for Industrial Workers — Requirements*, 1997.

**2.3.2 API Publication.** American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, 1996.

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

ANSI/ASME B31.3, *Process Piping*, 2004.

ASME *Boiler and Pressure Vessel Code*, Section VIII, X, 2004.

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

ASTM A 47, *Standard Specification for Ferritic Malleable Iron Castings*, 1995.

ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*, 1993.

ASTM A 536, *Standard Specification for Ductile Iron Castings*, 1993.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2005.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube at 750°C*, 2004.

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

CGA C-6, *Standards for Visual Inspection of Steel Compressed Gas Cylinders*, 2001.

CGA G-5.5, *Hydrogen Vent Systems*, 2004.

CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*, 2003.

CGA S-1.2, *Pressure Relief Device Standards—Part 2—Cargo and Portable Tanks for Compressed Gases,* 2005.

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

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

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

CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*, 1995.

CSA 12.54, *Breakaway Devices for Dispensing Systems*, 1999.

**2.3.7 ICC Publication.** International Code Council, 5203 Leesburg Pike, Suite 600, Falls Church, VA 22041.

ICBO *Uniform Building Code*, 1997.

**2.3.8 IHS–CSA America Publications.** International Approval Services, 15 Inverness Way East, Englewood, CO 80112.

ANSI/IAS NGV1, *Standard for Compressed Natural Gas Vehicle (NGV) Fueling Connection Devices*, 1994.

ANSI/IAS NGV2, *Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers*, 2000.

ANSI/IAS NGV 4.4, *Breakaway Devices for Dispensing Systems*, 1999.

IAS U.S. Requirement 5-96, *Basic Requirements for Natural Gas Vehicle (NGV) Fuel Containers*, 1996.

**2.3.9 NACE Publication.** National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, TX 77084.

NACE RP0169, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems,* 1996.

**2.3.10 NB Publication.** National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, OH 43229-1183.

NB-23, *National Board Inspection Code*, 2004.

**2.3.11 SAE Publications.** Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

SAE J2343, *Recommended Practice for LNG Medium and Heavy-Duty Powered Vehicles*, November 2007.

SAE J2600, *Compressed Hydrogen Surface Refueling Connection Devices*, 2002.

**2.3.12 SSPC Publications.** Steel Structures Painting Council, 4516 Henry Street, Pittsburgh, PA 15213.

SSPC-PA 1, *Shop, Field and Maintenance Painting*, 1991.

SSPC-PA 2, *Measurement of Dry Paint Thickness with Magnetic Gages*, 1991.

SSPC-SP 6, *Commercial Blast Cleaning*, 1991.

**2.3.13 CTA Publications.** Canadian Transportation Agency, Queen's Printer, Ottawa, Ontario, Canada. (Available from the Canadian Communications Group Publication Centre, Ordering Department, Ottawa, Canada K1A 059.)

*Transportation of Dangerous Goods Regulations.*

**2.3.14 U.S. Department of Transportation Publications.** 1200 New Jersey Avenue, SE, Washington, DC 20590.

DOT Specification 4L.

**2.3.15 U.S. Government Publications.** U.S. Government Printing Office, Washington, DC 20402.

Title 29, Code of Federal Regulations, Part 1910.

Title 49, Code of Federal Regulations, Parts 100–185.

Title 49, Code of Federal Regulations, Part 571.304.

**2.3.16 Other Publications.**

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

**2.4 References for Extracts in Mandatory Sections.**

NFPA 30, *Flammable and Combustible Liquids Code,* 2008 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2010 edition.

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG),* 2009 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations,* 2008 edition.

NFPA 1925, *Standard on Marine Fire-Fighting Vessels,* 2008 edition.

*NFPA 5000®, Building Construction and Safety Code®*, 2009 edition.

## Chapter 3 Definitions

**3.1 General.** The definitions contained in this chapter shall apply to the terms used in this code. 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* Code.** A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

**3.2.4 Labeled.** Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

**3.2.5* Listed.** Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

**3.2.6 Shall.** Indicates a mandatory requirement.

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

**3.3 General Definitions.**

**3.3.1 ANSI.** American National Standards Institute.

**3.3.2 Area.**

**3.3.2.1** ***Indoor Area.*** An area that is within a building or structure having overhead cover, other than a structure qualifying as "weather protection" *(See also 3.3.2.2, Outdoor Area.)* [**55,** 2010]

**3.3.2.2** ***Outdoor Area.*** An area that is not an indoor area. [**55,** 2010]

**3.3.3 ASME Code.** The American Society of Mechanical Engineers *Boiler and Pressure Vessel Code.*

**3.3.4 Buildings.** Structures, usually enclosed by walls and a roof, constructed to provide support or shelter for an intended occupancy. [**5000,** 2009]

**3.3.4.1*** ***Important Building.*** A building that is considered nonexpendable in an exposure fire. [**30,** 2008]

**3.3.5 Capacity.** The water volume of a container in liters (gallons).

**3.3.6* Cathodic Protection.** A technique to resist the corrosion of a metal surface by making the surface the cathode of an electrochemical cell. [**55,** 2010]

**3.3.7 Cathodic Protection Tester.** A person who demonstrates an understanding of the principles and measurements of all common types of cathodic protection systems applicable to metal piping and container systems who has education and experience in soil resistivity, stray current, structure-to-soil potential, and component electrical isolation measurements of metal piping and container systems. [**55**, 2010]

**3.3.8 Certified.** A formally stated recognition and approval of an acceptable level of competency, acceptable to the AHJ. [**96,** 2008]

**3.3.9 Container.** A pressure vessel, cylinder, or cylinder(s) permanently manifolded together used to store CNG, $GH_2$, LNG, or $LH_2$.

**3.3.9.1** ***Cargo Transport Container.*** A mobile unit designed to transport LNG, CNG, $GH_2$, or $LH_2$.

**3.3.9.2** ***Composite Container.*** A container consisting of an inner metal or plastic gas-containing component, reinforced with a filament and resin outer layer.

**3.3.9.3** ***Fuel Supply Container.*** A container mounted on a vehicle to store LNG, CNG, $LH_2$, or $GH_2$ as the fuel supply to the vehicle.

**3.3.9.4** ***Fueling Facility Container.*** Primary storage for vehicular fueling.

**3.3.10 Container Appurtenances.** Devices connected to container openings for safety, control, or operating purposes.

**3.3.11 Container Valve.** See 3.3.62.1.

**3.3.12 Corrosion Expert.** A person who, by reason of knowledge of the physical sciences and the principles of engineering acquired through professional education and related practical experience is qualified to engage in the practice of corrosion control of container systems. [**55,** 2010]

**3.3.13 Corrosion Protection.** Protecting a container, piping, or system to resist degradation of the metal through oxidation or reactivity with the environment in which it is installed. [**55,** 2010]

**3.3.14 Cylinder.** A container constructed, inspected, and maintained in accordance with DOT and Transport Canada regulations or ANSI/IAS NGV2, *Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers.*

**3.3.15 Device.**

**3.3.15.1** ***Emergency Shutdown Device (ESD).*** A device that closes all operations within the fueling facility from either local or remote locations.

**3.3.15.2** ***Fixed Liquid Level Device.*** A device that indicates when the container is filled to its maximum permitted filling volume.

**3.3.15.3** ***Pressure Relief Device (PRD).*** A device designed to open to prevent a rise of internal pressure in excess of a specified value due to emergency or abnormal conditions. The device can be of the reclosing or other type, such as one having a rupture disk or fusible plug that requires replacement after each use.

**3.3.16* Dew Point (at Container Pressure).** The dew point value of the gas at the maximum anticipated container pressure of the CNG or $GH_2$ vehicular fuel system usually measured in the container prior to pressure reduction.

**3.3.17 Dike.** A structure used to establish an impounding area or containment.

**3.3.18 Dispensing Station.** A natural gas or hydrogen installation that dispenses CNG, LNG, $GH_2$, or $LH_2$ from storage containers or a distribution pipeline into vehicular fuel supply containers or into portable cylinders by means of a compressor, reformer, vaporizer, or pressure booster.

**3.3.19 DOT.** U.S. Department of Transportation.

**3.3.20 Enclosure.** A structure that protects equipment from the environment or provides noise attenuation.

**3.3.20.1** ***Dispenser Enclosure.*** A cabinet that contains process piping and equipment for dispensing fuel.

**3.3.21 Engine Compartment (on a marine vessel).** An engine space on a marine vessel that is too small for an individual to enter.

**3.3.22 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.

**3.3.23 Fast-Fill Fueling.** A fueling operation in which the dispensing system is designed to fill motor vehicle fuel tanks with compressed, gasified hydrogen ($GH_2$) where the vehicle fuel tank is filled at a rate exceeding 12 scf/min (0.34 SCM/min).

**3.3.24 Flame Spread Index.** A comparative measure, expressed as a dimensionless number, derived from visual measurements of the spread of flame vs. time for a material tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, or with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials.*

**3.3.25 Fuel Line.** The pipe, tubing, or hose on a vehicle, including all related fittings, through which natural gas or hydrogen passes.

**3.3.26 Fueling Nozzle.** A mating device at the refueling station, including shutoff valves, that connects the fueling dispenser hose to the vehicle fuel filling system receptacle for the transfer of liquid or vapor.

**3.3.27 Fueling Receptacle.** The mating part of the fueling connector mounted on a vehicle.

**3.3.28 Gaseous Fuels.** All combinations of gaseous natural gas, hydrogen, propane, ethane, and butane commonly used as automotive fuels as they pertain to refueling sites, onboard fuel systems, safety, dispensing, and vehicle onboard use regardless of the fuel combinations.

**3.3.29 Hydrogen ($H_2$).** Hydrogen in gaseous or liquid form for use as a vehicular fuel.

**3.3.29.1** ***$GH_2$.*** Hydrogen in a gaseous form.

**3.3.29.2** ***$LH_2$.*** Hydrogen in a liquid form normally stored below its critical pressure (190.43 psi).

**3.3.30 Hydrogen Generator.** A packaged or factory matched hydrogen gas generation device that (a) uses electrochemical reactions to electrolyze water to produce hydrogen and oxygen gas (electrolyzer) and (b) converts hydrocarbon fuel to a hydrogen-rich stream of composition and conditions suitable for the type of device (e.g., fuel cells) using the hydrogen (reformer).

**3.3.31 Ignition Source.** Any item or substance capable of an energy release of type and magnitude sufficient to ignite any flammable mixture of gases or vapors that could occur at the site or onboard the vehicle.

**3.3.32 Impounding Area.** An area that can be defined through the use of containment or the topography at the site for the purpose of containing any accidental spill of LNG, $LH_2$, or flammable refrigerants.

**3.3.33* Installation.** A system that includes natural gas or hydrogen containers, pressure booster, compressors, vaporizers, and all attached valves, piping, and appurtenances.

**3.3.34 Liquefied Natural Gas (LNG).** A fluid in the cryogenic liquid state that is composed predominantly of methane.

**3.3.34.1*** ***Saturated LNG Gas.*** Preheated LNG held under pressure and released to atmosphere as a gas.

**3.3.35 Lower Flammability Limit (LFL).** That concentration of a combustible material in air below which ignition will not occur.

**3.3.36 Material.**

**3.3.36.1** ***Combustible Material.*** A material that, in the form in which it is used and under the conditions anticipated, will ignite, burn, support combustion, or release flammable vapors when subjected to fire of heat, when tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C.*

**3.3.36.2*** ***Limited-Combustible Material.*** As applied to a material of construction, any material that does not meet the definition of noncombustible, as stated elsewhere in this section, and that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) when tested in accordance with NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, and also meets one of the following: (1) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of 0.13 in. (3.2 mm) that has a flame spread index not greater than 50, when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.* (2) Materials, in the form and thickness used and not described by (1), having neither a flame spread index greater than 25 nor evidence of continued progressive combustion and having such composition that surfaces that would be exposed by cutting through the material in any plane have neither a flame spread index greater than 25 nor evidence of continued progressive combustion, when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

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

**3.3.37 Maximum Filling Volume.** The maximum volume to which a liquid-containing vessel could be filled.

**3.3.38 Metallic Hose.** A hose whose strength depends primarily on the strength of its metallic parts; it can have metallic liners or covers, or both.

**3.3.39 Mobile Refueling.** A DOT-approved vehicle with tank(s) and pump(s) that dispenses engine fuel directly to vehicles.

**3.3.40 Natural Gas.** Mixtures of hydrocarbon gases and vapors consisting principally of methane in gaseous form.

**3.3.40.1** ***Compressed Natural Gas (CNG).*** Mixtures of hydrocarbon gases and vapors consisting principally of methane in gaseous form that has been compressed for use as a vehicular fuel.

**3.3.41 Operating Company.** The individual, partnership, corporation, public agency, or other entity that owns or operates a plant or site.

**3.3.42* Original Equipment Manufacturer (OEM).** Any vehicle manufacturer or importer that is subject to DOT regulations and first introduces a vehicle for sale.

**3.3.43 Overhead (Marine).** The unfinished area in the top of a room or compartment but not a ceiling.

**3.3.44 Overpressure.** The pressure in a blast wave above atmospheric pressure, or a pressure within a containment structure that exceeds the maximum allowable working pressure of the containment structure.

**3.3.45 Piping.** A means of transporting natural gas or hydrogen. This term applies to refueling facilities.

**3.3.46 Point of Transfer.** The location where connections and disconnections are made.

**3.3.47 Pressure.**

**3.3.47.1** ***Compression Discharge Pressure.*** The varying pressure at the point of discharge from the compressor.

**3.3.47.2** ***Maximum Allowable Working Pressure (MAWP).*** The maximum pressure to which any component or portion of the pressure system can be subjected over the entire range of design temperatures. This value is 1.1 × 1.25 × the service pressure.

**3.3.47.3** ***Operating Pressure.*** The varying pressure in a fuel supply container during normal container use.

**3.3.47.3.1*** ***Maximum Operating Pressure.*** The steady-state gauge pressure at which a part or system normally operates. This value is 1.25 × the pressure.

**3.3.47.4** ***Service Pressure.*** The settled gas pressure at a uniform gas temperature of 70°F (21°C) in CNG systems, and at 59°F (15°C) for $GH_2$ systems when the equipment is fully charged with gas.

**3.3.47.5** ***Set Pressure.*** The start-to-discharge pressure for which a relief valve is set and marked.

**3.3.47.6** ***Settled Pressure.*** The pressure in a container after the temperature of the gas reaches equilibrium.

**3.3.47.7** ***Storage Pressure.*** The varying pressure in the storage containers.

**3.3.48 Pressure Regulator.** A device, either adjustable or nonadjustable, for controlling and maintaining, within acceptable limits, a uniform outlet pressure.

**3.3.49 Pressure Relief Device Channels.** The passage or passages beyond the operating parts of the pressure relief device through which fluid passes to reach the atmosphere.

**3.3.50 Pressure Vessel.** A container or other component designed in accordance with the ASME *Boiler and Pressure Vessel Code* or CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code.*

**3.3.51 Remotely Located, Manually Activated Shutdown Control.** A control system that is designed to initiate shutdown of the flow of gases or liquids and that is manually activated from a point located some distance from the delivery system.

**3.3.52 Residential CNG Fueling Facility (RFF-CNG).** An assembly with a capacity not exceeding 5 scf/min (0.14 SCM/min) of natural gas, that can be used for fueling a vehicle at a home or residence.

**3.3.53 Residential $GH_2$ Fueling Facility (RFF-$GH_2$).** An assembly with a capacity not exceeding 18 scf/min (0.5 SCM/min) of $GH_2$, that generates and compresses hydrogen and that can be used for fueling a vehicle at a home or residence.

**3.3.54 Room.**

**3.3.54.1** ***Engine Room (on a marine vessel).*** An engine space on a marine vessel that is large enough for an individual to enter.

**3.3.54.2** ***Tank Room.*** A space on a marine vessel dedicated for fuel tanks that is large enough for an individual to enter.

**3.3.55 Standard Cubic Foot (scf) of Gas.** Cubic foot of gas at an absolute pressure of 14.7 psi (101 kPa) and a temperature of 70°F (21°C). [**55,** 2010]

**3.3.56 Space.**

**3.3.56.1** ***Accommodation Space.*** Space designed for human occupancy as living space for persons aboard a vessel.

**3.3.56.2** ***Control Space.*** Space on a marine vessel in which the vessel's radio, the main navigation equipment, or the emergency source of power is located or in which the fire control equipment, other than fire-fighting control equipment, is centralized.

**3.3.56.3** ***Gas-Dangerous Space.*** An enclosed or semi-enclosed space on a marine vessel in which piping contains compressed natural gas or where fuel containers or the engine room or compartment is located.

**3.3.56.4** ***Gas-Safe Space.*** Any space on a marine vessel that is not a gas-dangerous space.

**3.3.56.5** ***Service Space.*** Space on a marine vessel outside the cargo area that is used for a galley; a pantry containing cooking appliances, lockers, or storerooms; workshops (except those workshops located in machinery spaces); and other similar spaces and access trunk to those spaces.

**3.3.57 System.**

**3.3.57.1*** ***Bulk Hydrogen Compressed Gas System.*** An assembly of equipment that consists of, but is not limited to, storage containers, pressure regulators, pressure relief devices, compressors, manifolds, and piping, with a storage capacity of more than 400 $ft^3$ (scf) (11 $m^3$) of compressed hydrogen gas, including unconnected reserves on hand at the site, and that terminates at the source valve. [**55,** 2010]

**3.3.57.2*** ***Bulk Liquefied Hydrogen Gas System.*** An assembly of equipment that consists of, but is not limited to, storage containers, pressure regulators, pressure relief devices, vaporizers, liquid pumps, compressors, manifolds, and piping, with a storage capacity of more than 39.7 gal (150 L) of liquefied hydrogen, including unconnected reserves on hand at the site, and that terminates at the source valve. [**55,** 2010]

**3.3.57.3** ***Cascade Storage System.*** Storage in multiple pressure vessels, cylinders, or containers, which can be at different pressures, such that fueling is normally done initially from lower pressure containers and completed from higher pressure containers.

**3.3.57.4** ***Fuel Dispenser System.*** All the pumps, meters, piping, hose, and controls used for the delivery of fuel to, and the removal of vapor from, a vehicle.

**3.3.57.5** ***Gas Detection System.*** One or more sensors capable of detecting natural gas or hydrogen at specified concentrations and activating alarms and safety systems.

**3.3.57.6** ***Metal Hydride Storage System.*** A system for the storage of hydrogen gas in metal hydride material.

**3.3.57.7*** ***Piping System.*** Interconnected piping consisting of mechanical components suitable for joining or assembly into pressure-tight fluid-containing system. Components include pipe, tubing, fittings, flanges, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, in-line portions of instruments, and wetted components other than individual pieces or stages of equipment. [**55,** 2010]

**3.3.58 Tank Compartment.** A space on a marine vessel that is dedicated for fuel tanks and is too small for an individual to enter.

**3.3.59 TC.** Transport Canada.

**3.3.60 Temperature Compensation.** A process that allows the gauge pressure in a container at the actual present gas temperature to be calculated so that the quantity of gas contained is the same as will be in the container at a specified settled pressure at a specified temperature.

**3.3.61 Validation.** Verification by responsible individuals as indicated in the code text where the requirement appears.

**3.3.62 Valve.**

**3.3.62.1** ***Container Valve.*** A valve connected directly to a container outlet.

**3.3.62.2*** ***Source Valve.*** A shut-off valve on the piping system serving a bulk gas supply system where the gas supply, at service pressure, first enters the supply line. [**55,** 2010]

**3.3.63 Vaporizer.** A device other than a container that receives LNG or $LH_2$ in liquid form and adds sufficient heat to convert the liquid to a gaseous state, or a device used to add heat to LNG or $LH_2$ for the purpose of saturating LNG or $LH_2$.

**3.3.63.1** ***Ambient Vaporizer.*** A vaporizer that derives heat for vaporization from a naturally occurring heat source such as the atmosphere, seawater, or geothermal waters. If the naturally occurring heat source is separated from the actual vaporizing heat exchanger and a controllable heat transport medium is used between the heat source and the vaporizing exchanger, the vaporizer shall be considered to be a remote heated vaporizer.

**3.3.63.2** ***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.

**3.3.63.2.1** ***Integral Heated Vaporizer.*** A vaporizer, including submerged combustion vaporizers, in which the heat source is integral to the actual vaporizing exchanger.

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

**3.3.64 Vehicle.** A device or structure for transporting persons or things; a conveyance (e.g., automobiles, trucks, marine vessels, railroad trains).

**3.3.65 Vehicle Fueling Appliance (VFA).** A listed, self-contained system that compresses natural gas or that generates and compresses hydrogen and dispenses the natural gas or hydrogen to a vehicle's engine fueling system.

**3.3.66 Vehicular Fuel.** Fuel stored on board a vehicle.

**3.3.67 Water Capacity.** The amount of water at 60°F (16°C) required to fill a container.

**3.3.68 Weather Deck.** Any deck that is exposed to the weather and normally accessible to personnel and that permits walking or moving around outboard of the superstructure. [**1925**, 2008]

## Chapter 4 General CNG Requirements and Equipment Qualifications

**4.1* Application.** This chapter applies only to pressurized system components handling CNG.

**4.2* Composition.** Natural gas composition in the container shall comply with 4.2.1.

**4.2.1** The contained natural gas shall be composed of the following:

(1) Hydrogen sulfide and soluble sulfides, 1 gr/100 scf (23 mg/$m^3$), maximum
(2) Water ($GH_2O$), 7.0 lb/MMScf (110 mg/$m^3$), maximum
(3) Carbon dioxide, 3.0 volume percent, maximum
(4) Oxygen, 0.5 volume percent, maximum

*Exception: Where the dew point of the natural gas entering the cylinder is below the lowest anticipated container temperature at the maximum anticipated container pressure, no limits shall apply.*

**4.2.1.1** Natural gas introduced into any system covered by this code shall have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over one-fifth of the lower limit of flammability. Natural gas or blends not meeting this definition shall have site and onboard methane detection systems installed and certified by a qualified engineer with expertise in methane detection or fire protection.

**4.2.1.2** Methanol and/or glycol shall not be deliberately added to the natural gas at the fueling station.

**4.2.1.3** Recognizing that the natural gas supplied to the vehicle might not always be in compliance with 4.2.1, containers shall be designed to tolerate being filled with natural gas meeting both of the following conditions:

(1) Dry gas in which water vapor would normally be limited to less than 2 lb/MMScf (32 mg/$m^3$), a pressure dew point of 7°F (−9°C) at 3000 psi (20,700 kPa). There would be no maximum constituent limits for dry gas, except for the following:
  (a) $GH_2S$, 1 gr/100 scf (23 mg/$m^3$)
  (b) $O_2$, 1 percent by volume
(2) Wet gas in which gas that contains 2 lb/MMScf (32 mg/$m^3$) of water or more normally meets the following maximum constituent limits:
  (a) $GH_2S$ and other soluble sulfides, 1 gr/100 scf (23 mg/$m^3$)
  (b) Total sulfur, 5 gr/MMScf (115 mg/$m^3$)
  (c) $O_2$, 1 percent by volume
  (d) $CO_2$, 3 percent by volume
  (e) Hydrogen, 0.1 percent by volume

**4.2.1.4** Under wet gas conditions, a minimum of 0.007 grains of compressor oil per pound of gas (1 mg of compressor oil per kilogram of gas) shall be considered necessary to protect metallic containers, liners, and bosses.

**4.3 System Approvals.**

**4.3.1** The following systems and system components shall be listed or approved:

(1) Pressure relief devices, including pressure relief valves
(2) Pressure gauges
(3) Pressure regulators
(4) Valves
(5) Hose and hose connections
(6) Vehicle fueling connections (nozzle and receptacle)
(7) Engine fuel systems
(8) Electrical equipment related to CNG systems
(9) Gas detection equipment and alarms
(10) Fire protection and suppression equipment

*Exception: Vehicles certified by the manufacturer to be in compliance with applicable federal motor vehicle safety standards.*

**4.3.2** Devices not otherwise specifically provided for shall be constructed to provide safety equivalent to that required for other parts of a system.

**4.4* Design and Construction of Containers.**

**4.4.1** Containers shall be fabricated of steel, aluminum, or composite materials.

**4.4.2** The container shall be designed for CNG service and shall be permanently marked "CNG" by the manufacturer.

**4.4.3** Containers manufactured prior to the effective date of this code shall be permitted to be used in CNG service if recommended for CNG service by the container manufacturer or if approved by the authority having jurisdiction.

**4.4.4*** Cylinders shall be manufactured, inspected, marked, tested, retested, equipped, and used in accordance with the following:

(1) U.S. Department of Transportation (DOT) or Transport Canada (TC) regulations, exemptions, or special permits
(2) ANSI/IAS NGV2, *Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers*, specifically for CNG service
(3) CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*
(4) U.S. Federal Motor Vehicle Safety Standard, 49 CFR 571.304, *Compressed Natural Gas Fuel Container Integrity*

**4.4.4.1** Cylinders that have reached the labeled expiration date shall be removed from service.

**4.4.4.2*** Composite reinforced cylinders or other cylinders marked with exemption or special permit numbers shall be removed from service at the end of the service life designated in the exemption or special permit.

**4.4.5 ASME Compliance.**

**4.4.5.1** Pressure vessels shall be manufactured, inspected, marked, and tested in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII or Section X.

**4.4.5.2** Adherence to applicable ASME *Boiler and Pressure Vessel Code* case interpretations and addenda shall be considered as compliant with the ASME *Boiler and Pressure Vessel Code.*

**4.4.5.3*** Pressure vessels manufactured to the requirements of the ASME *Boiler and Pressure Vessel Code* shall be registered with the National Board of Boiler and Pressure Vessel Inspectors.

**4.4.6** The + (plus) and * (star) markings on DOT and TC cylinders shall not apply in accordance with DOT and TC regulations for cylinders for flammable compressed gases.

**4.4.6.1** The star marking shall be removed or obliterated.

**4.4.6.2** The removal of the star marking shall be by peening and otherwise shall be in accordance with DOT or TC regulations.

**4.4.6.3** Grinding shall be prohibited.

**4.4.7** The repair or alteration of an ASME pressure vessel shall comply with the requirements of the NB-23, *National Board Inspection Code.*

**4.4.7.1** Other welding or brazing shall be permitted only on saddle plates, lugs, or brackets attached to the pressure vessel by the pressure vessel manufacturer.

**4.4.7.2** The exchange or interchange of pressure vessel appurtenances intended for the same purpose shall not be considered a repair or alteration.

**4.5 Pressure Relief Devices (PRDs).** *(See Annex C.)*

**4.5.1** Each cylinder complying with 4.4.4 shall be fitted with one or more pressure relief devices (PRDs) with the number, location, and part number as specified by the cylinder manufacturer and OEM for CNG service for a new vehicle, in accordance with the following:

(1) For a retrofitted vehicle, each cylinder complying with 4.4.4 shall be of the number, location, and part number as specified by the cylinder manufacturer.
(2) A PRD shall be in accordance with one of the following standards:
   (a) CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*
   (b) IAS U.S. Requirement 5-96, *Basic Requirements for Natural Gas Vehicle (NGV) Fuel Containers*
   (c) ANSI/ISA PRD-1, *Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers*
(3) The PRD shall be in direct communication with the fuel and shall be vented to the atmosphere by a method that can withstand the maximum pressure that results.

**4.5.1.1** The discharge flow rate of the PRD shall not be reduced below that required for the capacity of the container upon which the device is installed.

**4.5.1.2** PRDs shall be located so that the temperature to which they are subjected shall be representative of the temperature to which the fuel supply container is subjected.

**4.5.1.3** Where parts of the vehicular fuel container can be exposed to higher temperatures than the PRD during a localized fire, the fuel container shall be protected by any of the following:

(1) Noncombustible heat-insulating shielding to retard localized heating of the container
(2) Installation of a thermally sensitive "fusing" system to trigger the PRD in a fire situation
(3) Other design for venting of the fuel container in a fire situation

**4.5.2** Pressure vessels complying with 4.4.5 or cylinders used for stationary storage without temperature compensation of the storage pressure shall be protected with one or more spring-loaded pressure relief valves in accordance with the ASME *Boiler and Pressure Vessel Code.*

**4.5.2.1** The minimum rate of discharge of PRDs on containers shall be in accordance with CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*, or the ASME *Boiler and Pressure Vessel Code*, whichever is applicable.

**4.5.2.2** Pressure relief valves (PRVs) for CNG service shall not be fitted with lifting devices.

**4.5.2.2.1** The adjustment, if external, shall be provided with a means for sealing the adjustment to prevent tampering.

**4.5.2.2.2** If at any time it is necessary to break such a seal, the valve shall be removed from service until it has been reset and sealed.

**4.5.2.2.3** Adjustments shall be made only by the manufacturer or other companies having competent personnel and facilities for the repair, adjustment, and testing of such valves.

**4.5.2.2.4** The organization making such adjustment shall attach a permanent tag with the setting, capacity, and date.

**4.5.2.3** PRVs protecting ASME pressure vessels shall be repaired, adjusted, and tested in accordance with NB-23, *National Board Inspection Code.*

**4.5.3** Containers and pressure vessels not constructed in accordance with 4.4.4 or 4.4.5 shall be provided with PRDs approved by the authority having jurisdiction.

**4.6 Pressure Gauges.** A pressure gauge, if provided, shall be capable of reading at least 1.2 times the system design pressure.

**4.7 Pressure Regulators.**

**4.7.1** A pressure regulator inlet and each chamber shall be designed for its service pressure with a pressure safety factor of at least 4.

**4.7.2** Low-pressure chambers shall provide for overpressure relief or shall be able to withstand the service pressure of the upstream pressure chamber.

**4.8 Fuel Lines.**

**4.8.1** Pipe, tubing, fittings, gaskets, and packing material shall be compatible with the fuel under the maximum service conditions.

**4.8.2** Pipe, tubing, fittings, and other components shall be designed with a minimum safety factor of 3.

**4.8.3** Natural gas piping shall be fabricated and tested in accordance with ANSI/ASME B31.3, *Process Piping*.

**4.8.4** The following components shall not be used for CNG service:

(1) Fittings, street els, and other piping components of cast irons other than those complying with ASTM A 47, *Standard Specification for Ferritic Malleable Iron Castings (Grade 35018)*; ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures;* and ASTM A 536, *Standard Specification for Ductile Iron Castings (Grade 60-40-18)*
(2) Plastic pipe, tubing, and fittings for high-pressure service
(3) Galvanized pipe and fittings
(4) Aluminum pipe, tubing, and fittings
(5) Pipe nipples for the initial connection to a container
(6) Copper alloy with copper content exceeding 70 percent

**4.8.4.1** The refueling connection shall be permitted to be made of nonsparking wrought aluminum alloy designed for the pressure employed.

**4.8.4.2** Aluminum pipe, tubing, and fittings shall be permitted to be used downstream of the first-stage pressure regulator in an engine fuel system.

**4.8.5** Piping components such as strainers, snubbers, and expansion joints shall be permanently marked by the manufacturer to indicate the service ratings.

**4.9 Valves.**

**4.9.1** Valves, valve packing, and gaskets shall be designed or selected for the fuel over the full range of pressures and temperatures to which they can be subjected under normal operating conditions.

**4.9.1.1** Shut-off valves shall have a rated service pressure not less than the rated service pressure of the entire system and shall be capable of withstanding a hydrostatic test of at least four times the rated service pressure without rupture.

**4.9.1.2** Leakage shall not occur at less than one-and-a-half the rated service pressure.

**4.9.2** Valves of cast irons other than those complying with ASTM A 47, *Standard Specification for Ferritic Malleable Iron Castings (Grade 35018);* ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*; and ASTM A 536, *Standard Specification for Ductile Iron Castings (Grade 60-40-18),* shall not be used as primary stop valves.

**4.9.3** Valves of a design that allows the valve stem to be removed without removal of the complete valve bonnet or without disassembly of the valve body shall not be used.

**4.9.4** The manufacturer shall stamp or otherwise permanently mark the valve body to indicate the service ratings.

*Exception: Container valves incorporating integral PRDs complying with 4.5.1 shall not require additional marking.*

**4.10 Hose and Hose Connections.**

**4.10.1** Hose and metallic hose shall be constructed of or lined with materials that are resistant to corrosion and exposure to natural gas.

**4.10.2** Hose, metallic hose, flexible metal hose, tubing, and their connections shall be designed or selected for the most severe pressures and temperatures under normal operating conditions with a burst pressure of at least four times the service pressure.

**4.10.3** Prior to use, hose assemblies shall be tested by the OEM or its designated representative at a pressure at least twice the service pressure.

**4.10.4** Hose and metallic hose shall be distinctly marked by the OEM or component manufacturer, either by the manufacturer's permanently attached tag or by distinct markings indicating the manufacturer's name or trademark, applicable service identifier, and design pressure.

**4.11 Vehicle Fueling Connection.**

**4.11.1** CNG vehicle fueling connection devices shall be listed in accordance with ANSI/IAS NGV1, *Standard for Compressed Natural Gas Vehicle (NGV) Fueling Connection Devices*.

**4.11.2** The use of adapters shall be prohibited.

## Chapter 5 General $GH_2$ Requirements and Equipment Qualifications

**5.1* Application.** This chapter applies only to pressurized system components handling $GH_2$ at fueling stations.

**5.2 System Approvals.**

**5.2.1** The following systems and system components shall be listed or approved:

(1) (PRDs), including pressure relief valves
(2) Pressure gauges
(3) Pressure regulators
(4) Valves
(5) Hose and hose connections
(6) Vehicle fueling connections (nozzle)
(7) Metal hydride storage
(8) Electrical equipment used with $GH_2$ systems
(9) Gas detection equipment and alarms
(10) Hydrogen generators
(11) Hydrogen dispensers
(12) Pressure switches
(13) Flow meters

**5.2.2** Devices not otherwise specifically provided for shall be constructed to provide safety equivalent to that required for other parts of a system.

**5.3* Design and Construction of Containers, Cylinders, and Tanks.**

**5.3.1 General.** Containers, cylinders and tanks used for stationary storage shall be in accordance with 5.3.1.

**5.3.1.1 Design and Construction.** Containers, cylinders, and tanks shall be designed, fabricated, tested, and marked (stamped) in accordance with regulations of DOT, Transport Canada (TC) *Transportation of Dangerous Goods* Regulations, or the ASME *Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," Section VIII. [**55:**7.1.5.1]

**5.3.1.2** Containers, cylinders, and tanks shall be fabricated of materials compatible with hydrogen service.

**5.3.1.3** Containers, cylinders, and tanks shall be designed for $GH_2$ service and shall be permanently marked "Hydrogen" by the manufacturer.

**5.3.1.4** Containers, cylinders, and tanks manufactured prior to the effective date of this code shall be permitted to be used in $GH_2$ service if designated for $GH_2$ service by the container manufacturer or if approved by the AHJ.

**5.3.1.5 Supports.** Stationary cylinders, containers, and tanks shall be provided with engineered supports of noncombustible material on noncombustible foundations. [**55:**7.1.5.3]

**5.3.2 DOT Compliance.**

**5.3.2.1** Pressure vessels manufactured to DOT specifications shall not be used as stationary storage containers. *(See also NFPA 55.)*

**5.3.2.2** Pressure vessels manufactured to DOT specifications shall be in accordance with the requirements of 49 CFR, Parts 100–185. *(See also NFPA 55.)*

**5.3.3 Composite Containers and Cylinders. (Reserved)**

**5.3.4 ASME Compliance.**

**5.3.4.1** Pressure vessels shall be manufactured, inspected, marked, and tested in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII or Section X, and shall be designed for $GH_2$ service.

**5.3.4.2** Adherence to applicable ASME *Boiler and Pressure Vessel Code* case interpretations and addenda shall be considered as compliant with the ASME *Boiler and Pressure Vessel Code*.

**5.3.4.3** Welding or brazing for the repair or alteration of an ASME pressure vessel shall comply with the documents under which the pressure vessel was fabricated.

**5.3.4.3.1** Other welding or brazing shall be permitted only on saddle plates, lugs, or brackets attached to the pressure vessel by the pressure vessel manufacturer.

**5.3.4.3.2** The exchange or interchange of pressure vessel appurtenances intended for the same purpose shall not be considered a repair or alteration.

**5.4* Pressure Relief Devices.** When required by 5.4.1, pressure relief devices shall be provided to protect containers and systems containing compressed gases from rupture in the event of overpressure from thermal exposure. [**55:**7.1.5.5.1]

**5.4.1** Pressure relief devices to protect containers shall be designed and provided in accordance with CGA S-1.1, *Pressure Relief Device Standards – Part 1 – Cylinders for Compressed Gases*, for cylinders; CGA S-1.2, *Pressure Relief Device Standards – Part 2 – Cargo and Portable Tanks for Compressed Gases*, for portable tanks; and CGA S-1.3, *Pressure Relief Device Standards – Part 3 – Stationary Storage Containers for Compressed Gases*, or ASME *Boiler and Pressure Vessel Code*, Section VIII, for stationary tanks or applicable equivalent requirements in the country of use. [**55:**7.1.5.5.2]

**5.4.2** Pressure relief devices shall be sized in accordance with the specifications to which the container was fabricated. [**55:**7.1.5.5.3]

**5.4.3** The pressure relief device shall have the capacity to prevent the maximum design pressure of the container or system from being exceeded. [**55:**7.1.5.5.4]

**5.4.4** Pressure relief devices shall be arranged to discharge unobstructed to the open air in such a manner as to prevent any impingement of escaping gas upon the container, adjacent structures, or personnel. This requirement shall not apply to DOT specification containers having an internal volume of 2.0 $ft^3$ (0.057 $m^3$) or less. [**55:**7.1.5.5.5]

**5.4.5** Pressure relief devices or vent piping shall be designed or located so that moisture cannot collect and freeze in a manner that would interfere with operation of the device. [**55:**7.1.5.5.6]

**5.4.6** Pressure relief valves for $GH_2$ service shall not be fitted with lifting devices.

**5.4.6.1** The adjustment, if external, shall be provided with a means for sealing the adjustment to prevent tampering.

**5.4.6.2** If at any time it is necessary to break such a seal, the valve shall be removed from service until it has been reset and sealed.

**5.4.6.3** Adjustments shall be made only by the manufacturer or other companies having competent personnel and facilities for the repair, adjustment, and testing of such valves.

**5.4.6.4** The organization making such adjustment shall attach a permanent tag with the setting, capacity, and date.

**5.4.7** Pressure relief valves protecting ASME pressure vessels shall be repaired, adjusted, and tested in accordance with the ASME *Boiler and Pressure Vessel Code*.

**5.5 Vent Pipe Termination.**

**5.5.1** Hydrogen venting systems discharging to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*. [**55:**10.2.2]

**5.5.2** Venting of gas through PRDs shall be to an approved location.

**5.5.2.1** The termination point for piped vent systems serving cylinders, containers, tanks, and gas systems used for the purpose of operational or emergency venting shall be located to prevent impingement exposure on the system served and to minimize the effects of high temperature thermal radiation or the effects of contact with the gas from the escaping plume to the supply system, personnel, adjacent structures, and ignition sources. [**55:**6.14]

**5.6 Pressure Gauges.**

**5.6.1** A pressure gauge, if provided, shall be capable of reading at least 1.2 times the system MAWP.

**5.6.2** A gauge shall have an opening not to exceed 0.055 in. (1.4 mm) (No. 54 drill size) at the inlet connection.

**5.7 Pressure Regulators.**

**5.7.1** A pressure regulator inlet and each chamber shall be designed for its service pressure with a safety factor of at least 3.

**5.7.2** Low-pressure chambers shall provide for overpressure relief or shall be able to withstand the service pressure of the upstream pressure chamber.

**5.8 Fuel Lines.**

**5.8.1** Pipe, tubing, and fittings shall be suitable for hydrogen service and for maximum pressures and minimum and maximum temperatures.

**5.8.1.1** Pipe, tubing, fittings, gaskets, and packing material shall be compatible with the fuel under service conditions.

**5.8.1.2** Gray, ductile, and cast iron pipe and fittings shall not be used.

**5.8.2** Pipe, tubing, fittings, and other components shall be designed with a minimum safety factor of 3.

**5.8.3*** Hydrogen gas piping shall be fabricated and tested in accordance with ANSI/ASME B31.3, *Process Piping*.

**5.8.4 Piping Joints.**

**5.8.4.1** Piping joints made with tapered threaded pipe and sealant shall not be used in hydrogen service above 3000 psi (20.7 MPa).

**5.8.4.2** Tapered joints shall be allowed on systems exceeding 3000 psi (20.7 MPa) under the following conditions:

(1) Where valves or instrumentation are not available with straight threads
(2) Where tapered joints are seal welded in accordance with the requirements of ANSI/ASME B31.3, *Process Piping*

**5.8.5** Piping components such as strainers, snubbers, and expansion joints shall be permanently marked by the manufacturer to indicate the service ratings.

**5.9 Valves.**

**5.9.1** Valves, valve packing, and gaskets shall be designed or selected for the fuel over the full range of pressures and temperatures to which they can be subjected under any operating conditions.

**5.9.1.1** Shut-off valves shall have a rated service pressure not less than the rated service pressure of the entire system and shall be designed with a minimum safety factor of 3.

**5.9.1.2** Leakage shall not occur when tested to at least one-and-a-half of the rated service pressure, using an inert gas as the test medium.

**5.9.2** Valves of a design that allows the valve stem to be removed without removal of the complete valve bonnet or without disassembly of the valve body shall not be used.

**5.9.3** The manufacturer shall stamp or otherwise permanently mark the valve body to indicate the service ratings.

*Exception: Container valves incorporating integral pressure relief devices complying with Section 5.4 shall not require additional marking.*

**5.10 Hose and Hose Connections.**

**5.10.1** Hose shall be constructed of or lined with materials that are resistant to corrosion and exposure to hydrogen.

**5.10.2** Hose, metallic hose, flexible metal hose, tubing, and their connections shall be designed or selected for the most severe pressures and temperatures expected under normal operating conditions with a burst pressure of at least three times the MAWP.

**5.10.3** Prior to use, hose assemblies shall be tested by the component OEM or its designated representative at a pressure at least twice the maximum allowable pressure.

**5.10.4** Hose and metallic hose shall be distinctly marked by the manufacturer, either by the manufacturer's permanently attached tag or by distinct markings indicating the manufacturer's name or trademark, applicable service identifier, design pressure, and flow direction.

**5.11 Vehicle Fueling Connection.**

**5.11.1** Fueling nozzles for $GH_2$ service shall be listed or approved in accordance with SAE J2600, *Compressed Hydrogen Surface Refueling Connection Devices*.

**5.11.2** The use of adapters shall be prohibited.

## Chapter 6 CNG Engine Fuel Systems

**6.1* Application.**

**6.1.1** This chapter applies to the design, installation, inspection, and testing of CNG fuel supply systems for vehicular internal combustion engines.

**6.1.2* Final-Stage Vehicle Integrator/Manufacturer.**

**6.1.2.1*** The FSVIM shall have the responsibility for integration of the engine, fuel system, and gaseous detection system, where required, onto the vehicle chassis and for the safe operation of the vehicle.

**6.1.2.2** The FSVIM shall obtain, when available, documented approval of the chassis original equipment and component manufacturers of the onboard fuel and detection systems components, proper installation, and application from each of the following:

(1) Automobile
(2) Truck
(3) Bus
(4) Chassis
(5) Engine
(6) Gas detection
(7) Fuel system

**6.1.2.3** All gaseous fuel modifications of a vehicle shall conform with, when available, the engineering recommendations of the original specifications of the original chassis vehicle manufacturer.

**6.2 System Component Qualifications.**

**6.2.1** System components shall comply with the appropriate provisions in Chapter 4 and with this section.

**6.2.2 Temperature Range.**

**6.2.2.1** Components in the engine compartment shall be designed or selected for at least a minimum temperature range of −40°F to 250°F (−40°C to 121°C).

**6.2.2.2** All other components shall be designed or selected for service per the OEM's engineering requirements.

**6.2.3** Aluminum or copper pipe, tubing, or fittings shall not be used between the fuel container and the first-stage pressure regulator.

**6.2.4** Fuel-carrying components, with the exception of container valves, tubing, and fittings, shall be labeled or stamped with the following:

(1) Manufacturer's name or symbol
(2) Model designation
(3) Design service pressure
(4) Direction of fuel flow where necessary for correct installation
(5) Capacity or electrical rating, as applicable

**6.3 Installation of Fuel Supply Containers.**

**6.3.1** Fuel supply containers shall be installed in accordance with the instructions of the container manufacturer and the requirements in 6.3.2 through 6.3.12.

**6.3.2** Fuel supply containers on vehicles shall be permitted to be located within, below, or above the driver or passenger compartment, provided all connections to the container(s) are external to, or sealed and vented from, these compartments.

**6.3.2.1** Fuel supply containers shall be protected with a means to prevent damage that can occur due to road hazards, loading, unloading, direct sunlight, exhaust heat, and vehicle use, including accidental cargo leakage.

**6.3.2.2** Shields, if present, shall be installed in a manner that prevents the following occurrences:

(1) Direct contact between the shield and the fuel supply container
(2) Trapping of solid materials or liquids between the shield and fuel supply container that could damage the container or its coating

**6.3.2.3** The fuel supply container shall be positioned to prevent contact with vehicle components such as frame members, body panels, brake lines, and so forth, that can lead to container fretting or abrasion over time.

**6.3.3** Each automobile fuel supply container shall be mounted in a location to minimize damage from collision.

**6.3.3.1** No part of a container or its appurtenances shall protrude beyond the sides or top of the automobile at the point where it is installed.

**6.3.3.2** The cylinder shall be protected by covers from accidental contact with overhead electrical wiring.

**6.3.3.3** The fuel system shall be installed with as much road clearance as practical but with not less than the minimum road clearance of the vehicle when loaded to its gross vehicle weight rating.

**6.3.3.4** This minimum clearance shall be measured from the lowest part of the fuel system.

**6.3.3.5** The minimum clearance in 6.3.3.4 shall be met when the vehicle tires are deflated.

**6.3.3.6** No portion of a fuel supply container or container appurtenance mounted on the undercarriage of the vehicle shall be located ahead of the front axle or behind the point of attachment of the rear bumper to the vehicle. Container valves shall be protected from physical damage using the vehicle structure, valve protectors, or a suitable metal shield.

**6.3.3.7** No part of the fuel supply container or its appurtenances shall protrude beyond the sides or top of any vehicle where the container can be struck or punctured.

**6.3.4** Each fuel supply container rack shall be secured to the vehicle body, bed, or frame to prevent damage from road hazards, slippage, loosening, or rotation using a method capable of withstanding a static force in the six principal directions shown in Figure 6.3.4 of eight times the weight of a fully pressurized container(s).

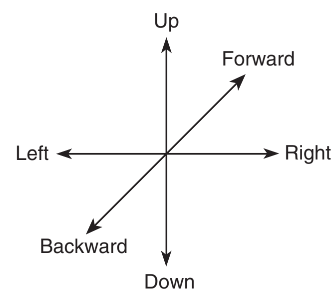



**FIGURE 6.3.4 The Six Principal Directions.**

**6.3.5** Each fuel supply container in the rack shall be secured to its cradle in a manner that it is capable of withstanding a static force, applied in the six principal directions *(see Figure 6.3.4)*, of eight times the weight of the fully pressurized container with a maximum displacement of 0.50 in. (13 mm).

**6.3.6** The fuel supply container weight shall not be supported by outlet valves, manifolds, or other fuel connections.

**6.3.7** Fuel supply containers located less than 8 in. (200 mm) from the exhaust system shall be shielded against direct heat.

**6.3.8** The mounting system shall minimize fretting corrosion between the fuel supply container and the mounting system.

**6.3.9** Fuel supply containers shall not be installed so as to adversely affect the driving characteristics of the vehicle.

**6.3.10** Metal clamping bands and their supports shall not be in direct contact with a fuel supply container.

**6.3.10.1** A resilient gasket that does not retain water shall be installed between the clamping bands and their supports and a container.

**6.3.10.2** The resilient gasket shall provide insulation to protect clamping bands from galvanic corrosion in contact with the containers.

**6.3.11** The minimum clearance from the road to a fuel supply container, its housing, or fittings, whichever is lowest where the container is installed below the frame and between the axles of a CNG vehicle, with the vehicle loaded to its gross weight rating, shall be in accordance with Table 6.3.11.

**Table 6.3.11 Fuel Supply Container (and Container Housing and Fitting) Road Clearance**

| Vehicle Wheel Base | | Minimum Road Clearance | |
|---|---|---|---|
| in. | mm | in. | mm |
| ≤127 | ≤3230 | 7 | 180 |
| >127 | >3230 | 9 | 230 |

**6.3.12** Fuel supply containers that are installed behind a rear axle of a CNG vehicle shall be installed transversely.

*Exception: Containers shall be permitted to be installed in other orientations where the container valve and fittings are located at the end of the container most protected from a source of impact.*

**6.4* Installation of Venting Systems.**

**6.4.1*** All pressure relief devices and connections between pressure-carrying components installed within driver, passenger, or a closed compartment *(see 5.2.2)* shall be vented to the outside of the vehicle.

*Exception: This requirement shall not include plugs in the ends of containers with openings in each end.*

**6.4.2** The venting system shall be secured at intervals in such a manner as to minimize the possibility of damage, corrosion, breakage, or dislocation due to gas flow forces during venting, expansion, contraction, vibration, strains, or wear and to preclude any loosening while in operation.

**6.4.3** The vent or vents for the venting system shall not exit into a wheel well.

**6.4.4** A vent shall not restrict the operation of a container pressure relief device or pressure relief device channel.

**6.4.5** Means shall be provided to prevent water, dirt, insects, and any foreign objects from collecting in the vent lines or pressure relief devices.

**6.4.6** Protective devices in 6.4.5 shall not restrict the flow of gas.

**6.4.7 Gastight Enclosures.**

**6.4.7.1** The neck of the container and all CNG fittings within the compartment shall be enclosed in a gastight enclosure made of linear, low-density polyethylene having a minimum thickness of 8 mils (0.20 mm) or an equally gastight alternate enclosure that is vented directly to the outside of the vehicle.

**6.4.7.2** The gastight enclosure shall not be constructed of fire-resistant material.

**6.4.8** Where located in a vehicle compartment capable of accumulating natural gas, a container shall be installed so that the following conditions are met:

(1) The PRD for the protection of the container is installed in the same vehicle compartment as the container.
(2) The discharge from the PRD is vented to the outside through an electrically conductive tube or hose, which shall be in accordance with the following:
    (a) The tube or hose is secured at intervals in such a manner as to minimize the possibility of damage, corrosion, or breakage of either the vent line or the pressure relief device due to expansion, contraction, vibration, strains, or wear and to preclude any loosening while in operation.
    (b) The tube or hose has a burst pressure of at least 1½ times the pressure in the vent that results from activation of the PRD.
    (c) The vent line shall not lose its gas-carrying ability when exposed to 1120°F (590°C) for 20 minutes.
(3) The vent opening is not blocked by debris thrown up from the road, such as snow, ice, mud, and so forth, or otherwise affected by the elements.

**6.5 Installation of Piping.**

**6.5.1** Manifolds connecting fuel containers shall be fabricated to minimize vibration and shall be installed in a protected location or shielded to prevent damage from unsecured objects.

**6.5.2** Manifolds connecting containers or container pressure relief devices shall be designed to vent gas from the individual container(s) exposed to a fire so that all containers meet the requirements of Section 4.5.

**6.5.3** A pipe thread jointing material impervious to the action of the natural gas used in the system shall be applied to all male pipe threads prior to assembly.

**6.5.4** Piping and fittings shall be clear and free from cutting or threading burrs and scales, and the ends of all piping shall be reamed.

**6.5.5** Where necessary to prevent abrasion, fuel lines passing through a panel shall be protected by grommets or similar devices.

**6.5.6** Fuel lines shall have the maximum practical clearance from the engine exhaust system to protect the fuel lines from excessive heat by durable and effective means.

**6.5.7** Fuel lines shall be mounted, braced, and supported to minimize vibration and shall be protected against damage, corrosion, or breakage due to strain or wear.

**6.5.8** A bend in piping or tubing shall be prohibited where such a bend weakens the piping or tubing.

**6.5.9** A joint or connection shall be located in an accessible location.

**6.5.10** Where a fuel supply container is located on a trailer, the fuel supply line shall contain an emergency breakaway device designed to retain CNG on both sides of the breakaway point.

**6.6 Installation of Valves.**

**6.6.1** Every cylinder shall be equipped with either of the following:

(1) A manual valve
(2) A normally closed, remotely actuated shut-off valve connected directly to the cylinder and equipped to bleed the cylinder manually

**6.6.2** In addition to the valve required by 6.6.1, a manual shut-off valve or a normally closed, automatically actuated shutoff valve shall be installed that allows isolation of the container(s) from the remainder of the fuel system.

*Exception: In installations on vehicles that are not normally operated on public streets, that have a single fuel supply cylinder, and that are equipped with an accessible manual cylinder shut-off valve, no additional manual shut-off valve shall be required.*

**6.6.2.1** The valve shall be securely mounted and shielded or installed in a protected location to minimize damage from vibration and unsecured objects.

**6.6.2.2** Where a manual shut-off valve is used, it shall be in an accessible location and shall have not more than 90 degrees rotation (quarter turn fuel delivery valve) from the open to the closed positions.

**6.6.2.3** Access to the manual shut-off valve shall not require the use of any key or tool.

**6.6.2.4** Where a manual valve is used, the valve location shall be indicated with the words "MANUAL SHUT-OFF VALVE."

**6.6.2.5** A weather-resistant decal or label with red, blue, or black letters on a white or silver reflective background shall be used.

**6.6.3** A valve that automatically prevents the flow of gaseous fuel to the engine when the engine is not running, even if the ignition is switched on, shall be provided in the system.

**6.6.4*** Where multiple fuel systems are installed on the vehicle, automatic valves shall be provided, as necessary, to shut off the fuel not being used.

**6.6.5** The fueling system shall be equipped with a backflow check valve that prevents the return flow of gas from the container(s) to the filling connection.

**6.6.5.1** The backflow check valve shall be mounted to withstand the breakaway force specified in 8.11.6.2.

**6.6.5.2** A second check valve shall be located between the fueling receptacle and the cylinders.

**6.7 Installation of Pressure Gauges.**

**6.7.1** A pressure gauge located within a driver or passenger compartment shall be installed in such a manner that no gas flows into the passenger compartment in the event of failure.

**6.7.2** A pressure gauge installed outside a driver or passenger compartment shall be equipped with a limiting orifice, a shatterproof dial lens, and a body relief.

**6.7.3** Gauges shall be securely mounted, shielded, and installed in a protected location to prevent damage from vibration and unsecured objects.

**6.8 Installation of Pressure Regulators.**

**6.8.1** An automatic pressure-reducing regulator(s) shall be installed to reduce the fuel container pressure to a level consistent with the service pressure required by the gas–air mixer, throttle body, or fuel injectors.

**6.8.2** Means shall be provided to prevent regulator malfunctions due to refrigeration effects.

**6.8.3** Regulators shall be installed so that their weight is not placed on, or supported by, the attached gas lines.

**6.9 Installation of Fueling Connection.**

**6.9.1** Fueling connections installed on vehicles less than 10,000 lb (4500 kg) gross vehicle weight rating (GVWR) shall comply with Section 4.11. Larger vehicles such as buses and trucks shall be permitted to use fueling connections that are designed to prevent the connection of a lower service pressure vehicle to a higher service pressure source.

**6.9.2** The fueling connection receptacle shall be mounted to withstand the breakaway force specified in 8.11.6.2.

**6.9.3** The receptacle shall be installed in accordance with the manufacturer's instructions.

**6.9.4** The clearance around the fueling connection shall be free of interference that prevents the connection of the fueling nozzle.

**6.9.5 Service Pressure.**

**6.9.5.1** The service pressure of the fueling connection receptacle shall not exceed the marked service pressure of the fuel supply cylinders.

**6.9.5.2** The service pressure of the fueling receptacle shall not exceed 80 percent of the set pressure of any relief valves installed on fuel supply containers in the vehicle.

**6.10 Wiring Installation.**

**6.10.1** All wiring shall be secured and protected from abrasion and corrosion to the same standard as the original wiring on the vehicle.

**6.10.2** All wiring shall be sized according to the Society of Automotive Engineers (SAE) and fuse-protected.

**6.11 Labeling.**

**6.11.1** A vehicle equipped with a CNG fuel system shall bear the following durable labels:

(1) A label readily visible and located in the engine compartment shall include the following:
  (a) Identification as a CNG-fueled vehicle
  (b) System service pressure
  (c) Installer's name or company
  (d) Fuel container life expires (insert date for limited-life fuel containers. This label item not required for containers with unlimited life.)
  (e) Total container water volume in gallons (liters)
  (f) Date by which fuel containers are to be inspected (insert date) and every (insert number) months thereafter
(2) A label located at the fueling connection receptacle shall include the following:
  (a) Identification as a CNG-fueled vehicle
  (b) System working pressure
  (c) Fuel container life expires (insert date for limited-life fuel containers. This label item not required for containers with unlimited life.)
  (d) Fuel containers are to be inspected by (insert date) and each (insert number) months thereafter.

**6.11.1.1** The fuel container inspection dates shall be changed after each required container inspection to denote the next required inspection date and shall be permitted on a separate additional label.

**6.11.2** If both labels are located in one of the above areas, the labels shall be permitted to be combined into a single label.

**6.11.3** Each vehicle shall be identified with a weather-resistant, diamond-shaped label located on an exterior vertical surface or near-vertical surface on the lower right rear of the vehicle (e.g., on the trunk lid of a vehicle so equipped, but not on the bumper of any vehicle) inboard from any other markings.

**6.11.3.1** The label shall be a minimum of 4.72 in. long × 3.27 in. high (120 mm × 83 mm).

**6.11.3.2** The marking shall consist of a border and the letters "CNG" [1 in. (25 mm) minimum height centered in the diamond] of silver or white reflective luminous material on a blue background.

**6.12 System Testing.**

**6.12.1*** The complete assembly shall be leak tested using natural gas or nonflammable gas.

**6.12.2** Before use, every connection shall be verified leak free with a noncorrosive leak detector solution or a leak detector instrument after the equipment is connected and pressurized to its service pressure.

**6.12.3** If the completed assembly is leak tested with natural gas, the testing shall be done under ventilated conditions.

**6.12.4*** Where a vehicle is involved in an accident or fire causing damage to the CNG container, or if the container is subjected to a pressure greater than 125 percent of service pressure, the CNG container shall be replaced or removed, inspected, and retested in accordance with the document under which it was originally manufactured before being returned to service.

**6.12.5** Where a vehicle is involved in an accident or fire causing damage to any part of the CNG fuel system, the system shall be repaired and retested *(see Section 6.13)* before being returned to service.

**6.12.6** Where a CNG container is removed from a vehicle in order to be installed within a different vehicle, it shall be inspected or retested in accordance with the inspection or requalification procedures of the standard under which it was originally manufactured before it is reinstalled.

**6.13 System Maintenance and Repair.**

**6.13.1** Damaged fuel lines shall be replaced and not repaired.

**6.13.2** All containers, container appurtenances, piping systems, venting systems, and other components shall be maintained in a safe condition.

**6.13.3** Vehicle fuel supply containers shall be inspected periodically in accordance with the vehicle label required in 6.11.1, the vehicle manufacturer's instructions, or the label on each container.

**6.13.3.1** Fuel containers whose service life has expired shall be removed from service.

**6.13.3.2** After periodic container inspection, a label showing the next required inspection date shall be affixed as required in 6.11.1.

**6.13.4** Pressure relief devices on the cylinder shall be maintained in accordance with CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases.*

**6.13.5** Pressure relief devices on all other containers shall be maintained in accordance with the following:

(1) Pressure relief device channels or other parts that could interfere with the functioning of the device shall not be plugged by paint or accumulation of dirt.
(2) Only qualified personnel shall be permitted to service pressure relief devices.
(3) Only assemblies or original manufacturer's parts shall be used in the repair of pressure relief devices unless the interchange of parts has been proved by tests.
(4) No pressure relief device that has been in service shall be reinstalled on another fuel cylinder.

**6.13.6** The following shall be done during vehicle maintenance:

(1) Ensure the engine is isolated from the fuel supply unless engine operation is required. If a manual valve is used it shall comply with 6.6.2.
(2) Prohibit torches, welding, or grinding equipment on or near high-pressure fuel lines and containers.
(3) Prevent damage to containers, including actions such as dropping, dragging, or rolling of the container.
(4) Prevent exposure of containers to strong chemicals such as battery acid or metal cleaning solvents.
(5) Store CNG containers in a manner to avoid damage.
(6) Reinstall containers to their original configuration using approved gaskets, bolts, nuts, washers, and so forth, per recommendations of the container manufacturer.
(7) Prevent hoists or jacks from coming into direct contact with containers.
(8) Prohibit personnel from walking on roof-mounted containers.

**6.14 Discharge from Vehicle Containers.**

**6.14.1** The venting or depressurization of a CNG container shall be performed only by trained personnel using written procedures.

**6.14.1.1** The gas to be removed from the container shall be discharged into a closed transfer system or shall be vented by an approved method of atmospheric venting.

**6.14.1.2** A valve shall be used to control the discharge of gas from high-pressure systems to a venting system.

**6.14.2** Personnel performing container depressurization shall do the following:

(1) Use grounding to prevent static electrical charge buildup.
(2) Limit the rate of gas release from plastic-lined containers to a value not greater than that specified by the container manufacturer.
(3) Restrain containers during depressurization to prevent container movement.

**6.14.3** Direct gas venting shall be done through a vent tube that diverts the gas flow to atmosphere.

**6.14.3.1** The vent tube shall have a gastight connection to the container prior to venting, and all components shall be grounded.

**6.14.3.2** The vent tube shall be constructed of Schedule 80 pipe of at least 2 in. (51 mm) diameter.

**6.14.3.3** The vent tube shall not be provided with any feature that limits or obstructs gas flow.

## Chapter 7 Service and Maintenance of $GH_2$ Engine Fuel Systems

**7.1* Application.**

**7.1.1** This chapter applies to service, maintenance, and testing facilities for hydrogen-fueled vehicles.

**7.1.2* Final-Stage Vehicle Integrator/Manufacturer (FSVIM).**

**7.1.2.1*** The FSVIM shall have the responsibility for integration of the engine, fuel system, and gaseous detection system, where required, onto the vehicle chassis and for the safe operation of the vehicle.

**7.1.2.2** The FSVIM shall obtain documented approval of the original equipment/component manufacturers of the onboard fuel and detection systems components, proper installation, and application from each of following:

(1) Automobile
(2) Truck
(3) Bus
(4) Chassis
(5) Engine
(6) Gas detection
(7) Fuel system

**7.1.2.3** All gaseous fuel modifications of a vehicle shall conform with the specifications of the original vehicle manufacturer.

**7.2 System Component Qualifications.**

**7.2.1*** Receptacles for use with hydrogen shall comply with SAE J2600, *Compressed Hydrogen Surface Refueling Connection Devices*. Fuel supply containers shall be certified by the container manufacturer for use with hydrogen.

**7.2.2** Components shall be installed in accordance with the original component manufacturer's instructions and engineering recommendations.

**7.3 System Testing.** Unless specified by the vehicle manufacturers and importers regulated by FMVSS requirements, the requirements of Section 7.3 shall apply.

**7.3.1** The requirements of Section 7.3 shall apply only to vehicle importers and manufacturers not regulated by Federal Motor Vehicle Safety Standards (FMVSS).

**7.3.2** The complete assembly shall be leak tested at the maximum system operating pressure using hydrogen or helium.

**7.3.3** Where hydrogen is to be used as the leak test media, the system first shall be purged with an inert gas to ensure that all oxygen is removed.

**7.3.4** If the completed assembly is leak tested with hydrogen, the testing shall be done under ventilated conditions.

**7.3.5** Before use, every connection shall be verified leak free with a noncorrosive leak detector solution or a leak detector instrument after the equipment is connected and pressurized to its service pressure.

**7.3.6** Where a vehicle is involved in an accident or fire causing damage to the $GH_2$ container, or if the container is subjected to a pressure greater than 125 percent of service pressure, the $GH_2$ container shall be replaced or removed, inspected, and retested in accordance with the document under which it was originally manufactured before being returned to service.

**7.3.7** Cylinder damage assessment for tanks shall be done in accordance with the manufacturer's instructions, or CGA C-6, *Standards for Visual Inspection of Steel Compressed Gas Cylinders*.

**7.3.8** Where a vehicle is involved in an accident or fire causing damage to any part of the $GH_2$ fuel system, the system shall be repaired and retested *(see Section 7.4)* before being returned to service.

**7.3.9** Where a $GH_2$ container is removed from a vehicle in order to be installed within a different vehicle, it shall be inspected or retested in accordance with the inspection or requalification procedures of the standard under which it was originally manufactured before it is reinstalled.

**7.4 System Maintenance and Repair.** System maintenance and repair shall comply with maintenance and repair guidelines and specifications of the original system manufacturer.

**7.4.1** The requirements of Section 7.4 shall apply only to non-OEM vehicles.

**7.4.2** Damaged fuel lines shall be replaced and not repaired.

**7.4.3** All containers, container appurtenances, piping systems, venting systems, and other components shall be maintained in a safe condition.

**7.4.4** The container retest date or expiration date shall be verified to be current.

**7.4.5** PRDs on the cylinder shall be maintained in accordance with CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases.*

**7.4.6** PRDs on all other containers shall be maintained in accordance with the following:

(1) PRD channels or other parts that could interfere with the functioning of the device shall not be plugged by paint or accumulation of dirt.
(2) Only qualified personnel shall be permitted to service PRDs.
(3) Only assemblies and components of original manufacturer's parts shall be used in the repair of PRDs unless the interchange of parts has been proved by tests.
(4) No PRD that has been in service shall be reinstalled on another fuel cylinder.

**7.4.7** The following measures shall be taken during vehicle maintenance:

(1) Closing the "quarter turn" fuel delivery valve nearest the engine unless engine operation is required
(2) Prohibiting torches, welding, or grinding equipment on or near high-pressure fuel lines and containers
(3) Preventing damage to containers, including actions such as dropping, dragging, or rolling of the container
(4) Preventing exposure of containers to strong chemicals such as battery acid or metal cleaning solvents
(5) Storing compressed hydrogen containers in a manner to avoid damage
(6) Reinstalling containers to their original configuration using approved gaskets, bolts, nuts, washers, and so forth, per recommendations of the container manufacturer
(7) Preventing hoists or jacks from coming into direct contact with containers
(8) Prohibiting personnel from walking on roof-mounted containers

**7.5 Discharge from Vehicle Containers.**

**7.5.1** The requirements of Section 7.5 shall apply only to non-OEM vehicles.

**7.5.2** The venting or depressurization of a hydrogen container shall be performed only by trained personnel using written procedures from the OEM fuel system supplier.

**7.5.2.1** The hydrogen to be removed from the container shall be discharged into a closed transfer system or shall be vented by an approved method of atmospheric venting.

**7.5.2.2** A valve shall be used to control the discharge of gas from high-pressure systems to a venting system.

**7.5.3** Container depressurization systems shall include provisions for the following:

(1) Common grounding to prevent static electrical charge buildup between the vehicle container and venting system
(2) Limiting the rate of gas release from plastic-lined containers to a value not greater than that specified by the container manufacturer
(3) If used for portable containers, a method to restrain containers during depressurization to prevent container movement

**7.5.4** Hydrogen shall be vented in accordance with guidelines and specifications of the vehicle integrator/manufacturer.

**7.5.4.1** Direct gas venting shall be done through a vent tube that diverts the gas flow to the atmosphere.

**7.5.4.2** The vent tube shall have a gastight connection to the container prior to venting, and all components shall be grounded.

**7.5.4.3** The vent tube shall be constructed of suitable material and be designed so as to not reduce the discharge flow rate below that required for the pressure relief devices.

**7.5.4.4** The vent tube shall not be provided with any feature that limits or obstructs gas flow.

**7.5.4.5** A valve shall be used to control the discharge of gas from high-pressure systems to a venting system.

# Chapter 8 CNG Compression, Gas Processing, Storage, and Dispensing Systems

## 8.1 Application.

**8.1.1** This chapter applies to the design, construction, installation, and operation of containers, pressure vessels, compression equipment, buildings and structures, and associated equipment used for storage and dispensing of CNG as an engine fuel in fleet and public dispensing operations.

**8.1.2** Mobile refueling vehicles, temporary trailers (with or without tractors), and other means of providing vehicle refueling or onsite storage shall be subject to the same requirements as a permanent refueling or storage installation, with the exception of vessel requirements.

**8.1.3** Mobile refueling equipment shall meet the requirements of DOT or TC.

**8.2 System Component Qualifications.** System components shall comply with the appropriate provisions in Chapter 4 and with Sections 8.5 through 8.13.

## 8.3 General System Requirements.

**8.3.1** Where systems are served by a gas utility, the utility shall be notified of all CNG installations.

**8.3.2** Equipment related to a compression, storage, or dispensing installation shall be protected to prevent damage from vehicles and minimize the possibilities of physical damage and vandalism.

**8.3.3*** Control devices shall be installed so that internal or external icing or hydrate formation does not cause vehicle or fueling station malfunction.

**8.3.4** Vehicles shall not be considered a source of ignition with respect to the provisions of this chapter.

*Exception: Vehicles containing fuel-fired equipment (e.g., recreational vehicles and catering trucks) shall be considered a source of ignition unless this equipment is shut off completely before entering an area in which ignition sources are not permitted.*

**8.3.5** The fueling connection shall prevent the escape of gas where the connector is not engaged or becomes separated.

**8.3.6** Fueling nozzles installed on vehicles less than 10,000 lb (4500 kg) GVWR shall comply with Section 4.11. Larger vehicles such as buses and trucks shall be permitted to use fueling nozzles that are designed to prevent the connection of a lower service pressure vehicle to a higher service pressure source.

**8.3.7** Compression equipment shall be designed for use with CNG and for the pressures and temperatures to which it can be subjected under normal operating conditions.

**8.3.8** Compression equipment shall have pressure relief devices that limit each stage pressure to the maximum allowable service pressure for the compression cylinder and piping associated with that stage of compression.

**8.3.9** Where CNG compression equipment is operated unattended, it shall be equipped with a high discharge and a low suction pressure automatic shutdown control.

**8.3.10** Control circuits that shut down shall remain down until manually activated or reset after a safe shutdown is performed.

**8.3.11** Engine-driven compressor installations shall conform, where applicable, to NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

**8.3.12*** Compression equipment shall incorporate a means to minimize liquid carryover to the storage system.

## 8.4 System Siting.

### 8.4.1 General.

**8.4.1.1** CNG compression, storage, and dispensing shall be located and conducted outdoors or indoors in compliance with this section.

**8.4.1.2** This equipment shall be installed on foundations with anchoring systems designed to meet the requirements of the adopted building code for the appropriate seismic and wind conditions.

### 8.4.2 Outdoors.

**8.4.2.1** CNG storage containers charged with CNG not connected for use shall be located outdoors.

**8.4.2.2** A facility in which CNG compression, storage, and dispensing equipment are sheltered by an enclosure that is constructed of noncombustible or limited-combustible materials and that has at least one side predominantly open and a roof designed for ventilation and dispersal of escaped gas shall be considered to be located outdoors.

**8.4.2.3** Compression, storage, and dispensing equipment located outdoors shall be above ground, shall not be beneath electric power lines or where exposed by their failure, and shall be a minimum of 10 ft (3 m) from the nearest important building or line of adjoining property that can be built upon or from any source of ignition.

**8.4.2.4** Compression, storage, and dispensing equipment located outdoors shall be not less than 10 ft (3 m) from the nearest public street or sidewalk line and at least 50 ft (15 m) from the nearest rail of any railroad main track.

**8.4.2.5** A clear space of at least 3 ft (1 m) shall be provided for access to all valves and fittings of multiple groups of containers.

**8.4.2.6** Readily ignitible material shall not be permitted within 10 ft (3 m) of any stationary container.

**8.4.2.7** The minimum separation between containers and aboveground tanks containing flammable or combustible liquids shall be 20 ft (6 m).

**8.4.2.8** During outdoor fueling operations, the point of transfer shall be located at least 10 ft (3 m) from any important building, mobile home, public sidewalk, highway, street, or road and at least 3 ft (1 m) from storage containers.

*Exception: The point of transfer shall be permitted to be located at a lesser distance from buildings or walls constructed of concrete or masonry materials or of other material having a fire resistance rating of at least 2 hours, but at least 10 ft (3 m) from any building openings.*

**8.4.2.9** Areas for compression, storage, and dispensing shall be classified in accordance with Table 8.4.2.9 for installations of electrical equipment.

**8.4.3 Indoors.**

**8.4.3.1 General.** Compression, dispensing equipment, and storage containers connected for use shall be permitted to be located inside of buildings reserved exclusively for these purposes or in rooms within or attached to buildings used for other purposes in accordance with this section.

**8.4.3.2 Limits of Storage in Buildings.** Storage shall be limited to not more than 10,000 scf (283 $m^3$) of natural gas in each building or room.

*Exception: CNG stored in vehicle-mounted fuel supply containers.*

**8.4.3.3* Deflagration Venting.**

**8.4.3.3.1** Deflagration (explosion) venting shall be provided in exterior walls or roof only.

**8.4.3.3.2** Vents shall be permitted to consist of any one or any combination of the following:

(1) Walls of light material
(2) Lightly fastened hatch covers
(3) Lightly fastened, outward opening doors in exterior walls
(4) Lightly fastened walls or roofs

**8.4.3.3.3** Where applicable, snow loads shall be considered.

**8.4.3.4 Rooms Within Buildings.**

**8.4.3.4.1** Rooms within or attached to other buildings shall be constructed of noncombustible or limited-combustible materials.

*Exception: Window glazing shall be permitted to be plastic.*

**8.4.3.4.2** Interior walls or partitions shall be continuous from floor to ceiling, shall be securely anchored, and shall have a fire resistance rating of at least 2 hours.

**8.4.3.4.3** At least one wall shall be an exterior wall.

**8.4.3.4.4** Explosion venting shall be provided in accordance with 8.4.3.3.

**8.4.3.4.5** Access to the room shall be from outside the primary structure.

**Table 8.4.2.9 Electrical Installations**

| Location | Division or Zone | Extent of Classified Area |
|---|---|---|
| Containers (other than mounted fuel supply containers) | 2 | Within 10 ft (3 m) of container |
| Area containing compression and ancillary equipment | 2 | Up to 15 ft (4.6 m) from equipment |
| Dispensing equipment outdoors | 1 | Inside the dispenser enclosure |
| Outdoors | 2 | From 0 to 5 ft (0 to 1.5 m) from the dispenser |
| Indoors | 1 | Inside the dispenser enclosure |
| Indoors | 2 | Entire room, with adequate ventilation *(see 8.4.3)* |
| Discharge from relief valves or vent | | |
| Outdoors | 1 | 5 ft (1.5 m) in all directions from the point source |
| Outdoors | 2 | Beyond 5 ft (1.5 m) but within 15 ft (4.6 m) in all directions from point of discharge |
| Valves, flanges of screwed fittings | None | Unclassified |
| Discharge from relief valves within 15 degrees of the line of discharge | 1 | 15 ft (4.6 m) |

**8.4.3.4.6** If access to the room from outside the primary structure is not possible, access from within the primary structure shall be permitted where such access is made through a barrier space having two vapor-sealing, self-closing fire doors having the appropriate rating for the location where installed.

**8.4.3.5 Ventilation Inlets and Outlets.**

**8.4.3.5.1** Indoor locations shall be ventilated utilizing air supply inlets and exhaust outlets arranged to provide uniform air movement to the extent practical.

**8.4.3.5.2** Inlets shall be uniformly arranged on exterior walls near floor level.

**8.4.3.5.3** Outlets shall be located in exterior walls at the high point of the room or in the roof.

**8.4.3.5.4 Ventilation.**

**8.4.3.5.4.1** Ventilation shall be by a continuous mechanical ventilation system or by a mechanical ventilation system activated by a continuously monitoring natural gas detection system where a gas concentration of not more than one-fifth of the lower flammable limit is present.

**8.4.3.5.4.2** In either case in 8.4.3.5.4.1, the system shall immediately shut down the fueling system in the event of detection of an alarm condition or failure of the ventilation system, the detection system, or the controls.

**8.4.3.5.5*** The ventilation rate shall be at least 1 $ft^3$/min · 12 $ft^3$ (0.03 $m^3$/min · 0.34 $m^3$) of room volume.

**8.4.3.5.6** A ventilation system for a room within or attached to another building shall be separate from any ventilation system for the other building.

**8.4.3.6** Where installed, a gas detection system shall be equipped to sound a latched alarm and visually indicate when a maximum of one-fifth of the lower flammable limit is reached.

**8.4.3.7** Reactivation of the fueling system shall be by manual restart and shall be conducted by trained personnel.

**8.4.3.8** Buildings and rooms used for compression, storage, and dispensing shall be classified in accordance with Table 8.4.2.9 for installations of electrical equipment.

**8.4.3.9** Nonelectrical sources of ignition shall not be permitted.

**8.4.3.10** Pressure relief devices on storage systems shall have pressure relief device channels *[see 4.5.1(3)]* to convey escaping gas to the outdoors and then upward to a safe area to prevent impinging on buildings, other equipment, or areas open to the public (e.g., sidewalks).

**8.4.3.11 Warning Signs.**

**8.4.3.11.1** Access doors shall have warning signs with the words "WARNING — NO SMOKING — FLAMMABLE GAS."

**8.4.3.11.2** The wording shall be in plainly legible, bright red letters not less than 1 in. (25 mm) high on a white background.

**8.4.3.12 Indoor Fast-Fill Fueling, Outdoor Storage, and Compression.** Fast-fill fueling indoors shall be permitted where storage and compression equipment is located outdoors complying with 8.4.2.1 through 8.4.2.7 and 8.4.2.9.

**8.4.3.12.1** Where attended fast-fill fueling is performed indoors, the following shall be installed:

(1) An emergency manual shutdown device shall be installed as required by 8.11.5.
(2) A gas detection system equipped to sound a latched alarm and visually indicate when a maximum of one-fifth of the lower flammable limit is reached shall be installed.

**8.4.3.12.2** The actuation of the gas detection system shall shut down the compressor and stop the flow of gas into the structure.

**8.5 Installation of Containers and Container Appurtenances (Other than Pressure Relief Devices).**

**8.5.1*** Storage containers shall be installed above ground on stable, noncombustible foundations or in vaults with ventilation and drainage.

**8.5.1.1** Horizontal containers shall have no more than two points of support longitudinally.

**8.5.1.2** Where flooding can occur, each container shall be anchored to prevent floating.

**8.5.2** Containers shall be protected by painting or other equivalent means where necessary to inhibit corrosion.

*Exception: Composite containers shall not be painted without prior permission from the container manufacturer.*

**8.5.2.1** Horizontally installed containers shall not be in direct contact with each other.

**8.5.2.2** Composite containers shall be protected from UV radiation as required by the manufacturer.

**8.5.3** Means shall be provided to prevent the flow or accumulation of flammable or combustible liquids under containers, such as by grading, pads, or diversion curbs.

**8.6 Installation of Pressure Relief Devices.**

**8.6.1** Pressure relief valves shall be so arranged that they discharge to a safe area and so that escaping gas does not impinge on buildings, other equipment, or areas that could be occupied by the public *(see 8.4.3.10)*.

**8.6.2** Pressure relief valves on pressure vessels shall be installed so that any discharge is in a vertical position and shall be fitted with rain caps.

**8.6.3** An overpressure protection device, other than a rupture disc, shall be installed in the fueling transfer system to prevent overpressure in the vehicle.

**8.6.4** The set pressure of the overpressure protection device shall not exceed 125 percent of the service pressure of the fueling nozzle it supplies.

**8.6.5** If approved, full port block valves shall be permitted to be installed between the relief valves and the storage vessel or fueling transfer system.

**8.6.6** The block valves shall be locked open.

**8.7 Installation of Pressure Regulators.**

**8.7.1** Regulators shall be designed, installed, or protected so that their operation is not affected by freezing rain, sleet, snow, ice, mud, insects, or debris.

**8.7.2** Regulator protection of 8.7.1 shall be permitted to be integral with the regulator.

**8.8 Installation of Pressure Gauges.** Gauges or other readout devices shall be installed to indicate compression discharge pressure, storage pressure, and dispenser discharge pressure.

**8.9 Installation of Piping and Hoses.**

**8.9.1*** Piping and hose shall be run as directly as practical and with adequate provisions for expansion, contraction, jarring, vibration, and settling.

**8.9.1.1** Exterior piping shall be either buried or installed above ground and shall be supported and protected against mechanical damage.

**8.9.1.2** Underground piping shall be buried not less than 18 in. (460 mm) below the surface of the ground unless otherwise protected from damage by movement of the ground.

**8.9.1.3** Underground and aboveground piping shall be protected from corrosion in compliance with recognized practices.

**8.9.1.4** Threaded pipe and fittings shall not be used underground.

**8.9.1.5 Piping Connections.**

**8.9.1.5.1** Manifolds connecting fuel containers shall be fabricated to minimize vibration and shall be installed in a protected location or shielded to prevent damage from unsecured objects.

**8.9.1.5.2** A pipe thread jointing material impervious to the action of the natural gas used in system shall be applied to all male pipe threads prior to assembly.

**8.9.1.5.3** Threaded piping and fittings shall be clear and free from cutting or threading burrs and scales, and the ends of all piping shall be reamed.

**8.9.1.5.4** A bend in piping or tubing shall be prohibited where such a bend weakens the pipe or tubing.

**8.9.1.5.5** A joint or connection shall be located in an accessible location.

**8.9.1.5.6** The number of joints shall be minimized and placed in a location considering personnel safety.

**8.9.2** Natural gas shall be vented only to a safe point of discharge.

**8.9.2.1** A vent pipe or stack shall have the open end protected to prevent entrance of rain, snow, and solid material.

**8.9.2.2** Vertical vent pipes and stacks shall have provision for drainage.

**8.9.3** The use of hose in an installation shall be limited to the following:

(1) Vehicle fueling hose
(2) Inlet connection to compression equipment
(3) Section of metallic hose not exceeding 36 in. (910 mm) in length in a pipeline to provide flexibility where necessary

**8.9.3.1** Each section shall be installed so that it is protected against mechanical damage and is visible for inspection.

**8.9.3.2** The manufacturer's identification shall be retained in each section.

**8.9.4** At fueling stations, gas used for calibration and testing shall be vented to a safe location.

**8.10 System Testing.**

**8.10.1** Piping, tubing and hose, and hose assemblies shall be leak tested after assembly to prove them free from leaks at a pressure equal to at least the normal service pressure of that portion of the system.

**8.10.2** Pressure relief valves shall be tested at least every 3 years.

**8.11 Installation of Emergency Shutdown Equipment.**

**8.11.1 Manually Operated Container Valve.**

**8.11.1.1** A manually operated container valve shall be provided for each DOT or TC storage cylinder.

**8.11.1.2** Each group of ASME storage vessels up to a maximum combined capacity of 10,000 scf (283 $m^3$) shall be provided with a manually operated shutoff valve.

**8.11.1.3** A manually operated shutoff valve shall be installed in a manifold as close to a container or group of containers as practical.

**8.11.1.4** The valve in 8.11.1.3 shall be located downstream of the backflow check valve specified in 8.11.2.

**8.11.2** The fill line on a storage container shall be equipped with a backflow check valve to prevent discharge of natural gas from the container in case of the rupture of the line, hose, fittings, or other equipment upstream of the storage containers.

**8.11.3** Where excess-flow check valves are used, the closing flow shall be greater than the maximum system design flow rate and less than the flow rating of the piping system that results from a complete line failure between the excess-flow valve and the equipment downstream of the excess-flow check valve.

**8.11.4** Gas piping from an outdoor compressor or storage system into a building shall be provided with shut-off valves located outside the building.

**8.11.5** An emergency manual shutdown device shall be provided within 10 ft (3.0 m) of the dispensing area and also greater than 25 ft (7.6 m) from the dispensing area.

**8.11.5.1** This device, when activated, shall shut off the power supply and gas supply to the compressor and the dispenser.

**8.11.5.2** Emergency shutdown devices shall be distinctly marked for easy recognition with a permanently affixed legible sign.

**8.11.6** Breakaway protection shall be provided in a manner that, in the event of a pullaway, natural gas ceases to flow at any separation.

**8.11.6.1** A breakaway device shall be installed at every dispensing point.

**8.11.6.2** A breakway device shall be arranged to separate using a force not greater than 150 lb (68 kg) when applied in any direction that the vehicle would move.

**8.11.6.3** Breakaway devices shall comply with ANSI/IAS NGV 4.4, *Breakaway Devices for Dispensing Systems.*

**8.11.7** Control circuits shall be arranged so that, when an emergency shutdown device is activated or electric power is cut off, systems that shut down shall remain down until manually activated or reset after a safe condition is restored.

**8.11.8 Fast-Fill Station.**

**8.11.8.1** Each line between a gas storage facility and a dispenser at a fast-fill station shall have a valve that closes when one of the following occurs:

(1) The power supply to the dispenser is cut off.
(2) Any emergency shutdown device at the refueling station is activated.

**8.11.8.2** A fast-closing, "quarter turn" manual shut-off valve shall be provided at a fast-fill station upstream of the breakaway device specified in 8.11.6, where it is accessible to the person dispensing natural gas, unless one of the following occurs:

(1) The self-closing valve referred to in 8.11.8.1 is located immediately upstream of the dispenser.
(2) The dispenser is equipped with a self-closing valve that closes each time the control arm is turned to the OFF position or when an emergency device is activated.

**8.11.9** A self-closing valve shall be provided on the inlet of the compressor that shuts off the gas supply to the compressor when one of the following occurs:

(1) An emergency shutdown device is activated.
(2) A power failure occurs.
(3) The power to the compressor is switched to the OFF position.

**8.12* Installation of Electrical Equipment.**

**8.12.1** Fixed electrical equipment and wiring within areas specified in Table 8.4.2.9 shall comply with Table 8.4.2.9 and shall be installed in accordance with *NFPA 70, National Electrical Code.*

*Exception: Electrical equipment on internal combustion engines installed in accordance with NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

**8.12.2** With the approval of the AHJ, classified areas specified in Table 8.4.2.9 shall be permitted to be reduced or eliminated by positive pressure ventilation from a source of clean air or inert gas in conjunction with effective safeguards against ventilator failure by purging methods recognized in NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment.*

**8.12.3** Classified areas shall not extend beyond an unpierced wall, roof, or vaportight partition.

*Exception: Listed dispensers shall be permitted to be installed using classified areas in accordance with the terms of the listing.*

**8.12.4** Space around welded pipe and equipment without flanges, valves, or fittings shall be a nonhazardous location.

**8.13 Stray or Impressed Currents and Bonding.**

**8.13.1*** Where stray or impressed currents are used or can be present on dispensing systems, such as cathodic protection, protective measures to prevent ignition shall be taken.

**8.13.2*** Static protection shall not be required where CNG is transferred by conductive or nonconductive hose, flexible metallic tubing, or pipe connections where both halves of the metallic couplings are in continuous contact.

**8.14 System Operation.**

**8.14.1** A cylinder shall not be charged in excess of the design pressure at the normal temperature for that cylinder.

**8.14.1.1** DOT, TC, and ANSI/IAS NGV2 cylinders shall be charged in accordance with DOT, TC, and ANSI/IAS NGV2 regulations.

**8.14.1.2** DOT, TC, and ANSI/IAS NGV2 cylinders shall not be subjected to pressure in excess of 125 percent of the marked service pressure even if, on cooling, the pressure settles to the marked service pressure.

**8.14.2** A fuel supply container shall not have a settled pressure above the service pressure that is stamped on the container and displayed on a label near the filling connection, corrected for the ambient temperature at the time of filling.

**8.14.3** CNG dispensing systems shall be equipped to stop fuel flow automatically when a fuel supply container reaches the temperature-corrected fill pressure *(see 8.6.3).*

**8.14.4** The dispenser shall be designed to detect any malfunction that fills the vehicle fuel container in excess of the limits specified, or causes the relief valve required in 8.6.3 to open.

**8.14.4.1** After any such malfunction, the dispenser shall be repaired and calibrated in accordance with 8.16 before continued operation, and the excess fuel shall be removed from the vehicle.

**8.14.4.2** If the vehicle fuel system has been pressurized in excess of 1.25 times the service pressure of the fueling connection, the dispenser shall be shut down until repaired and calibrated, and the vehicle operator shall be notified to contact the container manufacturer for approval before continued operation.

**8.14.5** The transfer of CNG into a fuel supply container shall be performed in accordance with instructions posted at the dispensing station.

**8.14.6** Where CNG is being transferred to or from a motor vehicle, the engine shall be turned off.

**8.14.7** During the transfer of CNG to or from cargo vehicles, the hand or emergency brake of the vehicle shall be set, and chock blocks shall be used to prevent rolling of the vehicle.

**8.14.8** Transfer systems shall be capable of depressurizing to facilitate disconnection.

**8.14.9** Bleed connections shall lead to a safe point of discharge.

**8.14.10** CNG shall not be used to operate any device or equipment that has not been designed or modified for CNG service.

**8.14.11** Sources of ignition shall not be permitted within 10 ft (3.0 m) of any filling connection during a transfer operation.

**8.14.12*** A warning sign(s) shall be posted at the dispensing points with the following words:

**A. STOP MOTOR.**

**B. NO SMOKING.**

**C. FLAMMABLE GAS.**

**D. NATURAL GAS VEHICLE FUEL CYLINDERS SHALL BE PERIODICALLY INSPECTED (NORMALLY EVERY 3 YEARS) TO ENSURE SAFE OPERATION OF THE VEHICLE. CONTACT VEHICLE OR CYLINDER MANUFACTURER.**

**8.14.12.1** A warning sign with the words "NO SMOKING, FLAMMABLE GAS" shall be posted in all compressor and storage areas.

**8.14.12.2** The location of signs shall be determined by local conditions.

**8.14.12.3** The lettering on the sign shall be large enough to be visible and legible from each point of transfer.

**8.14.12.4** The service pressure of each dispenser shall be posted in view of the operator.

**8.15 Fire Protection.** A portable fire extinguisher having a rating of not less than 20-B:C shall be provided at the dispensing area.

**8.16* System Maintenance.**

**8.16.1** Containers and their appurtenances, piping systems, compression equipment, controls, and detection devices shall be maintained in safe operating condition and according to manufacturers' instructions.

**8.16.2** Maintenance records shall be kept on site.

**8.16.3 Hose Assemblies.** After the original installation, vehicle fueling hoses shall be examined visually according to the manufacturers' recommendations or at least monthly to ensure that they are safe for use.

**8.16.4** Hoses shall be tested for leaks per manufacturers' requirements, and any leakage or surface cracks shall be reason for rejection and replacement.

**8.16.5** While in transit, fueling hose and flexible metal hose on a cargo vehicle to be used in a transfer operation, including their connections, shall be depressurized and protected from wear and injury.

**8.16.6*** PRVs shall be maintained in safe operating condition.

**8.16.7** Maintenance personnel shall be trained in leak detection procedures and equipment in accordance with manufacturers' recommendations.

**8.17 Vehicle Fueling Appliances in Nonresidential Occupancies.**

**8.17.1** VFAs shall not exceed a gas flow of 10 scf/min (0.28 SCM/min).

**8.17.2** VFAs shall be listed.

**8.17.3** The installation of VFAs shall be exempt from the requirements of Sections 4.5 through 4.10, 8.2 through 8.4, 8.6, and 8.8 through 8.16.

**8.17.4** VFAs shall be permitted to be used to fill stationary containers at vehicle fueling locations.

**8.17.4.1** The method of connecting the VFA to such storage shall comply with the provisions of Chapters 4 and 8 and shall be approved.

**8.17.4.2** The provisions of 8.17.3 shall apply to the VFA where connected to stationary containers at vehicle fueling locations.

**8.17.5** The installation of VFAs shall comply with the requirements of Chapter 10.

*Exception No. 1: The requirements of 10.1.2 and 10.1.3 shall not apply to the installation of VFAs.*

*Exception No. 2: Gas detectors shall be located in accordance with good engineering practice.*

**8.17.6** VFAs shall not be installed within 10 ft (3.0 m) of any flammable gas or liquid storage.

*Exception: Storage in the vehicle fuel supply container.*

**8.17.7** Where installed indoors in public assembly and educational occupancies, a VFA shall be located in a portion of the occupancy where NFPA *101*, *Life Safety Code*, or the local building code permits the installation of hazardous equipment.

*Exception: Where the VFA is located outdoors, the dispensing point shall be permitted to be located indoors without the need for a separate room.*

## Chapter 9 $GH_2$ Compression, Gas Processing, Storage, and Dispensing Systems

**9.1 System Component Qualifications.** System components shall comply with the appropriate provisions in Chapters 5 and 7.

**9.2 General System Requirements.** All hydrogen fuel dispensing facilities shall meet the provisions of this chapter.

**9.2.1*** Where systems are served by a gas utility, the utility shall be notified of all $GH_2$ installations.

**9.2.2** Dispensing and storage facilities shall be certified as meeting the requirements of this code by qualified engineer(s) with expertise and competence in the design, fabrication, and construction of hydrogen containers, piping systems, site fire protection, gaseous detection, emergency shutdown provisions, isolation, drainage, site spacing, fire protection equipment, operating procedures, worker protection, and other components of the facility.

**9.2.3*** A hazard analysis shall be conducted on every hydrogen fueling system installation by a qualified engineer(s) with proven expertise in hydrogen fueling systems and installations.

**9.2.3.1** The hazard analysis shall include the following fire protection measures: fire protection and suppression systems, detection systems, and ventilation.

**9.2.3.2** The hazard analysis shall include consideration of potential failures in hoses, nozzles, dispensing equipment, as well as failures for maintenance and service.

**9.2.4* Out-of-Service Stationary Bulk Gas Systems.** Installed bulk gas systems no longer in use that remain in place shall be removed from service by the supplier or shall be safeguarded in accordance with the following:

(1) Required permits shall be maintained.
(2) The source and fill valves shall be closed to prevent the intrusion of air or moisture.
(3) Cylinders, containers, and tanks shall be maintained in a serviceable condition.
(4) Security shall be maintained in accordance with 9.2.5.[**55:**4.4]

**9.2.5 Equipment Security and Vehicle Protection.**

**9.2.5.1** Vehicular protection shall be provided in accordance with 9.2.5.

**9.2.5.2** Compression, processing, generation, storage, and dispensing equipment shall be protected to prevent damage from vehicles and to minimize physical damage and vandalism.

**9.2.5.3** Compressed gas containers, cylinders, tanks, and systems shall be secured against accidental dislodgement and against access by unauthorized personnel. [**55:**7.1.8.1]

**9.2.5.4** Where guard posts are installed, the posts shall meet the following criteria:

(1) They shall be constructed of steel not less than 4 in. (10 cm) in diameter and concrete filled.
(2) They shall be spaced not more than 4 ft (1.2 m) between posts on center.
(3) They shall be set not less than 3 ft (0.9 m) deep in a concrete footing of not less than a 15 in. (38 cm) diameter.
(4) They shall be set with the top of the posts not less than 3 ft (0.9 m) above ground.
(5) They shall be located not less than 5 ft (1.5 m) from the tank. [**1:**60.1.15.2]

**9.2.6 Cargo Transport Unloading.**

**9.2.6.1** Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 9.3.1.3(a) or Table 9.3.1.3(b) than the distances given for the storage system. [**55:**10.3.2.3]

**9.2.6.2** During transfer of hydrogen from cargo vehicles, the hand or emergency brake of the vehicle shall be set, and chock blocks shall be used to prevent rolling of the vehicle. [**55:**10.7.2]

**9.2.6.3** Cargo vehicles equipped with air-brake interlock in front of the unloading connection to protect against driveaways shall be engaged such that the interlock is activated. [**55:**10.7.3]

**9.2.6.4** Mobile hydrogen supply units shall be electrically bonded to the storage system before hydrogen is discharged from the supply unit. [**55:**10.7.4]

**9.2.6.5 Transfer System Depressurization.** [**55:**10.7.5]

**9.2.6.5.1** The transfer systems shall be capable of depressurizing to facilitate disconnection. [**55:**10.7.5.1]

**9.2.6.5.2** Bleed connections shall be connected to a hydrogen venting system in accordance with 5.5.1. [**55:**10.7.5.2]

**9.2.6.6** Backflow prevention or check valves shall be provided where the backflow of hazardous materials could create a hazardous condition or cause the unauthorized discharge of hazardous materials. [**55:**7.3.1.3.2]

**9.2.6.7** Prohibitions on smoking or the use of open flame shall be in accordance with 9.14.12. [**55:**10.7.7]

**9.2.6.8** An emergency shutoff valve shall be provided in accordance with 9.11.1. [**55:**10.7.8]

**9.2.7** Control devices shall be installed so that internal or external icing does not cause vehicle or fueling station malfunction.

**9.2.8** Vehicles shall not be considered a source of ignition with respect to the provisions of this chapter.

*Exception: Vehicles containing fuel-fired equipment (e.g., recreational vehicles and catering trucks) shall be considered a source of ignition unless this equipment is shut off completely before entering an area in which ignition sources are not permitted.*

**9.2.9** The fueling connection shall prevent the escape of gas where the connector is not properly engaged or becomes separated.

**9.2.10 Compression and Processing Equipment.** Compression and gas processing equipment integral to bulk gas storage systems shall be designed for use with $GH_2$ and for maximum pressures and temperatures to which it can be subjected under normal operating conditions. [**55:**10.8]

**9.2.10.1** Compression and gas processing equipment shall have pressure relief devices that limit each stage pressure to the maximum allowable working pressure for the compression cylinder and piping associated with that stage of compression. [**55:**10.8.1]

**9.2.10.2** Where $GH_2$ compression equipment is operated unattended, it shall be equipped with a high discharge and a low suction pressure automatic shutdown control. [**55:**10.8.2]

**9.2.10.3** Control circuits that automatically shut down shall remain down until manually activated or reset after a safe shutdown is performed. [**55:**10.8.3]

**9.2.11** Engine-driven compressor installations shall conform, where applicable, to NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

**9.2.12** Where hydrogen is used as a fuel in an engine-driven compressor installation, the engine shall comply with Section 9.3. For purposes of electrical classification, the engine shall be considered a source of ignition.

**9.2.13** Gas processing equipment including compression and hydrogen generation equipment, in processes where liquid is present, shall have means to prevent liquid carryover to the storage system.

**9.2.14** Dispensing equipment shall be provided with gas detectors, leak detection, and flame detectors such that fire and gas can be detected at any point on the equipment.

**9.2.14.1** These detectors shall be maintained and calibrated in accordance with the manufacturer's instructions on at least an annual basis or earlier if required by the manufacturer.

**9.2.14.2** The station owner or operator shall maintain a record of detector maintenance and calibration in good condition and accessible to the inspector.

**9.2.14.3** A sticker at least 6 in.$^2$ (39 cm$^2$) shall be affixed on the dispenser indicating the date of the next scheduled maintenance and calibration.

**9.3 System Siting.**

**9.3.1 General.**

**9.3.1.1** $GH_2$ compression, hydrogen generation equipment, storage, and dispensing shall be located and conducted outdoors or indoors in compliance with this section.

**9.3.1.2** This equipment is to be installed on foundations with anchoring systems designed to meet the requirements of the adopted building code for the appropriate seismic and wind conditions.

**9.3.1.3** The minimum distance from a bulk hydrogen compressed gas system located outdoors to specified exposure shall be in accordance with Table 9.3.1.3(a) or Table 9.3.1.3(b). *(See also Annex D.)* [**55:**10.3.2.2.1]

**Table 9.3.1.3(a) Minimum Distance from Outdoor Gaseous Hydrogen Systems to Exposures (U.S. Units)**

| | Total Gaseous Hydrogen Storage | | | |
|---|---|---|---|---|
| **Exposure** | **>15 to ≤250 psi 2.067 in. ID (ft)** | **>250 to ≤3000 psi 0.747 in. ID (ft)** | **>3000 to ≤7500 psi 0.312 in. ID (ft)** | **>7500 to ≤15,000 psi 0.282 in. ID (ft)** |
| (1) Lot lines[greater of a or b] | 40 | 45 | 30 | 35 |
| (2) Exposed persons other than those involved in servicing of the system[c] | 20 | 25 | 15 | 15 |
| (3) Buildings and structures | | | | |
| Combustible construction[d] | 15 | 20 | 10 | 15 |
| Noncombustible non-fire-rated construction[e] | 15 | 20 | 10 | 15 |
| Fire-rated construction with a fire resistance rating of not less than 2 hours[f] | 5 | 5 | 5 | 5 |
| (4) Openings in buildings of fire-rated or non-fire-rated construction (doors, windows, and penetrations) | | | | |
| Openable[a] | | | | |
| Fire-rated or non-fire-rated | 40 | 45 | 30 | 35 |
| Unopenable[d] | | | | |
| Fire-rated or non-fire-rated | 15 | 20 | 10 | 15 |
| (5) Air intakes (HVAC, compressors, other)[a] | 40 | 45 | 30 | 35 |
| (6) Fire barrier walls or structures used to shield the bulk system from exposures[f] | 5 | 5 | 5 | 5 |
| (7) Unclassified electrical equipment[g] | 15 | 15 | 15 | 15 |
| (8) Utilities (overhead), including electric power, building services, hazardous materials piping[d] | 15 | 20 | 10 | 15 |
| (9) Ignition sources such as open flames and welding[a] | 40 | 45 | 30 | 35 |
| (10) Parked cars[c] | 20 | 25 | 15 | 15 |
| (11) Flammable gas storage systems, including other hydrogen systems above ground | | | | |
| Nonbulk[d] | 15 | 20 | 10 | 15 |
| Bulk[h] | 15 | 15 | 15 | 15 |
| (12) Aboveground vents or exposed piping and components of flammable gas storage systems, including other hydrogen systems below ground[d] | | | | |
| Gaseous or cryogenic | 15 | 20 | 10 | 15 |
| (13) Hazardous materials (other than flammable gases) storage below ground[d] | | | | |
| Physical hazard materials or health hazard materials | 15 | 20 | 10 | 15 |

*(continues)*

**Table 9.3.1.3(a)** ***Continued***

| Exposure | Total Gaseous Hydrogen Storage >15 to ≤250 psi 2.067 in. ID (ft) | >250 to ≤3000 psi 0.747 in. ID (ft) | >3000 to ≤7500 psi 0.312 in. ID (ft) | >7500 to ≤15,000 psi 0.282 in. ID (ft) |
|---|---|---|---|---|
| (14) Hazardous materials storage (other than flammable gases) above ground[d] Physical hazard materials or health hazard materials | 15 | 20 | 10 | 15 |
| (15) Ordinary combustibles, including fast-burning solids such as ordinary lumber, excelsior, paper, and combustible waste and vegetation other than that found in maintained landscaped areas[d] | 15 | 20 | 10 | 15 |
| (16) Heavy timber, coal, or other slow-burning combustible solids[d] | 15 | 20 | 10 | 15 |

Note: All pressures are gauge pressures.
[a]Unignited jet concentration decay distance to 4 percent mole fraction (volume fraction) hydrogen.
[b]$D_{rad}$ – radiation heat flux level of 500 Btu/hr · ft$^2$.
[c]$D_{rad}$ for heat flux level of 1500 Btu/hr · ft$^2$ exposure to employees for a maximum of 3 minutes.
[d]The greater of $D_{rad}$ for combustible heat flux level of 6340 Btu/hr · ft$^2$ or the visible flame length.
[e]The greater of $D_{rad}$ for noncombustible equipment heat flux level of 8000 Btu/hr · ft$^2$ or the visible flame length.
[f]The minimum clearance between the structure and the system required for access for service-related activities.
[g]Equipment classified as meeting Class I, Division 2, Group B requirements of NFPA 70, *National Electrical Code*, when the area is in accordance with NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*
[h]Bulk hydrogen storage systems are allowed to integrate (co-locate) other nonliquefied flammable gas systems where the output of the system is designed to deliver a product in which the gases are mixed or blended for delivery into the user's system. The separation distance indicated requires a minimum separation between gaseous and liquid systems integrated into a single system where the liquid source is vaporized, compressed, and stored in the gaseous state.
[**55:** Table 10.3.2.2.1(a)]

**Table 9.3.1.3(b) Minimum Distance from Outdoor Gaseous Hydrogen Systems to Exposures (SI Units)**

| | Total Gaseous Hydrogen Storage | | | |
|---|---|---|---|---|
| Exposure | >103.4 to ≤1724 kPa 52.50 mm ID (m) | >1724 to ≤ 20,684 kPa 18.97 mm ID (m) | >20,684 to ≤51,711 kPa 7.92 mm ID (m) | >51,711 to ≤103,421 kPa 7.16 mm ID (m) |
| (1) Lot lines[greater of a or b] | 12.14 | 14.00 | 8.75 | 10.38 |
| (2) Exposed persons other than those involved in servicing of the system[c] | 5.94 | 7.02 | 4.13 | 5.05 |
| (3) Buildings and structures | | | | |
| Combustible construction[d] | 5.04 | 5.82 | 3.64 | 5.6 |
| Noncombustible non-fire-rated construction[e] | 5.04 | 5.82 | 3.64 | 3.64 |
| Fire-rated construction with a fire resistance rating of not less than 2 hours[f] | 1.5 | 1.5 | 1.5 | 1.5 |
| (4) Openings in buildings of fire-rated or non-fire-rated construction (doors, windows, and penetrations) | | | | |
| Openable[a] | | | | |
| Fire-rated or non-fire-rated | 12.14 | 14.00 | 8.75 | 10.38 |
| Unopenable[d] | | | | |
| Fire-rated or non-fire-rated | 5.04 | 5.82 | 3.64 | 4.31 |
| (5) Air intakes (HVAC, compressors, other)[a] | 12.14 | 14.00 | 8.75 | 10.38 |
| (6) Fire barrier walls or structures used to shield the bulk system from exposures[f] | 1.5 | 1.5 | 1.5 | 1.5 |
| (7) Unclassified electrical equipment[g] | 4.7 | 4.7 | 4.7 | 4.7 |
| (8) Utilities (overhead), including electric power, building services, or hazardous materials piping[d] | 5.04 | 5.82 | 3.64 | 4.31 |
| (9) Ignition sources such as open flames and welding[a] | 12.14 | 14.00 | 8.75 | 10.38 |
| (10) Parked cars[c] | 5.94 | 7.02 | 4.13 | 5.05 |
| (11) Flammable gas storage systems, including other hydrogen systems above ground | | | | |
| Nonbulk[d] | 5.04 | 5.82 | 3.64 | 4.31 |
| Bulk[h] | 4.7 | 4.7 | 4.7 | 4.7 |

*(continues)*

**Table 9.3.1.3(b)** ***Continued***

| Exposure | Total Gaseous Hydrogen Storage >103.4 to ≤1724 kPa 52.50 mm ID (m) | >1724 to ≤ 20,684 kPa 18.97 mm ID (m) | >20,684 to ≤51,711 kPa 7.92 mm ID (m) | >51,711 to ≤103,421 kPa 7.16 mm ID (m) |
|---|---|---|---|---|
| (12) Aboveground vents or exposed piping and components of flammable gas storage systems, including other hydrogen systems below ground[d] | | | | |
| Gaseous or cryogenic | 5.04 | 5.82 | 3.64 | 4.31 |
| (13) Hazardous materials (other than flammable gases) storage below ground[d] | | | | |
| Physical hazard materials or health hazard materials | 5.04 | 5.82 | 3.64 | 4.31 |
| (14) Hazardous materials storage (other than flammable gases) above ground[d] | | | | |
| Physical hazard materials or health hazard materials | 5.04 | 5.82 | 3.64 | 4.31 |
| (15) Ordinary combustibles, including fast-burning solids such as ordinary lumber, excelsior, paper, or combustible waste and vegetation other than that found in maintained landscaped areas[d] | 5.04 | 5.82 | 3.64 | 4.31 |
| (16) Heavy timber, coal or other slow-burning combustible solids[d] | 5.04 | 5.82 | 3.64 | 4.31 |

Note: All pressures are gauge pressures.

[a]Unignited jet concentration decay distance to 4 percent mole fraction (volume fraction) hydrogen.

[b]$D_{rad}$ – radiation heat flux level of 1577 W/m$^2$.

[c]$D_{rad}$ for heat flux level of 4732 W/m$^2$ exposure to employees for a maximum of 3 minutes.

[d]The greater of $D_{rad}$ for combustible heat flux level of 20,000 W/m$^2$ or the visible flame length.

[e]The greater of $D_{rad}$ for noncombustible equipment heat flux level of 25,237 W/m$^2$ or the visible flame length.

[f]The minimum clearance between the structure and the system required for access for service-related activities.

[g]Equipment classified as meeting Class I, Division 2, Group B requirements of *NFPA 70, National Electrical Code*, when the area is in accordance with NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

[h]Bulk hydrogen storage systems are allowed to integrate (co-locate) other nonliquefied flammable gas systems where the output of the system is designed to deliver a product in which the gases are mixed or blended for delivery into the user's system. The separation distance indicated requires a minimum separation between gaseous and liquid systems integrated into a single system where the liquid source is vaporized, compressed, and stored in the gaseous state.

[**55:** Table 10.3.2.2.1(b)]

**9.3.1.3.1 Maximum Internal Diameter of Interconnecting Piping.** The maximum internal diameter of the piping system used for interconnecting piping between the shutoff valve on any single storage container to the point of connection to the system source valve shall not exceed the values shown in Table 9.3.1.3(a) and Table 9.3.1.3(b) for the pressure range indicated except as allowed by 9.3.1.3.1.2 or 9.3.1.3.1.3. [**55:**10.3.2.2.1.1]

**9.3.1.3.1.1 Shutoff Valves on the Source of Supply.** When shutoff valves are not connected directly to the source of supply, all interconnecting piping between the source connection and points downstream shall be included in the determination of internal diameter for the piping system. [**55:**10.3.2.2.1.1(A)]

**9.3.1.3.1.2* Alternative Internal Diameters.** The separation distance for piping systems with internal diameters greater than those specified in Table 9.3.1.3(a) and Table 9.3.1.3(b) for the pressure range selected shall be permitted with tabular distances determined based on the use of the equations in Table 9.3.1.3.1.2. [**55:**10.3.2.2.1.1(B)]

**9.3.1.3.1.3** The separation distance for piping systems with internal diameters less than those specified in Table 9.3.1.3(a) and Table 9.3.1.3(b) for the pressure range selected shall be allowed to be reduced with tabular distances determined based on the use of equations in Table 9.3.1.3.1.2. [**55:**10.3.2.2.1.1(C)]

**9.3.1.3.1.4** Separation distances determined based on the use of Table 9.3.1.3.1.2 shall be subject to review and approval by the AHJ. [**55:**10.3.2.2.1.1(D)]

**9.3.1.3.1.5* Determination of Internal Diameter.** The internal diameter of the piping system shall be determined by the diameter of the piping serving a storage array with content greater than 400 scf (11.3 $m^3$). The piping system size used in the application of Table 9.3.1.3(a) and Table 9.3.1.3(b) shall be determined based on that portion of the system with the greatest maximum internal diameter. [**55:**10.3.2.2.1.1(E)]

**9.3.1.3.1.6* Determination of System Pressure.** The system pressure shall be determined by the maximum operating pressure of the storage array with content greater than 400 scf (11.3 $m^3$), irrespective of those portions of the system elevated to a higher pressure. [**55:**10.3.2.2.1.1(F)]

**9.3.1.3.2*** Except for distances to lot lines, operable building openings, air intakes, and overhead utilities, the distances in Table 9.3.1.3(a) and Table 9.3.1.3(b) shall not apply where fire barrier walls having a minimum fire resistance rating of 2 hours are located between the system and the exposure. [**55:**10.3.2.2.2]

**9.3.1.3.3*** The distances in (1), (2), (4), and (10) in Table 9.3.1.3(a) and Table 9.3.1.3(b) shall be permitted to be reduced by one-half where fire barrier walls having a minimum fire resistance rating of 2 hours are located between the system and the exposure. [**55:**10.3.2.2.3]

**9.3.1.4** The outdoor installation of hydrogen dispensers shall meet the separation distances shown in Table 9.3.1.4.

**9.3.2 Outdoors.**

**9.3.2.1** A facility in which $GH_2$ compression, gas processing, hydrogen generation equipment, storage, and dispensing equipment are sheltered by an enclosure that is constructed as weather protection in accordance with 9.3.2.1.1 with a roof designed for ventilation and dispersal of escaped gas shall be considered to be located outdoors.

**Table 9.3.1.3.1.2 Separation Distance Based on Alternative Pipe or Tube Internal Diameters**

| Notes* | >15 to ≤250 psi (>103.4 to ≤1724 kPa) | >250 to ≤3000 psi (>1724 to ≤ 20,684 kPa) | >3000 to ≤7500 psi (>20,684 ≤ 51,711 kPa) | >7500 to ≤15,000 psi (>51,711 ≤ 103,421 kPa) |
|---|---|---|---|---|
| (a) | $D_a = 0.23179d^{0.99931}$ | $D_a = 0.73903d^{0.99962}$ | $D_a = 1.1062d^{0.99959}$ | $D_a = 1.4507d^{0.9995}$ |
| (b) | $D_b = 0.091137d^{1.1303} + e^{-0.084081d}(0.087694d^{0.72681} - 0.091137d^{1.1303})$ | $D_b = 0.36599d^{1.1152} + e^{-0.10771d}(0.1885d^{1.2531} - 0.36599d^{1.1152})$ | $D_b = 0.60173d^{1.1063} + e^{-0.36516d}(-0.00002521d^{5.6078} - 0.60173d^{1.1063})$ | $D_b = 0.84053d^{1.1023} + e^{-0.40365d}(-0.000043007d^{5.7146} - 0.84053d^{1.1023})$ |
| (c) | $D_c = 0.075952d^{1.1022} + e^{-0.087589d}(0.076814d^{0.83088} - 0.075952d^{1.1022})$ | $D_c = 0.2889d^{1.092} + e^{-0.10392d}(0.18705d^{1.1795} - 0.2889d^{1.092})$ | $D_c = 0.45889d^{1.0887} + e^{-0.46723d}(-0.000027772d^{5.8841} - 0.45889d^{1.0887})$ | $D_c = 0.6324d^{1.0859} + e^{-0.52477d}(-0.000086234d^{5.8213} - 0.6324d^{1.0859})$ |
| (d) | $D_d = 0.096359d^{0.99928}$ | $D_d = 0.3072d^{0.99962}$ | $D_d = 0.45967d^{0.99971}$ | $D_d = 0.60297d^{0.99956}$ |
| (e) | $D_e = 0.096359d^{0.99928}$ | $D_e = 0.3072d^{0.99962}$ | $D_e = 0.45967d^{0.99971}$ | $D_e = 0.60297d^{0.99956}$ |

Notes:
(1) Use of this table assumes a leak diameter of 3 percent of the pipe flow area or internal diameter where $d$ = inside diameter (ID) of pipe or tube expressed in millimeters (mm), and $D_{a,b,c,d,\ or\ e}$ = separation distance in meters (m).
(2) All pressures are gauge pressures.
*Notes are from Table 9.3.1.3(a) and Table 9.3.1.3(b) as follows:
(a) Unignited jet concentration decay distance to 4 percent mole fraction (volume fraction) hydrogen
(b) $D_{rad}$ – radiation heat flux level of 500 Btu/hr·ft² (1577 W/m²)
(c) $D_{rad}$ for heat flux level of 1500 Btu/hr·ft² (4732 W/m²) exposure to employees for a maximum of 3 minutes
(d) The greater of $D_{rad}$ for combustible heat flux level of 6340 Btu/hr·ft² (20,000 W/m²) or the visible flame length
(e) The greater of $D_{rad}$ for noncombustible equipment heat flux level of 8000 Btu/hr·ft² (25,237 W/m²) or the visible flame length
[**55:** Table 10.3.2.2.1.1(B)]

**Table 9.3.1.4 Separation Distances for Outdoor Gaseous Hydrogen Dispensing Systems**

| System Component | Exposure | Required Separation ft | Required Separation m |
|---|---|---|---|
| Dispensing equipment | Nearest important building or line of adjoining property that can be built upon or from any source of ignition | 10 | 3.0 |
| Dispensing equipment | Nearest public street or public sidewalk | 10 | 3.0 |
| Dispensing equipment | Nearest rail of any railroad main track | 10 | 3.0 |
| Point of transfer | Any important building other than buildings of Type I or Type II construction with exterior walls having a fire resistance rating of not less than 2 hours | 10 | 3.0 |
| Point of transfer | Buildings of Type I or Type II construction with exterior walls having a fire resistance rating of not less than 2 hours or walls constructed of concrete or masonry, or of other material having a fire resistance rating of not less than 2 hours | No limit | No limit |
| Point of transfer | Storage containers | 3 | 1.0 |

**9.3.2.1.1* Weather Protection.** Where weather protection is provided for sheltering outside hazardous material storage or use areas, such storage or use areas shall be considered outside storage or use areas, provided that all of the following conditions are met:

(1) Supports and walls shall not obstruct more than one side or more than 25 percent of the perimeter of the storage or use area. [**5000:**34.2.5(1)]
(2) The distance from the structure and the structural supports to buildings, lot lines, public ways, or means of egress to a public way shall not be less than the distance required by NFPA 1 for an outside hazardous material storage or use area without weather protection. [**5000:**34.2.5(2)]
(3) Weather-protection structures constructed in accordance with 9.3.2.1.1 shall not contain explosive or detonable materials. [**5000:**34.2.5(3)]

**9.3.2.2** Aboveground installations shall include systems installed overhead on appropriately engineered structures.

**9.3.2.3** The point of transfer shall be permitted to be located at a lesser distance from buildings or walls constructed of concrete or masonry materials or of other material having a fire resistance rating of not less than 2 hours, but at least 10 ft (3.0 m) from any building openings.

**9.3.2.3.1** Dispensing points shall be permitted to be located at a lesser distance from buildings or walls constructed of materials having a fire resistance rating of not less than 2 hours, but at least 10 ft (3.0 m) from building openings.

**9.3.3 Indoors.**

**9.3.3.1 General.** Compression, gas processing, dispensing equipment, and storage containers connected for use shall be permitted to be located inside of buildings reserved exclusively for these purposes or in rooms within or attached to buildings used for other purposes in accordance with Section 9.3.

**9.3.3.2* Storage in Buildings.** Bulk hydrogen compressed gas systems shall be in accordance with NFPA 55, *Compressed Gases and Cryogenic Fluids Code*.

*Exception: $GH_2$ stored in vehicle-mounted fuel supply containers.*

**9.3.3.3 Dispensing.** Fuel dispensing indoors shall be in accordance with 9.3.3.3.

**9.3.3.3.1 Deflagration Venting.** When used, deflagration (explosion) venting shall be provided in exterior walls and roofs only.

**9.3.3.3.2** Vents shall be permitted to consist of any one or any combination of the following:

(1) Walls of light material
(2) Lightly fastened hatch covers
(3) Lightly fastened, outward opening doors in exterior walls
(4) Lightly fastened walls or roofs
(5) Other methods in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

**9.3.3.3.3** Where applicable, snow loads shall be included in the calculations of the building.

**9.3.3.4 Rooms Within Buildings.**

**9.3.3.4.1** Rooms within or attached to other buildings shall be constructed of noncombustible or limited-combustible materials.

*Exception: Window glazing shall be permitted to be plastic.*

**9.3.3.4.2** Interior walls or partitions shall be continuous from floor to ceiling, shall be anchored, and shall have a fire resistance rating of at least 2 hours.

**9.3.3.4.3** At least one wall shall be an exterior wall.

**9.3.3.4.4** Explosion venting shall be provided in accordance with 9.3.3.3.1.

**9.3.3.4.5** Access to the room shall be from outside the primary structure.

**9.3.3.4.6** If access to the room from outside the primary structure is not possible, access from within the primary structure shall be permitted where such access is made through a vapor-sealing, self-closing fire door having the appropriate rating for the location where installed.

**9.3.3.5 Ventilation.**

**9.3.3.5.1** Indoor locations shall be ventilated utilizing air supply inlets and exhaust outlets arranged to provide uniform air movement to the extent practical.

**9.3.3.5.2** Inlets shall be uniformly arranged on exterior walls near floor level.

**9.3.3.5.3** Outlets shall be located in exterior walls at the high point of the room or in the roof.

**9.3.3.5.4 Room Ventilation.**

**9.3.3.5.4.1** Ventilation shall be by a continuous mechanical ventilation system or by a mechanical ventilation system activated by a continuously monitoring hydrogen detection system where a gas concentration of not more than one-quarter of the lower flammable limit is present.

**9.3.3.5.4.2** In either case in 9.3.3.5.4.1, the system shall immediately shut down the fueling system in the event of detection of an alarm condition or failure of the ventilation system, the detection system, or of the controls.

**9.3.3.5.5** The ventilation rate shall be at least 1 $ft^3/min \cdot ft^2$ ($0.3\ m^3/min \cdot m^2$) of room area, but no less than 1 $ft^3/min \cdot 12\ ft^3$ ($0.03\ m^3/min \cdot 0.34\ m^3$) of room volume.

**9.3.3.5.6** A ventilation system for a room within or attached to another building shall be separate from any ventilation system for the other building.

**9.3.3.6** Where installed, a gas detection system shall be equipped to sound a latched alarm and visually indicate when a maximum of one-quarter of the lower flammable limit is reached.

**9.3.3.6.1** The gas detection system shall be certified by a qualified engineer with expertise in fire safety and gaseous detection.

**9.3.3.7** The gas detection system shall function during system maintenance operations.

**9.3.3.8** Reactivation of the fueling system shall be by manual restart and shall be conducted by trained personnel.

**9.3.3.9*** Buildings and rooms used for compression, other than that integral to the bulk storage system, gas processing, and dispensing, shall be classified in accordance with Table 9.3.3.9 for installations of electrical equipment.

**9.3.3.10** Nonelectrical sources of ignition, other than electrical installations as permitted by Table 9.3.3.9, shall not be permitted.

**9.3.3.11 Warning Signs.**

**9.3.3.11.1** Access doors shall have warning signs with the words "WARNING — NO SMOKING — FLAMMABLE GAS." "Non-odorized Gas."

**9.3.3.11.2** The wording shall be in plainly legible, bright red letters not less than 1 in. (25 mm) high on a white background.

**9.4 Indoor Fast-Fill Fueling, Outdoor Storage, and Compression.** Fast-fill fueling indoors shall be permitted where storage, gas processing, and compression equipment is located outdoors complying with 9.3.2.1 through 9.3.2.3.

**9.4.1 Qualified Operator.** Dispensing operations shall be performed by an operator who has been qualified by training to perform the functions necessary in the filling operation as described by the manufacturer's operating instructions.

**9.4.2 Construction of Indoor Areas.** Walls, ceilings, and floors within 15 ft (4.6 m) of the dispenser shall be constructed as fire barriers having a fire resistance rating of not less than 2 hours.

**Table 9.3.3.9 Electrical Installations**

| Location | Division or Zone | Extent of Classified Area |
|---|---|---|
| Containers (other than mounted fuel supply containers). Except 0 ft if the PRVs and PRDs are piped and vented as required in Chapter 5. | 2 | Within 15 ft (4.6 m) of container |
| Area containing compression and ancillary equipment | 2 | Up to 15 ft (4.6 m) from equipment |
| Outdoor Dispensing Equipment Enclosure Interior | 1 | Up to support mechanism or connection to the ground |
| Outdoor Dispensing Equipment Enclosure Exterior | 2 | Up to 5 ft (1.5 m) from dispenser |
| Indoor Dispensing Equipment Enclosure Interior | 1 | Up to support mechanism or connection to the ground |
| Indoor Dispensing Equipment Enclosure Exterior | 2 | Entire room with adequate ventilation *(See 9.3.3.5.5.)* |
| Outdoor discharge from relief valves or vents | 1 | 5 ft (1.5 m) from source |
| Outdoor discharge from relief valves or vents | 2 | 15 ft (4.6 m) from source |
| Discharge from relief valves within 15 degrees of the line of discharge | 1 | 15 ft (4.6 m) from source |

**9.4.2.1 Openings.** Opening protectives shall be provided for wall openings in accordance with the requirements of *NFPA 5000, Building Construction and Safety Code*.

**9.4.2.2 Penetrations.** Through-penetrations and membrane penetrations of fire resistance rated construction shall be protected in accordance with the requirements of *NFPA 5000, Building Construction and Safety Code*.

**9.4.2.3 Roof-Ceiling Assemblies.** The fire-resistive protection of a roof-ceiling assembly required by 9.4.2 shall not be required where every part of the roof-ceiling assembly is 20 ft (6.1 m) or more above any floor immediately below.

**9.4.2.4 Floors.** Floors in dispensing areas constructed of noncombustible or limited-combustible materials shall not be required to comply with 9.4.2.

**9.4.3 Ventilation.**

**9.4.3.1** Ventilation shall be in accordance with 9.3.3.5.

**9.4.3.2** The ventilation system of 9.3.3.5 shall not be required in industrial and storage occupancies when the room or area in which dispensing occurs is in accordance with 9.4.3.2.1 through 9.4.3.2.7.

**9.4.3.2.1*** The minimum volume of the room in which a dispenser is installed shall be not less than that specified by Table 9.4.3.2.1, and the maximum quantity of fuel to be dispensed per fueling event shall be limited to an amount not greater than that established by the minimum room volume.

**Table 9.4.3.2.1 Minimum Room Volume Based on Maximum Fueling Event**

| Maximum Fuel Quantity per Dispensing Event | | Minimum Room Volume | |
|---|---|---|---|
| lb | kg | $ft^3$ | $m^3$ |
| Up to 1.8 | Up to 0.8 | 40,000 | 1,000 |
| 1.8 to 3.7 | >0.8 to 1.7 | 70,000 | 2,000 |
| 3.7 to 5.5 | >1.7 to 2.5 | 10,0000 | 3,000 |
| 5.5 to 7.3 | >2.5 to 3.3 | 14,0000 | 4,000 |
| 7.3 to 9.3 | >3.3 to 4.2 | 18,0000 | 5,000 |

**9.4.3.2.2** The dispenser shall be equipped with an automatic shutoff control to shut down the source of fuel when the maximum fuel quantity per dispensing event is reached or when the vehicle has been fueled to capacity, whichever is less.

**9.4.3.2.2.1** In no case shall the amount of fuel being delivered exceed the maximum quantity per dispensing event as shown in Table 9.4.3.2.1.

**9.4.3.2.2.2** The shut-off control shall be tested at installation and annually thereafter.

**(A)** A sticker indicating that the required testing has occurred shall be affixed to the dispenser in accordance with 9.2.14.3 and shall also indicate the next test date.

**(B)** Failure of the controller shall shut down the dispensing system.

**9.4.3.2.3*** When multiple dispensers are installed in a room, the minimum room volume shall be incrementally increased for each additional dispenser.

**9.4.3.2.4** The height of the ceiling of the room, where dispensing occurs, shall be not less than 25 ft (8 m).

**9.4.3.2.5** The maximum refueling rate shall be limited to not more than 4.4 lb/min (2 kg/min) or 845 $ft^3$/min (24 $m^3$/min).

**9.4.3.2.6** All potential leak points between the dispenser cabinet and the refueling nozzle shall be monitored by the dispenser in accordance with 9.16.2.6 and 9.16.2.7. Activation of the monitoring system shall shut down the dispensing system.

**9.4.3.2.7** The fueling hose shall be limited to a maximum length of 25 ft (7.6 m) and shall be protected from mechanical damage, from abrasion, and from being driven over by a vehicle.

**9.4.3.2.7.1** Transfer systems shall be capable of depressurizing the nozzle through the dispenser vent line to facilitate disconnection.

**9.4.3.2.8** The dispensing area shall be inspected annually and certified in accordance with 9.2.2.

**9.4.3.2.9** The electrical area classification for the dispenser shall be Class 1 Division 2 within 15 ft (4.6 m) of the point of transfer during filling.

**9.4.3.2.9.1** The classified area shall extend outwards from the point of dispensing in the shape of a cylinder with a radius of 15 ft (4.6 m) that extends from the floor to the ceiling.

**9.4.3.2.9.2** The electrical area classification shall not apply to vehicles.

**9.4.4 Fire Alarm System.**

**9.4.4.1** The dispensing area shall be equipped with a protected premises (local) fire alarm system in accordance with *NFPA 72, National Fire Alarm and Signaling Code*.

**9.4.4.2 Manual Fire Alarm Boxes.** A manual fire alarm box shall be located not less than 20 ft (6.1 m) and not more than 100 ft (30.5 m) from the dispensing station.

**9.4.4.2.1** An additional manual fire alarm box shall be located at the nearest exit from the dispensing area.

**9.4.4.2.2** Activation of the fire alarm box shall sound a local fire alarm signal to alert building occupants of a fire in the dispensing area and shall shut down the dispenser, stop the flow of gas into the room, and start or continue to run the ventilation system.

**9.4.5 Fire Detection System.** The dispensing room or area shall be equipped with a fire detection system.

**9.4.5.1** Actuation of the fire detection system shall shut down the gas flow from the dispenser and stop the flow of gas into the piping system located in the room where dispensing occurs.

**9.4.5.2** Actuation of the fire detection system shall sound a local fire alarm signal to alert building occupants of a fire in the dispensing area and shall provide a visual indication in the dispensing area of an alarm condition.

**9.4.5.3** The fire detection system shall be maintained in an operational condition when the dispenser is either operating or being maintained.

**9.4.5.3.1** An interlock shall be provided so that the dispenser will not operate if the fire alarm is not operational.

**9.4.6 Emergency Shutdown Device (ESD).** A manual emergency shutdown device (ESD) shall be located in the dispensing area not less than 20 ft (6.1 m) and not more than 100 ft (30.5 m) in the path of egress from the dispensing area.

**9.4.6.1** An additional shutdown shall be installed on the dispenser.

**9.4.6.2** Actuation of the ESD shall shut down the dispenser, stop the flow of gas into the room, and start or continue to run the ventilation system.

**9.4.7 Dispensing Equipment.** Gas dispensing equipment shall be listed or approved for indoor use.

**9.4.7.1 Automatic Shut-off Valve.** Hydrogen gas piping used to transport $GH_2$ between the bulk hydrogen compressed gas storage system and a dispenser at a fast-fill station shall have a valve that closes when one of the following occurs:

(1) The power supply to the dispenser is shut off.
(2) Any ESD at the refueling station is activated.

**9.4.7.2 Manual Shut-off Valve.** A fast-closing, "quarter turn" manual shutoff valve shall be provided at a fast-fill station upstream of the breakaway device specified in 9.11.6, where it is readily accessible to the person dispensing hydrogen, unless one of the following occurs:

(1) The self-closing valve referred to in 9.4.7.1 is located immediately upstream of the dispenser.
(2) The dispenser is equipped with a self-closing valve that closes each time the control arm is turned to the OFF position or when the ESD is activated.

**9.4.7.3 Shutdown.**

**9.4.7.3.1** Actuation or failure of the following systems shall automatically shut down the gas flow from the dispenser, stop the flow of gas to the room, and start or continue to run the mechanical ventilation system:

(1) Gas detection system
(2) Fire alarm system
(3) Fire detection system
(4) Emergency shutdown system (ESD)
(5) Sensors or controls used to prevent overtemperature or overpressurization of the on-board fuel container
(6) Required ventilation systems
(7) Dispenser leak monitoring system

**9.4.7.3.2** Reactivation of the dispenser and gas flow into the room after system shutdown required by 9.4.7.1 or 9.4.7.3 shall be by manual restart and shall be conducted by trained personnel.

**9.4.7.4 Gas Detection System.** The dispenser enclosure or housing shall be equipped with a gas detection system, which shall actuate when a maximum of 25 percent of the lower flammable limit (LFL) is detected (1 percent $H_2$ in air).

**9.4.7.4.1** Actuation of the gas detection system shall shut down the dispenser, stop the flow of gas into the room, and start or continue to run the ventilation system.

**9.4.7.4.2** Actuation of the gas detection system shall sound a local alarm and provide visual indication when a maximum of 25 percent of the lower flammable limit (LFL) is detected (1 percent $H_2$ in air).

**9.4.7.4.3** The gas detection system shall function during maintenance operations on the ventilation system.

**9.4.7.5 Electrical.** Electrical equipment on dispensers shall be in accordance with 9.3.3.9.

**9.4.7.6 Temperature Limits.** Dispensing systems shall be provided with a means to prevent the on-board fuel system from exceeding prescribed temperature limits during fueling operations.

**9.4.7.7 Pressure Limits.** Dispensing systems shall be provided with a means to prevent the on-board fuel system from exceeding prescribed pressure limits during fueling operations.

**9.4.8 Ignition Source Control.** The owner/operator shall not allow hot work/open flames within 15 ft (4.6 m) of the refueling location unless the dispenser is shut down, depressurized, and purged.

**9.4.9 Defueling.** If $GH_2$ is to be removed from the vehicle storage system, $GH_2$ shall be discharged into a closed transfer system or vented outdoors through a vent pipe system installed and constructed in accordance with CGA G-5.5, *Hydrogen Vent Systems*.

**9.5 Installation of Containers and Container Appurtenances (Other than Pressure Relief Devices).**

**9.5.1** The installation of containers, cylinders, and tanks shall be in accordance with NFPA 55, *Compressed Gases and Cryogenic Fluids Code*.

**9.5.2** Stationary compressed gas containers, cylinders, and tanks shall be marked in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*. [**55:**7.1.7.3.1]

**9.5.3 Vaults for Aboveground Containers. (Reserved)**

**9.5.4 Underground Systems. (Reserved)**

**9.6 Installation of PRDs on Fueling Systems.**

**9.6.1** PRDs shall be in accordance with 9.6.1.1 through 9.6.1.2.

**9.6.1.1** PRDs shall be so arranged that they discharge in accordance with Section 5.4.

**9.6.1.2** An overpressure protection device, other than a rupture disc, shall be installed in the fueling transfer system to prevent overpressure in the vehicle.

**9.6.2** The set pressure of the overpressure protection device for the dispensing system shall not exceed 140 percent of the service pressure of the fueling nozzle it supplies.

**9.7 Installation of Pressure Regulators.**

**9.7.1** Regulators shall be designed, installed, or protected so that their operation is not affected by freezing rain, sleet, snow, ice, mud, insects, or debris.

**9.7.2** The regulator protection in 9.7.1 shall be permitted to be integral with the regulator.

**9.8 Installation of Pressure Gauges.** Gauges or other suitable readout devices shall be installed to indicate compression discharge pressure, storage pressure, and dispenser discharge pressure.

**9.9 Installation of Piping and Hoses.**

**9.9.1** Piping and hose shall be run as directly as practical and with provisions to protect the piping from the effects of expansion, contraction, jarring, vibration, and settling.

**9.9.1.1** Exterior piping shall be either buried, laid in a trench, or installed above ground and shall be supported and protected against mechanical damage.

**9.9.1.2** Underground piping shall be buried not less than 18 in. (460 mm) below the surface of the ground unless otherwise protected from damage by movement of the ground.

**9.9.1.3** Underground and aboveground piping shall be protected from corrosion in compliance with recognized practices.

**9.9.1.4 Piping Systems.**

**9.9.1.4.1** Piping systems shall be designed, installed, erected, tested, and maintained in accordance with the provisions of ANSI/ASME B31.3, *Process Piping*.

**9.9.1.4.1.1** Manifolds connecting fuel containers shall be fabricated to minimize vibration and shall be installed in a protected location or shielded to prevent damage from unsecured objects.

**9.9.1.4.1.2** A pipe thread jointing material impervious to the action of the hydrogen used in the system shall be applied to all male pipe threads prior to assembly.

**9.9.1.4.1.3** Threaded piping and fittings shall be clear and free from cutting or threading burrs and scales, and the ends of all piping shall be reamed.

**9.9.1.4.1.4** Threaded pipe and fittings shall not be used underground.

**9.9.1.4.2** Piping joints made with tapered threaded pipe and sealant shall not be used in hydrogen service.

*Exception: Tapered threads are allowed where instrumentation is not available with straight threads.*

**9.9.1.4.3** A bend in piping or tubing shall have the pressure rating reduced according to ANSI/ASME B31.3, *Process Piping*.

**9.9.1.4.4** Joints or connections shall be located in an accessible location.

**9.9.1.4.5** The number of joints shall be minimized and placed in a location considering personnel safety.

**9.9.2*** Hydrogen shall be vented in accordance with Section 5.4.

**9.9.3** The use of hose in an installation shall be limited to the following:

(1) Vehicle fueling hose
(2) Inlet connection to compression equipment
(3) Section of hose not exceeding 36 in. (910 mm) in length in a pipeline to provide flexibility where necessary

**9.9.3.1** Each section shall be so installed that it is protected against mechanical damage and is readily visible for inspection.

**9.9.3.2** The individual component and manufacturer's identification shall be retained in each section and throughout the system.

**9.9.4** The hose shall be approved or listed for hydrogen service.

**9.9.5** At fueling stations, gas used for calibration and testing shall be vented to a vent pipe in accordance with Section 5.5.

**9.10 System Testing.**

**9.10.1*** Piping, tubing and hose, and hose assemblies shall be leak tested after assembly to prove them free from leaks at a pressure equal to at least the normal service pressure of that portion of the system.

**9.10.1.1** This leak test shall be in addition to the ANSI/ASME B31.3, *Process Piping*, testing required by 5.4.

**9.10.1.2** The assembly shall be leak tested using hydrogen or helium.

**9.10.1.3** Where hydrogen is to be used as the leak test media, the system shall first be purged with an inert gas to ensure that all oxygen is removed.

**9.10.2** Pressure relief valves shall be tested at least every 3 years.

**9.11 Installation of Emergency Shutdown Equipment.**

**9.11.1 Manually Operated Container Valve.**

**9.11.1.1** Each group of storage vessels up to a maximum combined capacity of 10,000 scf (283 $m^3$) shall be provided with a manually operated shutoff valve.

**9.11.1.2** A manually operated shutoff valve shall be installed in a manifold as close to a container or group of containers as practical.

**9.11.1.3** The valve in 9.11.1.2 shall be located downstream of the backflow check valve specified in 9.11.2.

**9.11.2** The compressor discharge line supplying the storage container shall be equipped with a backflow check valve near the container to prevent discharge of hydrogen from the container in case of the rupture of the line, hose, or fittings.

**9.11.3** Where excess-flow check valves are used, the closing flow shall be greater than the design flow maximum system design flow rate and less than the flow rating of the piping system that results from a complete line failure between the excess-flow valve and the equipment downstream of the excess-flow check valve.

**9.11.4** Gas piping from an outdoor compressor or storage system into a building shall be provided with shut-off valves located outside the building.

**9.11.5** An emergency manual shutdown device shall be provided at the dispensing area and also at a location remote from the dispensing area.

**9.11.5.1** This device, when activated, shall shut off the power supply and gas supply to the compressor and the dispenser.

**9.11.5.2** When $GH_2$ is being produced from the conversion of $LH_2$, the emergency shutdown system also shall shut off the liquid supply and power to the $LH_2$ transfer equipment necessary for the conversion process.

**9.11.5.3** ESDs shall be distinctly marked for easy recognition with a permanently affixed legible sign.

**9.11.6** A breakaway device that causes hydrogen gas flow to stop shall be installed between the connection of the hose to the dispenser and the filling nozzle.

**9.11.6.1** Such a device shall be arranged to separate using a force not greater than 150 lb (68 kg) when applied in any direction that the vehicle would move.

**9.11.6.2** Breakaway devices shall be compatible with ANSI/IAS NGV 4.4, *Breakaway Devices for Dispensing Systems*.

**9.11.7** Control circuits shall be arranged so that, when an emergency shutdown device is activated or electric power is cut off, systems that shut down shall remain down until manually activated or reset after a safe condition is restored.

**9.11.8 Fast-Fill Station.**

**9.11.8.1** Each line between a gas storage facility and a dispenser at a fast-fill station shall have a valve that closes when one of the following occurs:

(1) The power supply to the dispenser is cut off.
(2) Any emergency shutdown device at the refueling station is activated.

**9.11.8.2** A fast-closing, "quarter turn" manual shut-off valve shall be provided at a fast-fill station upstream of the breakaway device specified in 9.11.6, where it is readily accessible to the person dispensing hydrogen, unless one of the following occurs:

(1) The self-closing valve referred to in 9.11.8.1 is located immediately upstream of the dispenser.
(2) The dispenser is equipped with a self-closing valve that closes each time the control arm is turned to the OFF position or when an emergency device is activated.

**9.11.9** A self-closing valve shall be provided on the inlet of the compressor that shuts off the gas supply to the compressor when one of the following occurs:

(1) An emergency shutdown device is activated.
(2) A power failure occurs.
(3) The power to the compressor is switched to the OFF position.

**9.12 Installation of Electrical Equipment.**

**9.12.1** Fixed electrical equipment and wiring within areas specified in Table 9.3.3.9 shall comply with Table 9.3.3.9 and shall be installed in accordance with *NFPA 70, National Electrical Code*.

*Exception: Electrical equipment on internal combustion engines installed in accordance with NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

**9.12.2** With the approval of the authority having jurisdiction, the classified areas specified in Table 9.3.3.9 shall be permitted to be reduced or eliminated by positive pressure ventilation from a source of clean air or inert gas in conjunction with effective safeguards against ventilator failure by purging methods recognized in NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*.

**9.12.2.1** Modifications shall be signed off by a qualified engineer with expertise in fire safety and gaseous fuels.

**9.12.3** Classified areas shall not extend beyond an unpierced wall, roof, or gastight partition.

**9.12.4** Space around welded pipe and equipment without flanges, valves, or fittings shall be a nonhazardous location.

*Exception: Listed dispensers shall be permitted to be installed using classified areas in accordance with the terms of the listing.*

**9.13 Stray or Impressed Currents and Bonding.**

**9.13.1*** Where stray or impressed currents are used or can be present on dispensing systems, such as cathodic protection, protective measures to prevent ignition shall be taken.

**9.13.2** Additional static protection shall not be required where $GH_2$ is transferred by conductive hose, flexible metallic tubing, or pipe connections where both halves of the metallic coupling are in continuous contact.

**9.13.3** A vehicle fueling pad shall be provided in the area where vehicles are to be refueled.

**9.13.3.1** The pad shall be constructed with a length and width to accommodate the types of vehicles to be fueled.

**9.13.3.2*** The vehicle fueling pad shall be of concrete or a material having a resistivity not exceeding 1 megohm as determined by an approved method.

**9.13.4 Cathodic Protection.** Where required, cathodic protection shall be in accordance with 9.13.4.1 through 9.13.4.4. [**55:**8.14.9]

**9.13.4.1 Operation.** Where installed, cathodic protection systems shall be operated and maintained to continuously provide corrosion protection. [**55:**8.14.9.1]

**9.13.4.2 Inspection.** Container systems equipped with cathodic protection shall be inspected for the intended operation by a cathodic protection tester. [**55:**8.14.9.2.1]

**9.13.4.2.1** The cathodic protection tester shall be certified as being qualified by the National Association of Corrosion Engineers, International (NACE). [**55:**8.14.9.2.2]

**9.13.4.3 Impressed Current Systems.** Systems equipped with impressed current cathodic protection systems shall be inspected in accordance with the requirements of the design and 9.13.4.2. [**55:**8.14.9.3.1]

**9.13.4.3.1** The design limits shall be available to the AHJ upon request. [**55:**8.14.9.3.2]

**9.13.4.3.2** The system owner shall maintain the following records to demonstrate that the cathodic protection is in conformance with the requirements of the design:

(1) The results of inspections of the system
(2) The results of testing that has been completed [**55:**8.14.9.3.3]

**9.13.4.4** Repairs, maintenance, or replacement of a cathodic protection system shall be under the supervision of a corrosion expert certified by NACE. [**55:**8.14.9.4]

**9.13.4.4.1** The corrosion expert shall be certified by NACE as a senior corrosion technologist, a cathodic protection specialist, or a corrosion specialist, or shall be a registered engineer with registration in a field that includes education and experience in corrosion control. [**55:**8.14.9.4.1]

**9.14 System Operation.**

**9.14.1** A vehicle container shall not be charged in excess of the service pressure compensated for differences in temperature from 59°F (15°C).

**9.14.1.1 $HV_2$. (Reserved)**

**9.14.1.2** System design shall take into account the possibility of pressure and/or temperature communication between dispenser and vehicle, although this communication is not required.

**9.14.2** A fuel supply container shall not have a settled pressure above the service pressure that is stamped on the container and displayed on a label near the filling connection, corrected for the ambient temperature at the time of filling.

**9.14.3** $GH_2$ dispensing systems shall be equipped to stop fuel flow automatically when a fuel supply container reaches the temperature-corrected fill pressure.

**9.14.4** Where an overpressure incident that results in operation of the overpressure protection system occurs, the dispenser pressure control system shall be examined and certified by a qualified technician prior to being returned to service.

**9.14.5** The transfer of $GH_2$ into a fuel supply container shall be performed in accordance with instructions posted at the dispensing station.

**9.14.6** Where $GH_2$ is being transferred to or from a motor vehicle, the engine shall be turned off.

**9.14.7** During the transfer of $GH_2$ to or from delivery transport vehicles, the hand or emergency brake of the vehicle shall be set, and chock blocks shall be used to prevent rolling of the vehicle.

**9.14.8** Transfer systems shall be capable of depressurizing to facilitate disconnection.

**9.14.9** Bleed connections shall lead to a safe point of discharge.

**9.14.10** $GH_2$ shall not be used to operate any device or equipment that has not been designed or modified for $GH_2$ service.

**9.14.11** Sources of ignition shall not be permitted within 10 ft (3.0 m) of any filling connection during a transfer operation.

**9.14.12** A warning sign with the words "STOP MOTOR, NO SMOKING, NO CELL PHONES, FLAMMABLE GAS" shall be posted at dispensing station and compressor areas.

**9.14.12.1** If the hydrogen is not odorized, the wording "HYDROGEN GAS DOES NOT HAVE A DISTINCTIVE ODOR" shall be added to the warning sign.

**9.14.12.2** The location of signs shall be determined by local conditions.

**9.14.12.3** The lettering on the sign shall be large enough to be visible and legible from each point of transfer.

**9.14.13** Personnel conducting transfer operations from the bulk transport vehicle shall be trained.

**9.15* Fire Protection.** A portable fire extinguisher having a rating of not less than 20-B:C shall be provided at the dispensing area in approved locations not more than 50 ft (15.2 m) away from the dispensing area.

**9.15.1** Fire extinguishers shall be inspected and maintained according to NFPA 10, *Standard for Portable Fire Extinguishers*.

**9.15.2** Equipment used for gas flame detection shall meet the requirements of 9.2.14.

**9.16 Maintenance System.**

**9.16.1** Containers and their appurtenances, piping systems, compression equipment, controls, and detection devices shall be maintained in operating condition and according to manufacturer's instructions.

**9.16.2 Hose Assemblies.**

**9.16.2.1** Hoses, nozzles, and breakaways shall be examined according to the manufacturers' recommendations or at least monthly and shall be maintained in accordance with the manufacturers' instructions.

**9.16.2.2** Hose shall be tested for leaks per manufacturer's requirements, and any unsafe leakage or surface cracks shall be reason for rejection and replacement.

**9.16.2.3** Testing shall be carried out using an inert gas as the test medium.

**9.16.2.3.1** Where this is not possible, the hose assembly shall be completely isolated from the system and tested with the flammable gas normally within the system, or with air and then purged with an inert gas.

**9.16.2.3.2** In the case of hydrogen, testing shall be carried out with helium or a helium inert gas blend (10 percent by volume or greater) as the test gas or, if this is not possible, with hydrogen using suitable precautions.

**9.16.2.4** The station operator shall maintain a maintenance log in good condition and accessible to the inspector.

**9.16.2.5** A sticker shall be affixed on the dispenser indicating that inspection maintenance was conducted and the date the facility was inspected.

**9.16.2.5.1** The sticker shall be affixed to the dispenser at eye level, or on the highest vertical surface if the dispenser is below eye level, on the side of the dispenser where the individual operating the dispenser will interface with the controls and/or readout.

**9.16.2.5.2** The sticker shall not cover the readout or display or otherwise interfere with the normal operation of the dispenser.

**9.16.2.6** Controllers on fuel stations shall be designed to verify the integrity of the fuel hose, breakaway, nozzle, and receptacle by pressurizing these components to at least the vehicle back pressure and checking pressure drop over a period of at least 5 seconds prior to the start of fueling.

**9.16.2.7** The integrity check shall then be repeated at 3000 psi (20.7 MPa) increments up to the final fill pressure.

**9.16.3** Pressure relief valves shall be maintained in operating condition.

**9.16.4*** Maintenance personnel shall be trained in leak detection procedures.

**9.16.5** Personnel performing maintenance on hydrogen installations shall be trained and wear personal protective equipment as prescribed in the material safety data sheets.

**9.17 Vehicle Fueling Appliances in Nonresidential Occupancies.**

**9.17.1** Vehicle fueling appliances (VFAs) shall not exceed a gas flow of 36 scf/min (1.0 SCM/min).

**9.17.2** VFAs shall be listed.

**9.17.3** The installation of VFAs shall be exempt from the requirements of Sections 5.3 through 5.8, 9.1 through 9.3, 9.6, and 9.8 through 9.16.

**9.17.4** VFAs shall be permitted to be used to fill stationary containers at vehicle fueling locations.

**9.17.4.1** The method of connecting the VFA to such storage shall comply with the provisions of Chapters 5 and 7 and shall be approved.

**9.17.4.2** The provisions of 9.17.2 shall apply to the VFA where connected to stationary containers at vehicle fueling locations.

**9.17.5** Where installed indoors in public assembly and educational occupancies, a VFA shall be located in a portion of the occupancy where NFPA *101*, *Life Safety Code*, or the local building code permits the installation of hazardous equipment.

*Exception: Where the VFA is located outdoors, the dispensing point shall be permitted to be located indoors without the need for a separate room.*

**9.17.6** VFAs shall not be installed within 10 ft (3.0 m) of any flammable gas or liquid storage.

*Exception: Storage in the vehicle fuel supply container.*

**9.18 Residential Fueling Facility (RFF-$GH_2$).**

**9.18.1 Application.** This section applies to the design, construction, installation, and operation of an RFF-$GH_2$.

**9.18.2** Storage of $GH_2$ shall be permitted in systems listed by a nationally recognized testing laboratory. Storage shall be in accordance with NFPA 55.

**9.18.2.1** The RFF-$GH_2$ shall store $GH_2$ indoors or outdoors. Indoor storage of $GH_2$ shall not exceed 6000 psi (41.4 MPa) and shall be ventilated per 9.3.3.5, or contained in a separate sealed enclosure ventilated directly to outdoors.

**9.18.3 System Component Qualifications.** System components not part of a listed VFA shall comply with the appropriate provisions of Chapter 5.

**9.18.3.1** VFAs shall be listed.

**9.18.3.2** VFAs shall be exempt from the requirements of Sections 5.4 through 5.9, 9.1 through 9.3, 9.6, and 9.8 through 9.17.

**9.18.4 General Safety Requirements.** All equipment related to RFF-$GH_2$ installation shall be protected to minimize the possibilities of physical damage and vandalism.

**9.18.4.1** The use of an enclosure for the compressor package, similar to that of a central air conditioner, shall be permitted to satisfy the requirement of 9.18.4.

**9.18.4.2** All equipment related to RFF-$GH_2$ installation shall be designed for the pressure, temperature, and service of the system.

**9.18.4.3** Vehicles shall be considered as unclassified electrically with respect to *NFPA 70, National Electrical Code*, Article 500.

**9.18.4.4** Vehicles containing fuel-fired equipment, such as recreational vehicles, shall be considered a source of ignition unless this equipment is shut off completely before entering an area in which ignition sources shall not be permitted.

**9.18.4.5** Unless specifically permitted in the recommendations of the manufacturers, multiple RFF-$GH_2$s shall not be manifolded together on the discharge side.

**9.18.4.6** Where more than one RFF-$GH_2$ is located in a common area, spacing between the RFF-$GH_2$s shall not be less than 3 ft (1 m) unless permitted by the installation instructions of the manufacturers.

**9.18.5 Installation.**

**9.18.5.1 General.**

**9.18.5.1.1** The RFF-$GH_2$ shall be installed outdoors and shall be installed, operated, and maintained in accordance with the manufacturer's instructions.

**9.18.5.1.2** The RFF-$GH_2$ shall have a nameplate marked with minimum and maximum gas inlet pressures and flow rates, gas outlet maximum pressure, and electrical requirements.

**9.18.5.2 Indoors. (Reserved)**

**9.18.6** Installation of pressure relief valves shall have pressure relief device vents or vent lines to convey escaping gas to the outdoors and then upward to a safe area to prevent impinging on buildings, other equipment, or areas open to the public, such as sidewalks.

**9.18.7 Piping and Hose.** The use of hose in an installation shall be restricted to the following:

(1) A fueling hose that is limited to a maximum length of 25 ft (7.6 m) and is protected from mechanical damage from abrasion and from being driven over by a vehicle
(2) A maximum of 3 ft (1 m) in length where used to prevent abrasion damage resulting from vibration on the inlet, outlet, or both

**9.18.7.1** Transfer systems shall be capable of depressurizing the nozzle to facilitate disconnection.

**9.18.7.2** Bleed connections shall lead to a safe point of discharge.

**9.18.8 Testing.**

**9.18.8.1** All piping and tubing shall be tested after assembly according to 9.9.1.4.

**9.18.8.2** Integral piping and tubing provided as part of a listed VFA shall not be required to be tested according to 9.9.1.4.

**9.18.9 Installation of Emergency Shutdown Equipment.** An RFF-$GH_2$ shall be equipped with emergency manual shutdown of the fuel supply and electrical supply prior to the RFF-$GH_2$ device.

**9.18.9.1** The emergency manual shutdown actuator shall be at least 5 ft (1.5 m) from the RFF-$GH_2$ and in view of the RFF-$GH_2$.

**9.18.9.2** Breakaway protection shall be provided in a manner so that, in the event of a pullaway, $GH_2$ ceases to flow.

**9.18.9.2.1** A breakaway device shall be installed at every dispensing point.

**9.18.9.2.2** The breakaway device in 9.18.9.2.1 shall be arranged to separate using a force not greater than 150 lb (68 kg) when applied in a horizontal direction.

**9.18.10 Operation.** An RFF-$GH_2$ shall be operated in accordance with the instructions of the manufacturer.

**9.18.10.1** A fuel supply container shall not be charged in excess of its maximum allowable service pressure at normal temperature.

**9.18.10.2** DOT and TC containers shall be charged in accordance with DOT and TC regulations.

**9.18.10.3** Where $GH_2$ is being transferred to a motor vehicle, the engine shall be turned off.

**9.18.11 Maintenance and Inspection.** All RFF-$GH_2$ equipment shall be inspected and maintained in accordance with the instructions of the manufacturer.

**9.18.11.1** After installation, all hose shall be examined visually as part of this inspection.

**9.18.11.2** Hose that is kinked or worn shall be replaced.

**9.18.11.3** All safety relief valves shall be maintained in operating condition in accordance with the recommendations of the manufacturer.

**9.19 Refueling from Transport Vehicles.** Mobile refueling vehicles, temporary trailers (with or without tractors), and other means of providing vehicle refueling or onsite storage shall be subject to the same requirements as a permanent refueling or storage installation, with the exception of vessel requirements.

**9.19.1** The dispensing of $GH_2$ in the open from a transport vehicle to a motor vehicle located at a separate fleet fueling area in connection with commercial, industrial, governmental, or manufacturing establishments and intended for fueling vehicles used in connection with their businesses shall be permitted if all the requirements of 9.19.1 through 9.19.12 have been met.

**9.19.2** The AHJ shall be notified before commencing operations, and permitting sought if required, under Section 9.19.

**9.19.3** The transport vehicle shall comply with U.S. DOT requirements for the transportation of $GH_2$.

**9.19.4** Nighttime deliveries shall be made only in an area considered to be adequately lighted.

**9.19.5** Smoking materials, including matches, lighters, and other sources of ignition, including torches, shall not be used within 20 ft (6.1 m) of the dispensing of $GH_2$ in the open from a transport vehicle to a motor vehicle.

**9.19.6** Each area where dispensing of $GH_2$ in the open from a transport vehicle to a motor vehicle shall be provided with one or more listed fire extinguishers that have a minimum capability of 40-B:C.

**9.19.6.1** The fire extinguishers shall be within the dispensing operation.

**9.19.6.2** Fire extinguishers shall be inspected and maintained under NFPA 10, *Standard for Portable Fire Extinguishers.*

**9.19.7** Transport vehicle brakes shall be set and chock blocks shall be in place.

**9.19.8** Persons performing dispensing operations shall be qualified to deliver and dispense $GH_2$ fuels.

**9.19.9** Operators of transport vehicles used for mobile fueling operations shall have access on site or be in possession of an emergency communications device to notify the authorities in the event of an emergency.

**9.19.10** The transport vehicles shall be positioned with respect to vehicles being fueled to prevent traffic from driving over the delivery hose and between the transport vehicle and motor vehicle being fueled.

**9.19.11** The dispensing hose shall be properly placed on an approved reel or in an approved compartment before moving the transport vehicle.

**9.19.12 Additional Requirements.** The transfer area shall meet the requirements of 9.13.3.

**9.20 Out-of-Service Aboveground Containers. (Reserved)**

# Chapter 10 CNG Residential Fueling Facilities (RFF-CNGs)

**10.1 Application.**

**10.1.1** This chapter applies to the design, construction, installation, and operation of a residential fueling facility (RFF-CNG).

**10.1.2** The capacity of an RFF-CNG shall not exceed 5 scf/min (0.14 SCM/min) of natural gas.

**10.1.3** Storage of CNG shall be prohibited.

*Exception: CNG shall be permitted to be stored in the vehicle fuel supply container.*

**10.2 System Component Qualifications.**

**10.2.1** System components not part of a listed VFA shall comply with the appropriate provisions in Chapter 4.

**10.2.2*** VFAs shall be listed.

**10.2.3** VFAs shall be exempt from the requirements of Sections 4.5 through 4.9, 8.2 through 8.4, 8.6, and 8.8 through 8.16.

**10.3 General Safety Requirements.**

**10.3.1** All equipment related to an RFF-CNG installation shall be protected to minimize the possibility of physical damage and vandalism.

**10.3.2** The use of an enclosure for the compressor package, similar to that of a central air conditioner, shall be permitted to satisfy 10.3.1.

**10.3.3** All equipment related to RFF-CNG installation shall be designed for the pressure, temperature, and service expected.

**10.3.4** Vehicles shall be considered as unclassified electrically with respect to *NFPA 70, National Electrical Code*, Article 500.

*Exception: Vehicles containing fuel-fired equipment (e.g., recreational vehicles) shall be considered a source of ignition unless this equipment is shut off completely before entering an area in which ignition sources shall not be permitted.*

**10.3.5** Natural gas shall not be vented to the atmosphere under normal operation.

*Exception: Leakage of 1.0 standard cubic in. (16 cm*$^3$*) of gas shall be permitted to be released to the atmosphere per filling during disconnection of the fueling hose.*

**10.3.6** Unless specifically permitted by the installation instructions, multiple VFAs shall not be manifolded together on the discharge side.

**10.3.7** Where more than one VFA is located in a common area, spacing between the VFAs shall not be less than 3 ft (1 m) unless permitted by the installation instructions.

**10.4 Installation.**

**10.4.1 General.**

**10.4.1.1** All RFF-CNG equipment shall be installed in accordance with the equipment manufacturer's instructions.

**10.4.1.2** The RFF-CNG shall have a nameplate marked with minimum and maximum gas inlet pressures and flow rates, gas outlet maximum pressure, and electrical requirements.

**10.4.2 Indoors.**

**10.4.2.1** Where it is necessary to install the compression unit and refueling connections indoors, the compression unit shall be mounted or otherwise located such that the compression unit is vented outdoors.

**10.4.2.2*** Where the RFF-CNG or the vehicle being fueled is located indoors, a gas detector set to operate at one-fifth the (LFL) lower flammable limit of natural gas shall be installed in the room.

**10.4.2.2.1** The detector shall be located within 6 in. (150 mm) of the ceiling or the highest point in the room.

*Exception: An RFF-CNG that is listed shall be permitted to utilize a combination of ventilation or gas detection to ensure that the room is maintained at a level below one-fifth of the lower limit of flammability of natural gas. This shall be deemed to be equivalent to a gas detector located within 6 in. (150 mm) of the ceiling or the highest point in the room.*

**10.4.2.2.2** The detector shall stop the compressor and operate an audible or a visual alarm.

**10.4.3 Outdoors.** The RFF-CNG shall be installed on a firm, noncombustible support to prevent undue stress on piping and conduit.

**10.5 Installation of PRVs.** PRVs shall have PRD vents or vent lines to convey escaping gas to the outdoors and then upward to a safe area to prevent impinging on buildings, other equipment, or areas open to the public (e.g., sidewalks).

**10.6 Installation of Pressure Gauges.** For measurement and test purposes, pressure gauges shall be permitted to be installed but shall not be required.

**10.7 Pressure Regulation.** An RFF-CNG shall be equipped to stop fuel flow automatically when the container(s) reaches the temperature-corrected fill pressure.

**10.8 Piping and Hose.**

**10.8.1** All piping and hose from the outlet of the compressor shall be supplied as part of the RFF-CNG.

**10.8.2** All gas piping to the RFF-CNG shall be installed in accordance with NFPA 54, *National Fuel Gas Code*.

**10.8.3** The use of hose in an installation shall be restricted to the following:

(1) A fueling hose that shall be limited to a maximum length of 25 ft (7.6 m) and shall be supported above the floor/ground level or otherwise protected from mechanical damage from abrasion and being driven over by a vehicle
(2) A maximum of 3 ft (1 m) in length where used to prevent abrasion damage resulting from vibration on the inlet or outlet, or both

**10.8.4** Transfer systems shall be capable of depressurizing to facilitate disconnection.

**10.8.5** Bleed connections shall lead to a safe point of discharge.

**10.9 Testing.** All piping and tubing shall be tested after assembly to be proven free of leaks at a pressure equal to the maximum service pressure of that portion of the system.

**10.10 Installation of Emergency Shutdown Equipment.**

**10.10.1** An RFF-CNG shall be equipped with emergency manual shutdown of the gas supply and electric power.

**10.10.1.1** The emergency electrical switch shall be at least 5 ft (1.5 m) from the RFF-CNG and in view of the RFF-CNG.

**10.10.1.2** An RFF-CNG equipped with a flexible cord terminated with a grounding-type attachment plug shall be deemed to be equivalent to the emergency switch.

**10.10.2** Breakaway protection shall be provided in a manner so that, in the event of a pullaway, natural gas ceases to flow.

**10.10.2.1** The breakaway devices shall be compatible with ANSI/IAS NGV 4.4, *Breakaway Devices for Dispensing Systems*, and CSA 12.54, *Breakaway Devices for Dispensing Systems*.

**10.10.2.2** The breakaway provided as a component of a listed VFA shall be permitted not to comply with ANSI/IAS NGV 4.4, *Breakaway Devices for Dispensing Systems*, and CSA 12.54, *Breakaway Devices for Dispensing Systems*.

**10.10.3** A breakaway device shall be installed at every dispensing point.

**10.10.4** The breakaway device in 10.10.3 shall be arranged to separate using a force not greater than 150 lb (68 kg) when applied in any horizontal direction.

**10.11 Operation.**

**10.11.1** An RFF-CNG shall be operated in accordance with the manufacturer's instructions.

**10.11.2** A fuel supply container shall not be charged in excess of its maximum allowable service pressure at normal temperature.

**10.11.3** DOT and TC containers shall be charged in accordance with DOT and TC regulations.

**10.11.4** Where CNG is being transferred to a motor vehicle, the engine shall be turned off.

**10.12 Maintenance and Inspection.**

**10.12.1** All RFF-CNG equipment shall be inspected and maintained in accordance with the manufacturer's instructions.

**10.12.2** After installation, all hose shall be examined visually as part of this inspection.

**10.12.3** Hose that are kinked or worn shall be replaced.

**10.12.4** All safety relief valves shall be maintained in operating condition in accordance with the manufacturer's/supplier's recommendation.

## Chapter 11 LNG Engine Fuel Systems

**11.1 Application.**

**11.1.1** This chapter applies to the design, installation, inspection, and testing of LNG fuel supply systems for vehicle engines.

**11.1.2** This chapter shall not apply to LNG railroad fuel tenders that are required to comply with applicable DOT (Federal Railroad Administration) regulations.

**11.2 Materials.**

**11.2.1** All metallic materials used, except fusible links, shall have a minimum melting point of 1500°F (816°C).

**11.2.2** All metallic material shall be listed per ANSI/ASME B31.3, *Process Piping,* and ASME *Boiler and Pressure Vessel Code,* or API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, Appendix Q, and shall not be used below the minimum design temperature established in these standards.

**11.2.3** The use of dissimilar metal junctions shall be minimized, but if such a junction cannot be avoided, good corrosion protection practice shall be employed to reduce the effect of such a material combination on the long-term corrosion behavior of the junction.

**11.2.4** All materials shall be selected or installed to minimize corrosion or to protect the material from corrosion.

**11.2.4.1** Stainless steels that do not resist chloride-induced pitting/corrosion cracking and sensitization-induced corrosion resistance reduction shall not be used.

**11.2.4.2** The use of all copper–zinc and copper–tin alloy families shall be restricted to those alloys that are metallurgically inhibited to prevent accelerated metallurgical deterioration from external environmental sources.

**11.2.5** Brazing filler material shall have a melting point exceeding 1000°F (538°C).

**11.2.6** Oxy–fuel gas welding shall not be permitted.

**11.2.7** Furnace butt-welded steel products shall not be used.

**11.3 Vehicular Fuel Containers.**

**11.3.1 Design.** Containers shall be designed, fabricated, tested, and marked (or stamped) in accordance with the Regulations of DOT Specification 4L or the "Rules for the Construction of Unfired Pressure Vessels," ASME *Boiler and Pressure Vessel Code*, applicable at the date of manufacture.

**11.3.1.1** LNG containers that are normally in contact with LNG or cold LNG vapor — therefore, all parts of the LNG fuel system — shall be physically and chemically compatible with LNG and suitable for service at −260°F (−162°C).

**11.3.1.2** Container appurtenances shall have a rated working pressure not less than the maximum allowable working pressure of the container.

**11.3.1.3** For vacuum insulation, the inner tank, outer tank, and internal lines shall be tested for vacuum leaks prior to installation on the vehicle.

**11.3.2 Container Filling.**

**11.3.2.1** Containers shall be equipped with a device or devices that provide an indication of when the container is filled to the maximum allowable liquid level.

**11.3.2.2** The function shall allow for the ullage volume to be determined by the manufacturer to be that which maintains the required hold time as required by 11.3.5.

**11.3.3 Structural Integrity.**

**11.3.3.1** The fully pressurized container, when filled to its maximum filling volume with LNG, together with valves, enclosures, and all other items that normally are mounted and attached thereto, and mounted by its normal means of attachment, shall be capable of withstanding without loss of contents a static force, in the six principal directions, equal to eight times the weight of the container plus its contents.

**11.3.3.2** The container, the plumbing, and the mounting attachments shall withstand the effects of shock, vibration, and acceleration encountered in normal service.

*Exception: Marine vessels shall be capable of withstanding forces appropriate for the vessel.*

**11.3.4* Container Shut-off Valves.**

**11.3.4.1** The container shall be equipped with shut-off valves that allow for its complete isolation from the rest of the vehicular fuel system.

**11.3.4.1.1** Container shut-off valves shall be labeled as to their function.

**11.3.4.1.2** Decals or stencils shall be acceptable.

**11.3.4.2** Normally closed automatic shut-off valves that are held open by electric current, pneumatic or hydraulic pressure, or a combination thereof, or manually operated shut-off valves shall be permitted to be used to meet this requirement.

**11.3.5 Heat Leak.** The manufacturer shall identify the maximum operating design pressure of the container.

**11.3.5.1** The construction of the container shall be such that the unrelieved pressure inside the container shall not exceed the maximum allowable working pressure of the container within a 72-hour period after the container has been filled to maximum filling volume with LNG stabilized at the designed operating pressure and the temperature equilibrium has been established.

**11.3.5.2** The ambient temperature during the 72-hour period shall be 70°F (21°C).

**11.3.5.3** SAE J2343, *Recommended Practice for LNG Medium and Heavy-Duty Powered Vehicles*, drop and heat leak testing shall be the final test criteria for acceptance for heat leak testing.

**11.3.6 Reuse.** Containers complying with 11.3.1 shall be permitted to be reused, reinstalled, or continued in use.

**11.3.6.1** A container shall be determined to be suitable for continued service prior to reuse by means of periodic validation.

**11.3.6.2** Validation shall be performed during normal revacuum or repair of the container.

**11.3.7 Repair.** Repair or alteration of containers shall comply with the code or original container manufacturer's design under which the container was fabricated.

**11.3.8 Markings.**

**11.3.8.1** The container shall have the following permanent identification markings:

(1) Total water capacity of the container in gallons (liters)
(2) Label or labels placed in a visible location near the vehicle fill connection identifying it as an LNG connection, indicating the maximum allowable working pressure of the LNG tank
(3) Markings to designate whether all inlets and outlets, except the relief valves and gauging devices, communicate with vapor or liquid space

**11.3.8.2** Decals or stencils shall be acceptable.

**11.3.8.3** All penetrations marked with the function of the penetration and identification shall not be obscured by frost.

**11.4 Pressure Relief Devices.**

**11.4.1** Containers shall be equipped with the PRDs or pressure control valves required by the code under which the containers were designed and fabricated.

**11.4.1.1** PRDs shall be sized for simultaneous conditions of fire and loss of vacuum.

**11.4.1.2** PRDs shall be sized in accordance with CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*, and CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Stationary Storage Containers for Compressed Gases*.

**11.4.2** The PRDs and pressure control valves shall communicate directly with the vapor space of the container in the normal operating position.

**11.4.3** The PRDs and pressure control valves shall not come into contact with the liquid within the container during normal operation.

**11.4.4** All safety relief devices on vehicular fuel containers that discharge to the atmosphere shall vent outside of the vehicle.

**11.4.5** All discharge lines and outlets shall be installed in accordance with 11.4.5.1 through 11.4.5.11.

**11.4.5.1** Pressure relief discharge lines shall be suitable for the pressure and temperature of the discharged LNG.

**11.4.5.2** Components shall be suitable for operation at an LNG temperature of −260°F (−162°C).

**11.4.5.3** Individual discharge lines and adapters shall be sized, located, and secured so as to permit the maximum required relief discharge capacity in order to minimize the possibility of physical damage.

**11.4.5.4** The discharge lines shall be able to withstand the pressure of the relief vapor discharge when the PRD is in the full-open position.

**11.4.5.5** A means shall be provided (e.g., loose-fitting caps) to minimize the possibility of the entrance of water or dirt into either the relief device or its discharge line and to drain any water that accumulates in the discharge line.

**11.4.5.6** The means of protection shall remain in place except when the PRD operates.

**11.4.5.7** In this event, the means of protection shall permit the relief device to operate at maximum required capacity.

**11.4.5.8** The outlet of the discharge line shall be fitted with a device or configured to prevent the formation or accumulation of any ice or frozen LNG that could prevent the relief device from operating at required capacity.

**11.4.5.9** The relief valve discharge shall be directed away from the refueling operator and not hinder manually shutting off any fuel system devices.

**11.4.5.10** The discharge line from PRDs on all vehicles shall be directed upward and extended to a safe location.

**11.4.5.11** Secondary relief devices designed to prevent rupture of the container upon failure of the primary relief device shall not be required to be piped away from the tank.

**11.4.6** PRDs and pressure control valves shall be so designed that the possibility of tampering is minimized.

**11.4.7** Externally set or adjusted valves shall be provided with a means of sealing the adjustment.

**11.5 Pressure Gauges.**

**11.5.1** Containers equipped with pressure gauges shall have the gauges connected to the container at a point above the maximum liquid level.

**11.5.2** Pressure gauges shall be designed for the maximum pressure and temperature conditions to which they can be subjected, with a minimum burst pressure safety factor of 4.

**11.5.3** Dials shall be graduated to indicate at least 1.2 times the pressure at which the pressure relief device incident to the pressure gauge is set to function.

**11.5.4** A gauge opening shall not exceed 0.055 in. (1.4 mm) (No. 54 drill size) at the inlet connection.

**11.6 Pressure Regulators.** The engine pressure regulator inlet and each chamber shall have a design operating pressure not less than the maximum pressure of the container.

**11.7 Pipe, Tubing, and Fittings.** Pipe, tubing, and fittings shall be in accordance with ANSI/ASME B31.3, *Process Piping*.

**11.8 Valves.**

**11.8.1** Valves, valve packing, gaskets, and seats shall be suitable for the intended service.

**11.8.2** All parts of container shut-off valves shall be suitable for temperatures of −260°F (−162°C) and shall be stainless steel, brass, or copper except gaskets, packing, and seats.

**11.8.3** Extended bonnet valves shall be installed with their stem packing seals in such a position as to prevent leakage or malfunction due to freezing.

**11.8.4** If the extended bonnet in a cryogenic liquid line is installed at an angle greater than 4 degrees from the upright vertical position, evidence of satisfactory service in the installed position shall be demonstrated and engineering validation shall be provided by the original equipment (bonnet valve) manufacturer.

**11.9 Pumps and Compressors.**

**11.9.1** Pumps and compressors shall be provided with a PRD to limit the discharge pressure to the maximum safe working pressure of the casing and downstream piping and equipment, unless these are designed for the maximum discharge pressure of the pumps or compressors.

**11.9.2** Each pump shall be provided with a vent, relief valve, or both that prevents overpressuring the pump case.

**11.9.3** Pumps used for transfer of LNG shall be provided with means for precooling to reduce the effect of thermal shock and overpressure.

**11.10 Vaporizers.**

**11.10.1** Vaporizers shall have the capacity to vaporize the LNG completely and heat the vapor to the safe design temperature of the downstream components prior to entry of the vapor into the pressure regulator when the vaporizer is subjected to the maximum vehicular fuel flow rate.

**11.10.2** Vaporizers shall be marked permanently at a readily visible point to indicate the maximum allowable working pressure of the fuel-containing portion of the vaporizer.

**11.10.3** Vaporizers shall be designed for a working pressure at least equal to the maximum discharge pressure of the pump or the pressurized system that supplies them, whichever is greater.

**11.10.4** The discharge valve of each vaporizer, if provided, its piping components, the relief valves installed upstream of the discharge valve, the vaporizer piping, and related components shall be suitable for operation at an LNG temperature of −260°F (−162°C).

**11.10.5** Engine exhaust gases shall not be used as a direct source of heat to vaporize fuel.

**11.10.6** If the engine exhaust is used to vaporize fuel, it shall be used via an indirect heating system.

**11.11 Component Qualification.**

**11.11.1** The following subsystems and components, if used, shall be recommended by the OEM manufacturer for the intended service:

(1) Vehicular fuel containers
(2) Fuel quantity gauging systems
(3) PRDs
(4) Pressure measurement devices
(5) Valves
(6) Pressure regulators
(7) Vaporizers
(8) Pumps
(9) Engine fuel delivery equipment
(10) Vehicle fueling receptacles
(11) Electrical equipment related to the LNG system
(12) Methane detection, fire protection, and suppression systems

**11.11.2 Engine Compartment.**

**11.11.2.1** Onboard fuel system components in the engine compartment shall be compatible with the liquids and gases throughout the full range of temperatures [−260°F to 250°F (−162°C to 121°C)].

**11.11.2.2** Onboard fuel system components that normally are in contact with LNG shall be suitable for service over a temperature range of −260°F to 250°F (−162°C to 121°C).

**11.11.3 Outside Engine Compartment.**

**11.11.3.1** Components outside the engine compartment that normally are in contact with LNG shall be suitable for service over a temperature range of −260°F to 180°F (−162°C to 82°C).

**11.11.3.2** Other components that normally are not in contact with LNG shall be suitable for service over a temperature range of −40°F to 180°F (−40°C to 82°C).

**11.11.4** Components that are not fuel system components and are located within the operational area of LNG or LNG liquid or gaseous leaks shall also be protected or maintain a service range equal to the onboard fuel system.

**11.12 Installation.**

**11.12.1 Vehicular Fuel Containers and Container Appurtenances.**

**11.12.1.1** Vehicular components or subsystems that can fail on exposure to LNG temperature and create a safety hazard shall be protected from LNG exposure.

**11.12.1.2** A fully engineered onboard application methane detection system shall be validated for each vehicle configuration and application and shall be certified by a qualified engineer with expertise in fire safety and gaseous fuels.

**11.12.1.3** A container shall be located in a place and in a manner so as to minimize the possibility of damage to the container and its appurtenances.

**11.12.1.3.1** Containers located in the rear of vehicles, where protected by bumpers or vehicular structure, shall be considered to be in conformance with 11.12.1.3.

**11.12.1.3.2** If fuel or container vent piping containing fuel is installed within 8 in. (200 mm) of engine or exhaust system components that exceed 250°F (121°C), it shall be shielded against direct heating.

**11.12.1.3.3 Structural Integrity.**

**11.12.1.3.4** Vehicles designed to meet SAE J2343, *Recommended Practice for LNG Medium and Heavy-Duty Powered Vehicles*, shall not have to meet 11.12.1.4.

**11.12.1.4 Markings.**

**11.12.1.4.1** Container markings shall be visible after the container's permanent installation on a vehicle.

**11.12.1.4.2** A portable lamp and mirror shall be permitted to be used when reading markings.

**11.12.1.5** Container valves, appurtenances, and connections shall be protected to prevent damage due to incidental contact with foreign objects.

**11.12.1.6 Position.**

**11.12.1.6.1** No part of the container or its appurtenances shall protrude beyond the sides or top of any vehicle where the container can be struck or punctured.

**11.12.1.6.2** Non-roof-mounted containers shall not be mounted ahead of the front axle or beyond the rear bumper on motor vehicles.

**11.12.1.6.3** Truck, transit, and commercial vehicles that meet SAE J2343, *Recommended Practice for LNG Medium and Heavy-Duty Powered Vehicles*, shall not be required to meet 11.12.1.7.1 or 11.12.1.7.2.

**11.12.1.6.4** All trucks [above 14,000 lb (6400 kg)], transit vehicles, school buses, and commercial vehicles utilizing LNG shall meet SAE J2343, *Recommended Practice for LNG Medium and Heavy-Duty Powered Vehicles*.

**11.12.1.7** Containers shall be installed to provide as much road clearance as practical.

**11.12.1.7.1** The minimum clearance from the road to the container, its housing, or its fittings, whichever is lowest, shall not, with the vehicle loaded to its gross weight rating, be less than that defined by the vehicle manufacturer's own design, or allow any component to touch the surface should the vehicle have a flat tire or the removal of any tire.

**11.12.1.7.2** Further requirements for clearances shall be measured as follows:

(1) Containers installed between axles shall comply with 11.12.1.7.2(3) or shall not be lower than the lowest point on a structural component of the body, frame or subframe, if any, engine, or transmission, including the clutch housing or torque converter housing, forward of the container measured as if the wheel rims were on the ground.

(2) Containers installed behind the rear axle and extending below the frame shall comply with 11.12.1.7.2(3) or shall not be lower than both of the following:
   (a) The lowest point of a structural component of the body, engine, or transmission, including clutch housing or torque converter housing, forward of the container
   (b) The lowest point of those lines extending rearward from each wheel at the point where the wheel rims contact the ground directly below the center of the axle to the lowest and most rearward structural interference (e.g., bumper, frame). Where there are two or more rear axles, the projections shall be made from the rearmost axle.
(3) Where an LNG container is substituted for the fuel container installed by the original chassis manufacturer of the vehicle, the LNG container shall either fit within the space in which the original fuel container was installed or comply with 11.12.1.7.2(1) or 11.12.1.7.2(2) and shall meet, when available, the specifications of the chassis and fuel system OEMs.

**11.12.1.8** Containers shall be mounted to prevent their jarring loose, slipping, or rotating.

**11.12.1.9** Containers shall be secured to the vehicle body, bed, or frame by means capable of withstanding the loads defined in 11.3.3.

**11.12.1.10** The container weight shall not be supported by outlet valves, manifolds, fuel lines, and other fuel-related components or connections.

**11.12.1.11** The mounting system shall minimize fretting corrosion between the container and the mounting system.

**11.12.1.12** Containers shall not be installed so as to affect adversely the operating characteristics of the vehicle.

**11.12.1.13** Vehicular fuel systems shall be equipped with at least one manual or automatic fuel shut-off valve.

**11.12.1.14** All manual fuel shut-off valves shall be readily accessible, operable without tools, and labeled as to their function.

**11.12.1.15** Where a container is installed above the operator or passenger compartment of a vehicle, the following requirements shall apply:

(1) The container and its piping, fittings, and valves shall be protected from damage by the following:
   (a) A guard rail or similar device that is designed to absorb the impact of a collision with a stationary object when the vehicle is moving either forward or backward at 5 mph/hr (8 km/hr)
   (b) A shield designed to absorb impacts that can occur during loading, unloading, or use of the vehicle
(2) The top of the container and any LNG-related piping, fitting, valve, housing, guardrail, or shield shall not be more than 13.5 ft (4.1 m) above the road surface.
(3) The cylinder shall be protected from accidental contact with overhead electrical wiring by metallic or nonmetallic covers.

**11.12.1.15.1** The guard rail or similar device shall be free of projections that could damage the container or its valves and fittings.

**11.12.1.15.2** The shield shall be free of projections that could damage the container or its valves and fittings.

**11.12.2 Containers Mounted in the Interior of Vehicles.**

**11.12.2.1** Containers shall be installed and fitted so that no gas from fueling operations can be released inside the passenger compartment by permanently installing the fueling receptacle outside the passenger compartment of the vehicle in a location protected from physical damage and dislodgment.

**11.12.2.2** Enclosures, structures, seals, and conduits used to vent enclosures shall be fabricated of materials designed to resist damage, blockage, or dislodgment caused by the movement of articles carried in the vehicle or by the closing of luggage compartment enclosures or vehicle doors and shall require the use of tools for removal.

**11.12.2.3** The detection system shall activate a visual alarm within the driver's compartment of the vehicle at a gas concentration not exceeding 20 to 30 percent of the LFL and sound an audible and visual alarm at a gas concentration not greater than 50 to 60 percent of the LFL.

**11.12.2.3.1** Sensor locations shall include at a minimum the engine and driver's compartment and any enclosed fuel container or installation within a compartment.

**11.12.3 Pipe, Tubing, and Fittings.**

**11.12.3.1** Manifolds connecting fuel containers shall be fabricated and installed to minimize vibration and shall be installed in a protected location or shielded to minimize damage from unsecured objects.

**11.12.3.2** Piping and tubing shall be installed, supported, protected, and secured in such a manner as to minimize the possibility of damage, corrosion, or breakage due to expansion, contraction, vibration, strains, or wear and to preclude any loosening while in transit.

**11.12.3.3** Piping and tubing passing through a panel or structural member shall be protected by grommets or similar devices that shall snugly fit the piping or tubing and the hole in the panel or structural member.

**11.12.3.4** Piping or tubing passing through the floor of a vehicle shall be installed to enter the vehicle through the floor directly beneath, or adjacent to, the container.

**11.12.3.4.1** If a branch line is required, the tee connection shall be located in the main fuel line under the floor and outside the vehicle.

**11.12.3.5** A fuel connection between a tractor and trailer or other over-the-road vehicle units shall not be permitted.

**11.12.3.6** A PRV shall be installed in each section of piping or tubing in which LNG can be isolated between shut-off valves so as to relieve the trapped fuel pressure to a safe atmosphere.

**11.12.3.7** The PRV shall not have a setting greater than the maximum allowable working pressure of the line it protects.

**11.12.4 Valves.**

**11.12.4.1** Valves shall be mounted securely and shielded or installed in a protected location to prevent damage from vibration, shock, and unsecured objects.

**11.12.4.2** Valves shall be installed so that their weight is not placed on, or supported by, the attached lines.

**11.12.4.3** A positive shut-off valve shall be installed in the fuel supply line.

**11.12.4.4** The shut-off valve shall close automatically and prevent the flow of fuel to the engine when the ignition switch is off or in the accessory position and when the engine is not running and the ignition switch is on.

**11.12.4.5** Where multiple fuel systems or containers are installed on a vehicle, automatic valves shall be provided to shut off the tank that is not being utilized.

**11.12.4.6** The vehicular fueling system shall be equipped with a backflow check valve to prevent the return flow of LNG from the container(s) to the filling connection.

**11.12.4.7** The check valve in 11.12.4.6 shall be permitted to be integral to another component in the system, such as the vehicular fueling connector.

**11.12.5 Pressure Regulators.**

**11.12.5.1** On fuel delivery systems that have operating pressures that exceed the engine operating pressure requirements, automatic pressure regulating equipment shall be installed between the vehicular fuel container and the engine to regulate the pressure of the fuel delivered to the engine.

**11.12.5.2** Pressure regulating equipment shall be installed so that its weight is not placed on, or supported by, the attached lines.

**11.12.6 Pressure Gauges.**

**11.12.6.1** A pressure gauge located within a driver or passenger compartment shall be installed in such a manner that no gas flows through the gauge in the event of gauge failure.

**11.12.6.2** Gauges shall be mounted securely, shielded, and installed in a protected location to prevent damage from vibration and unsecured objects.

**11.12.7 Electrical Wiring.**

**11.12.7.1** Wiring shall be installed, supported, and secured in a manner to prevent damage due to vibration, shock, strains, wear, or corrosion.

**11.12.7.2** All conductors shall be sized for the maximum anticipated load and shall be protected by overcurrent protection devices.

**11.12.8 Labeling.**

**11.12.8.1** A vehicle equipped with an LNG fuel system shall bear a durable label located at the fueling connection receptacle that shall include the following:

(1) Identification as an LNG-fueled vehicle
(2) Maximum allowable working pressure of the vehicular fuel container

**11.12.8.2** Each LNG-fueled vehicle shall be identified with a weather-resistant, diamond-shaped label located on an exterior vertical or near-vertical surface on the lower right rear of the vehicle (or on the trunk lid of a vehicle so equipped, but not on the bumper or tailgate of any vehicle), inboard from any other markings.

**11.12.8.3** The label dimensions shall be approximately 4¾ in. × 3¼ in. (120 mm × 83 mm).

**11.12.8.4** The marking shall consist of a border and the abbreviation “LNG” in minimum 1 in. (25 mm) high letters of silver or white reflective luminous material centered within the diamond on a blue background.

**11.12.9 Fueling Receptacle.**

**11.12.9.1** The fueling receptacle on the vehicular fuel system shall be firmly supported and shall meet all the following requirements:

(1) Receive the fueling connector and accommodate the service pressure of the vehicle fuel system
(2) Incorporate a means to minimize the entry of dust, water, and other foreign material
(3) Be suitable for any corrosive conditions that are anticipated

**11.12.9.2** The fueling receptacle shall be mounted to withstand a breakaway force such that the breakaway device specified in 12.4.5 operates before the receptacle separates from the vehicular fuel system.

**11.12.9.3** The receptacle shall be installed in accordance with the original component manufacturer’s instructions.

**11.13 System Testing.**

**11.13.1 Cold Test and Pressure Test.**

**11.13.1.1** After the system has been completely assembled, all fittings and connections shall be tested for leaks while pressurized to the maximum operating pressure.

**11.13.1.2** Liquid nitrogen or LNG shall flow through the system at least as far as LNG flows when the system is in operation to validate minimum temperature [−260°F (−162°C)] and maximum tank venting pressure.

**11.13.2** When a vehicle is involved in an accident or fire causing damage to the LNG fuel system container, the system, container, or both shall be inspected, repaired, or removed and retested before being restored to service.

**11.13.3** Onboard methane detection, fire suppression, and fire protection systems shall be installed, inspected, validated, and maintained per the system OEM written recommendations and shall be maintained as a permanent vehicle record.

**11.13.3.1** Periodic testing shall be done at a minimum of three times per year.

**11.13.3.2** The testing procedure shall simulate the same gas and climatic conditions for daily use of the system.

**11.13.3.3** Validation shall conform to the specifics of the component OEM recommendations and shall be maintained as a permanent vehicle record.

## Chapter 12 LNG Fueling Facilities

**12.1 Application.**

**12.1.1** This chapter applies to the design, siting, construction, installation, spill containment, and operation of containers, pressure vessels, pumps, vaporization equipment, buildings, structures, and associated equipment used for the storage and dispensing of LNG and L/CNG as engine fuel for vehicles of all types.

**12.1.2** All dispensing of LNG, including mobile refueling, into vehicle onboard fuel systems shall comply with the requirements of a permanent LNG refueling installation at the point of dispensing fuel.

**12.2 Facility Design.**

**12.2.1 General.**

**12.2.1.1** LNG fueling facilities that are permitted to be unattended shall be designed to secure all equipment from tampering.

**12.2.1.2** Storage and transfer equipment at unattended facilities shall be secured to prevent tampering.

**12.2.1.3** Operating instructions identifying the location and operation of emergency controls shall be posted conspicuously in the facility area.

**12.2.1.4** LNG fueling facilities transferring LNG during the night shall have permanent, adequate lighting at points of transfer and operation.

**12.2.1.5** Designers, fabricators, and constructors of LNG fueling facilities shall be competent in the design, fabrication, and construction of LNG containers, cryogenic equipment, loading and unloading systems, fire protection equipment, methane detection, and other components of the facility.

**12.2.1.6** Supervision shall be provided for the fabrication, construction, and acceptance tests of facility components to the extent necessary to ensure that facilities are structurally sound, suitable for the service, and otherwise in compliance with this code.

**12.2.1.7** LNG refueling sites utilizing or dispensing saturated LNG with personnel in the immediate vicinity shall provide barrier walls or equal protection in order to protect the refueling operator and vehicle.

**12.2.1.8** All facility piping other than the refueling hose to the vehicle shall be behind a barrier, which in the case of an equipment or device malfunction deflects the saturated LNG upward.

**12.2.2 Siting.**

**12.2.2.1** LNG tanks and their associated equipment shall not be located where exposed to failure of overhead electric power lines operating over 600 volts.

**12.2.2.2** Vaulted or underground installations shall be deemed to provide engineered protection from overhead power lines.

**12.2.2.3** If other combustible or hazardous liquids can encroach on the LNG fueling facility, means shall be provided to protect that facility.

**12.2.2.4** Fired equipment shall be located in accordance with Table 12.2.2.4 from any impounding area or container drainage system.

**12.2.2.5** Points of transfer shall be located not less than 25 ft (7.6 m) from the nearest important building not associated with the LNG facility, from the line of adjoining property that can be built upon, or from fixed sources of ignition.

**12.2.2.6** Points of transfer shall include the maximum length of refueling hose, off-loading LNG bulk supply tanker, and off-loading hoses.

**12.2.3 Spill Containment.**

**12.2.3.1** Site preparation shall include provisions for retention of spilled LNG within the limits of plant property and for surface water drainage.

**12.2.3.1.1** Saturated LNG in an ASME container [50 psi (345 kPa) and above] shall only have to meet the requirements of 12.2.3.1 with respect to construction of the impounding area.

**12.2.3.2** Enclosed drainage channels for LNG shall be prohibited.

**12.2.3.3*** Impounding areas, if provided to serve LNG transfer areas, shall have a minimum volumetric capacity equal to the greatest volume of LNG or flammable liquid that could be discharged into the area during a 10-minute period from any single accidental leakage source or a lesser time period based on demonstrable surveillance and shutdown provisions acceptable to the AHJ.

**12.2.3.4** Flammable liquid storage tanks shall not be located within an LNG container impounding area.

**12.2.3.5*** Impounding areas serving LNG containers shall have a minimum volumetric holding capacity, *V*, including any useful holding capacity of the drainage area and with allowance made for the displacement of snow accumulation, other containers, and equipment, in accordance with 12.2.3.5.1 and 12.2.3.5.2.

**12.2.3.5.1** For impounding areas serving one or more than one container with provisions made to prevent low temperature or fire exposure resulting from the leakage from any one container served from causing subsequent leakage from any other container served, the volume of the dike shall be the total volume of liquid in the largest container served, assuming the container is full.

**12.2.3.5.2** For impounding areas serving more than one container without provisions made in accordance with 12.2.3.5.1, the volume of the dike shall be the total volume of liquid in all containers served, assuming all containers are full.

**12.2.3.6** The containment design shall include calculations and shall be installed to prevent overflow due to spill wave action.

**12.2.3.7** The containment design shall prevent projecting LNG or cold gas beyond the containment area.

**12.2.3.8** Provisions shall be made to clear rain or other water from the impounding area.

**12.2.3.8.1** Automatically controlled sump pumps shall be permitted if equipped with an automatic cutoff device that prevents their operation when exposed to LNG temperatures.

**12.2.3.8.2** Piping, valves, and fittings whose failure could permit liquid to escape from the impounding area shall be suitable for continuous exposure to LNG temperatures.

**12.2.3.8.3** If gravity drainage is employed for water removal, provisions shall be made to prevent the escape of LNG by way of the drainage system.

**12.2.4 Indoor Fueling.**

**12.2.4.1 Building Construction.**

**12.2.4.1.1** Buildings reserved exclusively for an LNG fueling facility shall be of Type I or Type II construction in accordance with *NFPA 5000, Building Construction and Safety Code*.

**12.2.4.1.2** Windows and doors shall be located so as to permit ready egress in case of emergency.

**Table 12.2.2.4 LNG Fueling Facility Electrical Area Classification**

| Part | Location | Class I, Group D Division or Zone[a] | Extent of Classified Area[b] |
|---|---|---|---|
| A | **LNG Fueling Facility Container Area** | | |
| | Indoors | 1 | Entire room |
| | Outdoor, aboveground containers (other than portable) | 1 | Open area between a high-type dike and container wall where dike wall height exceeds distances between dike and container walls |
| | | 2 | Within 15 ft (4.6 m) in all directions from container, plus area inside a low-type diked or impounding area up to the height of the dike impoundment wall |
| | Outdoor, belowground containers | 1 | Within any open space between container walls and surrounding grade or dike |
| | | 2 | Within 15 ft (4.6 m) in all directions from roof and sides above grade |
| B | **Nonfired LNG Process Areas Containing Pumps, Compressors, Heat Exchangers, Piping, Connections Vessels, etc.** | | |
| | Indoors with adequate ventilation | 2 | Entire room and any adjacent room not separated by a gastight partition, and 15 ft (4.6 m) beyond any ventilation discharge vent or lower |
| | Outdoors in open air at or above grade | 2 | Within 15 ft (4.6 m) in all directions from this equipment |
| C | **Pits, Trenches, or Sumps Located in or Adjacent to Division 1 or 2 Areas** | 1 | Entire pit, trench, or sump |
| D | **Discharge from Relief Valves, Drains** | 1 | Within 5 ft (1.5 m) from point of discharge |
| | | 2 | Beyond 5 ft (1.5 m) but within 15 ft (4.6 m) in all directions from point of discharge |
| E | **Vehicle/Cargo Transfer Area** | | |
| | Indoors with adequate ventilation[c] | 1 | Within 5 ft (1.5 m) in all directions from point of transfer |
| | | 2 | Beyond 5 ft (1.5 m) of entire room and 15 ft (4.6 m) beyond ventilation vent |
| | Outdoors in open air at or above grade | 1 | Within 5 ft (1.5 m) in all directions from point of transfer |
| | | 2 | Beyond 5 ft (1.5 m) but within 15 ft (4.6 m) in all directions from the point of transfer |

[a]See Article 500, "Hazardous (Classified) Locations," in NFPA 70, *National Electrical Code,* for definitions of classes, groups, and divisions.
[b]The classified area shall not extend beyond an unpierced wall, roof, or solid vaportight partition.
[c]Ventilation is considered adequate when provided in accordance with the provisions of this code.

**12.2.4.2* Deflagration Venting.**

**12.2.4.2.1** Deflagration venting shall be provided only in the exterior walls or the roof.

**12.2.4.2.2** Vents shall consist of any one or a combination of the following:

(1) Walls of light material
(2) Lightly fastened hatch covers
(3) Lightly fastened, outward-opening doors in exterior walls
(4) Lightly fastened walls or roof

**12.2.4.2.3** Ventilation shall be by a continuous mechanical ventilation system or by a mechanical ventilation system activated by a continuously monitoring natural gas detection system when a gas concentration of not more than one-fifth of the LFL is present.

**12.2.4.2.4** In either case, the system shall shut down the fueling system in the event of failure of the ventilation system.

**12.2.4.2.5** Failures of any controllers used by the system shall result in a safe condition.

**12.2.4.2.6*** The ventilation rate shall be at least 1 $ft^3$/min/12 $ft^3$ (0.03 $m^3$/min/0.34 $m^3$) of room volume.

**12.2.4.3** Reactivation of the fueling system shall be by manual restart conducted by trained personnel and in accordance with a process safety analysis.

**12.2.4.4** A gas detection system shall be provided in all buildings containing LNG and shall activate a latched alarm when a maximum of 20 percent of the LFL is reached.

**12.2.4.4.1** The alarm shall be clearly audible and visible both inside and outside the whole building and potential affected area.

**12.2.4.4.2** The gas detection system shall not be shut down during fueling operations.

**12.2.4.5** Dispensing equipment located inside or attached to buildings used for other purposes shall comply with the following:

(1) The dispensing room shall have a minimum of one external wall.
(2) Interior walls or partitions shall be continuous from floor to ceiling, shall be anchored securely, and shall have a fire resistance rating of at least 2 hours.
(3) The interior finish of the dispensing room shall be constructed of noncombustible or limited-combustible materials.
(4) In the interior walls of the dispensing room, doors shall be listed as 1-hour self-closing fire doors and shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives.*
(5) A ventilation system for a dispensing room within or attached to another building shall be separated from any ventilation system for the other building.
(6) Access to the dispensing room shall be from outside the primary structure only.

*Exception: Access from within the primary structure shall be permitted where such access is made through a barrier space having two vapor-sealing, self-closing fire doors having a fire resistance rating equal to that of the wall.*

**12.2.4.6** Access doors or fire doors shall be kept unobstructed at all times.

**12.2.4.7** Appropriate signs and markings and the words "WARNING — NO SMOKING" shall be clearly legible in bright red letters at least 1 in. (25 mm) high on a white background.

**12.2.4.8** LNG piping entering a building shall be provided with shutoff valves located outside the building.

**12.2.4.9** Buildings and rooms used for storage or dispensing shall be classified in accordance with Table 12.2.2.4 for installations of electrical equipment.

**12.3 Cargo Transport Unloading.**

**12.3.1** Section 12.3 shall apply to the transfer of LNG between cargo transport containers and fueling facility containers.

**12.3.2** When transfers are made into fueling facility containers, the LNG shall be transferred at a pressure that shall not overpressurize the receiving tank. Venting of onsite containers shall only be done under emergency conditions and in a manner acceptable to the authority having jurisdiction.

**12.3.3 Isolation Valves.**

**12.3.3.1** The transfer piping shall have isolation valves at both ends.

**12.3.3.2** On facility containers with a capacity greater than 2000 gal (7.6 $m^3$), one remotely operated valve, automatic closing valve, or check valve shall be used to prevent backflow.

**12.3.4** If the fueling facility tank or transfer equipment is located in a remote area, operating status indicators, such as those that indicate container level, shall be provided in the unloading area.

**12.3.5** At least one qualified person shall be in continuous attendance and shall have an unobstructed view of the transfer point while unloading is in progress.

**12.3.6** Sources of ignition shall not be permitted in the unloading area while transfer is in progress.

**12.3.7 Methane Detection.**

**12.3.7.1** Offloading site methane detection and fire protection shall be provided.

**12.3.7.2** The methane detection system shall be capable of detection at multiple locations beyond the full radius of the transfer hose, measured at each point of transfer and receipt of LNG.

**12.3.8 Bleed Connections.**

**12.3.8.1** Bleed or vent connections shall be provided so that loading arms and hoses can be drained and depressurized prior to disconnection if necessary.

**12.3.8.2** The connections shall relieve to a safe area.

**12.3.9** Prior to connection, a cargo transport vehicle's wheels shall be rendered immobile.

**12.3.10** The cargo transport vehicle's engine shall be shut off while the transfer hose or piping is being connected or disconnected.

**12.3.11** If required for LNG transfer, the engine shall be permitted to be started and used during the liquid transfer operations.

**12.3.12** The LNG cargo transport unloading connection shall be at least 1.5 ft (0.46 m) from a storage container.

**12.4 Vehicle Fuel Dispensing Systems.**

**12.4.1** The dispensing device shall be protected from vehicle collision damage.

**12.4.2** An ESD shall be provided that includes a shut-off valve for stopping liquid supply and shutting down transfer equipment.

**12.4.3** An ESD actuator, distinctly marked for easy recognition with a permanently affixed, legible sign, shall be provided within 10 ft (3.1 m) of the dispenser and also at a safe, remote location.

**12.4.4** The maximum delivery pressure at the fueling nozzle shall not exceed the maximum allowable pressure of the vehicle fuel tanks.

**12.4.5** Hose and arms shall be equipped with a shut-off valve at the fuel end and a breakaway device to minimize release of liquid and vapor in the event that a vehicle pulls away while the hose remain connected. Such a device shall be installed and maintained in accordance with the OEM component manufacturer's maintenance/safety instructions.

**12.4.6** When not in use, hose shall be secured to protect it from damage.

**12.4.7** Where a hose or arm of nominal 3 in. (76 mm) diameter or larger is used for liquid transfer or where one of nominal 4 in. (100 mm) diameter or larger is used for vapor transfer, an emergency shut-off valve shall be installed in the piping of the transfer system within 10 ft (3.1 m) from the nearest end of the hose or arm.

**12.4.7.1** Where the flow is away from the hose, a check valve shall be permitted to be used as the shut-off valve.

**12.4.7.2** Where either a liquid or vapor line has two or more legs, an emergency shut-off valve shall be installed either in each leg or in the feed line before the legs.

**12.4.8 Bleed Connections.**

**12.4.8.1** Bleed or vent connections shall be provided so that loading arms and hose can be drained and depressurized prior to disconnection if necessary.

**12.4.8.2** Bleed or vent connections shall lead to a safe point of discharge.

**12.4.9** A fueling connector and mating vehicle receptacle shall be used for reliable, safe, and secure transfer of LNG or gas vapor to or from the vehicle with minimal leakage.

**12.4.10** The fueling connector either shall be equipped with an interlock device that prevents release while the line is open or shall have self-closing ends that automatically close upon disconnection.

**12.4.11** The transfer of LNG into vehicular onboard fuel containers shall be performed in accordance with the onboard tank and refueling component OEM manufacturer's instructions that shall be posted at the dispensing device.

**12.4.12** The spacing of LNG dispensing equipment relative to other equipment, activities, nearby property lines, and other exposures in a fuel dispensing forecourt shall be approved by the AHJ.

**12.4.13** The provisions of Section 12.4 shall not apply to dispensing from vehicle-mounted tanks located at commercial and industrial facilities used in connection with their business where the following conditions are met:

(1) An inspection of the premises and operations shall have been made and approval granted by the AHJ.
(2) The vehicle-mounted container shall comply with requirements of DOT.
(3) The dispensing hose shall not exceed 50 ft (15 m) in length.
(4) Nighttime deliveries shall be made only in lighted areas.

**12.5 Piping Systems and Components.** Piping shall be in accordance with Chapter 16.

**12.6 Safety and Relief Valves.**

**12.6.1** Pressure relieving safety devices shall be so arranged that the possibility of damage to piping or appurtenances is reduced to a minimum.

**12.6.2** The means for adjusting relief valve set pressure shall be sealed.

**12.6.3** Stationary LNG containers shall be equipped with pressure relief devices in accordance with CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Stationary Storage Containers for Compressed Gases*.

**12.6.4** A thermal expansion relief valve shall be installed as required to prevent overpressure in any section of a liquid or cold vapor pipeline that can be isolated by valves.

**12.6.4.1** Thermal expansion relief valves shall be set to discharge above the maximum pressure normally expected in the line but less than the rated test pressure of the line it protects.

**12.6.4.2** Discharge from thermal expansion relief valves shall be directed so as to minimize hazard to personnel and other equipment.

**12.7 Corrosion Control.**

**12.7.1** Underground and submerged piping shall be protected and maintained in accordance with the principles of NACE RP0169, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems*.

**12.7.2** Austenitic stainless steels and aluminum alloys shall be protected to minimize corrosion and pitting from corrosive atmospheric and industrial substances during storage, construction, fabrication, testing, and service.

**12.7.2.1** These substances shall include, but not be limited to, chlorides and compounds of sulfur or nitrogen.

**12.7.2.2** Tapes or other packaging materials that are corrosive to the pipe or piping components shall not be used.

**12.7.2.3** Where insulation materials can cause corrosion of aluminum or stainless steels, inhibitors or waterproof barriers shall be utilized.

**12.7.3** Corrosion protection of all other materials shall be in accordance with the requirements of SSPC-PA 1, *Shop, Field and Maintenance Painting*; SSPC-PA 2, *Measurement of Dry Paint Thickness with Magnetic Gages*; and SSPC-SP 6, *Commercial Blast Cleaning*.

**12.8 Stationary Pumps and Compressors.**

**12.8.1** Valves shall be installed such that each pump or compressor can be isolated for maintenance.

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

**12.8.3** Foundations and sumps for cryogenic pumps shall be designed and constructed to prevent frost heaving.

**12.8.4** Operation of all pumps and compressors shall cease when the facility's ESD system is initiated.

**12.8.5** Each pump shall be provided with an adequate vent or relief valve that prevents overpressurizing of the pump case under all conditions, including the maximum possible rate of cool down.

**12.8.6** Compression equipment handling flammable gases shall be provided with vent line connections from all points, including distance pieces of packing for piston rods, where gases can normally escape.

**12.8.7** Vents shall be piped outside of buildings to a point of safe disposal.

**12.9 Vaporizers.**

**12.9.1** Multiple vaporizers shall be manifolded such that both inlet and discharge block valves are installed on each vaporizer.

**12.9.2** If the intermediate fluid used with a remote heated vaporizer is flammable, shut-off valves shall be provided on both the hot and cold lines of the intermediate fluid system.

**12.9.3** A low temperature switch or other accepted means shall be installed on the vaporizer discharge to eliminate the possibility of LNG or cold natural gas entering CNG containers and other equipment not designed for LNG temperatures.

**12.9.4** Relief valves on heated vaporizers shall be located so that they are not subjected to temperatures exceeding 140°F (60°C) during normal operation unless they are designed to withstand higher temperatures.

**12.9.5** The combustion air required for the operation of integral heated vaporizers or the primary heat source for remote heated vaporizers shall be taken from outside an enclosed structure or building.

**12.9.6** Vaporizers for purposes other than pressure building coils or LNG-to-CNG (L/CNG) systems shall be in accordance with NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

**12.9.7** Installation of internal combustion engines or gas turbines shall conform to NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

**12.9.8** The vaporizer shall be anchored and its connecting piping shall be sufficiently flexible to provide for the effect of expansion and contraction due to temperature change.

**12.10 LNG-to-CNG (L/CNG) Systems.**

**12.10.1** Section 12.10 shall apply to the design, construction, installation, and operation of equipment used to produce CNG from LNG.

**12.10.2** The process shall be permitted to be accomplished by pumping LNG to high pressure and vaporizing it or by compressing vapor from an LNG tank.

**12.10.3** In addition to the emergency shutdown systems described in Section 12.4, the emergency shutdown system also shall shut off the liquid supply and power to the LNG transfer equipment necessary for producing CNG from LNG.

**12.10.4** Compressors, vaporizers, and CNG storage cylinders shall not be located inside the facility impounding area.

*Exception: Ambient and remotely heated vaporizers shall be permitted to be located inside the facility impounding area.*

**12.10.5** Transfer piping, pumps, and compressors shall be protected from vehicle collision damage.

**12.10.6** L/CNG or hydrogen–natural gas refueling site and automotive applications shall not be required to utilize an odorant if an engineered and validated methane detection system is in place.

**12.10.7** Unodorized L/CNG or hydrogen–natural gas shall not be dispensed at public refueling stations.

**12.10.8** Refueling stations dispensing odorant shall have safety measures in place to automatically and completely shut down all dispensing of L/CNG if the odorant supply is inadequate.

**12.10.9** Refueling station odorant dispensing equipment shall be certified by the dispenser OEM for automotive refueling station applications.

**12.10.10** Dispensing of odorant for automotive natural gas applications shall conform to the federal standards for natural gas pipeline percentages of odorant within the gaseous mixture.

**12.10.11** Dispensing of odorant for hydrogen–methane mixtures shall conform to the federal standards for natural gas pipeline percentages of odorant with the gaseous mixture.

**12.10.12** Onboard methane detection shall be required for vehicles that utilize unodorized natural gas or natural gas–hydrogen mixtures that do not meet the federal standards for pipeline gas odorization.

**12.11 Instrumentation.**

**12.11.1 Pressure Gauging.** Pressure gauges shall be installed on each pump and compressor discharge.

**12.11.2 Temperature Instruments.**

**12.11.2.1** Vaporizers and heaters shall be provided with instrumentation to monitor outlet temperatures.

*Exception: Ambient pressure–building coil vaporizers that are fed with liquid from, and return vapor to, a container.*

**12.11.2.2** Temperature monitoring systems shall be provided where the foundations supporting cryogenic containers and equipment can be affected adversely by freezing or frost heaving of the ground.

**12.11.3 Emergency Shutdown Device (ESD).**

**12.11.3.1** Instrumentation for LNG fueling facilities shall be designed so that, in the event of a power or instrumentation failure, the system shall go into a fail-safe condition that can be maintained until the operators can take appropriate action to either reactivate or secure the system.

**12.11.3.2** All ESDs shall be manually reset.

**12.12 Electrical Equipment.**

**12.12.1** Electrical equipment and wiring shall be as specified by and installed in accordance with *NFPA 70, National Electrical Code*, and shall meet the requirements of Class I, Group D, Division or Zone as specified in Table 12.2.2.4.

*Exception: Electrical equipment on internal combustion engines installed in accordance with NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

**12.12.1.1** The LNG container and associated piping shall be electrically bonded and grounded.

**12.12.2** Each interface between a flammable fluid system and an electrical conduit or wiring system, including process instrumentation connections, integral valve operators, foundation heating coils, canned pumps, and blowers, shall be sealed or isolated to prevent the passage of flammable fluids to another portion of the electrical installation.

**12.12.3** Each seal, barrier, or other means used to comply with 12.12.2 shall be designed to prevent the passage of flammable fluids or gases through the conduit, stranded conductors, and cables.

**12.12.4*** A primary seal shall be provided between the flammable fluid and gaseous systems and the electrical conduit wiring system.

**12.12.4.1** If the failure of the primary seal would allow the passage of flammable fluids and gases to another portion of the conduit or wiring system, an additional approved seal, barrier, or other means shall be provided to prevent the passage of the flammable fluid beyond the additional device or means in the event that the primary seal fails.

**12.12.5** Each primary seal shall be designed to withstand the service conditions to which it is expected to be exposed.

**12.12.5.1** Each additional seal or barrier and interconnecting enclosure shall meet the pressure and temperature requirements of the condition to which it could be exposed in the event of failure of the primary seal, unless other approved means are provided to accomplish this purpose.

**12.12.6** Unless specifically designed and approved for the purpose, the seals specified in 12.12.2 through 12.12.4 are not intended to replace the conduit seals required by 501.15 of *NFPA 70, National Electrical Code*.

**12.12.7** Where primary seals are installed, drains, vents, or other devices shall be provided for monitoring purposes to detect flammable fluids and leakage.

**12.12.8** Static protection shall not be required when cargo transport vehicles or marine equipment are loaded or unloaded by conductive or nonconductive hose, flexible metallic tubing, or pipe connections through or from tight (top or bottom) outlets where both halves of metallic couplings are in contact.

**12.13* Maintenance.**

**12.13.1** A preventive maintenance program consistent with the OEMs' recommendations shall be in place and shall include a written regular schedule of procedures for test and inspection of facility systems and equipment. The maintenance program shall be carried out by a qualified representative of the equipment owner.

**12.13.1.1** Maintenance shall be performed based on the component manufacturers' recommendations and not less than every 6 months.

**12.13.1.2** The refueling site shall have a maintenance program or process safety analysis program in place.

**12.13.1.3** Maintenance records shall be kept for the duration of the refueling site's operation.

**12.13.2** Each component in service, including its support system, shall be maintained in a condition that is compatible with its operation or safety purpose by repair, replacement, or other means as determined by the equipment OEM.

**12.13.3** If a safety device is taken out of service for maintenance, the component being served by the device shall be taken out of service unless the same safety function is provided by an alternative means.

**12.13.4** If the inadvertent operation of a component taken out of service could cause a hazardous condition, that component shall have a tag attached to its controls bearing the words DO NOT OPERATE or a similar warning.

**12.13.4.1** All maintenance and servicing shall be done in accordance with 29 CFR 1910 for energy control.

**12.13.5** LNG fueling facilities shall be free from rubbish, debris, and other material that present a fire hazard to a distance of at least 25 ft (7.6 m).

**12.13.6** Grass areas on the LNG fueling facility grounds shall be maintained in a manner that does not present a fire hazard.

**12.13.7** Safety and fire protection equipment shall be tested or inspected at intervals not to exceed 6 months.

**12.13.8** Maintenance activities on fire control equipment shall be scheduled so that a minimum of equipment is taken out of service at any one time and fire prevention safety is not compromised.

**12.13.9** Access routes for movement of fire control equipment to an LNG fueling facility shall be maintained at all times.

## Chapter 13 Reserved

## Chapter 14 $LH_2$ Fueling Facilities

**14.1 Application.** This chapter applies to the design, siting, construction, installation, and operation of containers, pressure vessels, pumps, vaporization equipment, and associated equipment used for the storage or dispensing of $LH_2$ as an engine fuel for vehicles of all types.

**14.2 Containers. (Reserved)**

**14.3 Facility Design.**

**14.3.1 General.** All hydrogen refueling station sites shall have a complete HAZOP or process safety analysis prior to dispensing fuel.

**14.3.1.1 Security.** Cryogenic containers and systems shall be secured against accidental dislodgement and against access by unauthorized personnel. [**55:**8.6.1]

**14.3.1.1.1** $LH_2$ dispensers shall be designed to secure all equipment from tampering.

**14.3.1.1.2** Storage containers, piping, valves, regulating equipment, and other accessories shall be accessible and shall be protected against physical damage and tampering. [**55:**11.2.4.2]

**14.3.1.2** Operating instructions identifying the location and operation of emergency controls shall be posted conspicuously in the facility area.

**14.3.1.2.1 Identification of Emergency Shutoff Valves.** Emergency shutoff valves on stationary containers shall be identified, visible, and indicated by means of a sign. [**55:**8.4.6]

**14.3.1.3 Lighting.** $LH_2$ dispensing areas transferring $LH_2$ during the night shall have permanent lighting at points of transfer and operation.

**14.3.1.3.1*** Where required by the authority having jurisdiction, lighting, including emergency lighting, shall be provided for fire appliances and operating facilities such as walkways, control valves, and gates ancillary to stationary containers. [**55:**8.12]

**14.3.1.3.2** The lighting shall be designed to provide illumination of the dispensing apparatus and dispensing area, such that all controls including emergency shutdown devices are visible to the operator.

**14.3.1.3.3** Lighting shall be provided for nighttime transfer operation, and supplemental lighting shall be provided where required by 14.3.1.3. [**55:**11.4.1.3]

**14.3.1.4** Designers, fabricators, and constructors of $LH_2$ fueling facilities shall be competent in the design, fabrication, and construction of $LH_2$ containers, cryogenic equipment, loading and unloading systems, fire protection equipment, hydrogen detection, and other components of the facility. Supervision shall be provided for the fabrication, construction, and acceptance tests of facility components to the extent necessary to ensure that facilities are structurally sound, suitable for the service, and otherwise in compliance with this code.

**14.3.1.4.1** Installation of bulk [cryogenic fluid] systems shall be supervised by personnel knowledgeable in the application of the standards for their construction and use. [**55:**7.1.1.2]

**14.3.1.5** $LH_2$ refueling sites utilizing or dispensing $LH_2$ shall provide personnel protection barriers such as walls, cabinets, vacuum-jacketed pipe, and similar barriers to protect the fueling operator and the vehicle being fueled from contact with a release of $LH_2$. All facility piping other than the refueling line to the vehicle shall be behind the barrier, to deflect any $LH_2$ that is released due to an equipment malfunction.

**14.3.1.6** All cryogenic containers, vessels, and tanks shall provide and maintain ullage space to prevent overfilling of the vessel.

**14.3.2 Stationary Storage Tanks.**

**14.3.2.1 Aboveground Tanks.** Aboveground tanks for the storage of liquid hydrogen shall be installed in accordance with NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, and this code.

**14.3.2.1.1 Siting.** The minimum distance from aboveground bulk liquefied hydrogen ($LH_2$) gas systems of indicated capacity to exposures shall be in accordance with Table 14.3.2.1.1.

**14.3.2.2 Underground Tanks.** Underground tanks for the storage of liquid hydrogen shall be in accordance with NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, and this code.

**14.3.2.2.1 Construction.** Stationary storage tanks for liquid hydrogen shall be designed and constructed in accordance with ASME *Boiler and Pressure Vessel Code* (Section VIII, Division 1) and shall be vacuum-jacketed in accordance with 14.3.2.2.1.1. [**55:**11.4.2.1]

**14.3.2.2.1.1 Vacuum Jacket Construction.** The vacuum jacket shall be designed and constructed in accordance with Section VIII of ASME *Boiler and Pressure Vessel Code* and shall be designed to withstand the anticipated loading, including loading from vehicular traffic, where applicable. [**55:**11.4.3.1.1.1]

**14.3.2.2.1.2** Portions of the vacuum jacket installed below grade shall be designed to withstand anticipated soil, hydrostatic, and seismic loading. [**55:**11.4.3.1.1.2]

**(A) Material.** The vacuum jacket shall be constructed of stainless steel or other approved corrosion-resistant material. [**55:**11.4.3.1.1.2(A)]

**(B) Corrosion Protection.** The vacuum jacket shall be protected by an engineered cathodic protection system. A cathodic protection system maintenance schedule shall be provided and reconciled by the owner/operator. Exposed components shall be inspected at least twice a year. [**55:**11.4.3.1.1.2(B)]

**14.3.2.2.2 Location.** Tanks shall be located in accordance with 14.3.2.2.2.1 through 14.3.2.2.2.4. [**55:**11.4.3.2]

**14.3.2.2.2.1** Underground storage tanks shall not be located beneath buildings. [**55:**11.4.3.2.1]

**14.3.2.2.2.2** Tanks and associated equipment shall be located with respect to foundations and supports of other structures such that the loads carried by such structures cannot be transmitted to the tank. [**55:**11.4.3.2.2]

**14.3.2.2.2.3** The distance from any part of the tank to the nearest wall of a basement, pit, cellar, or lot line shall not be less than 10 ft (3.1 m). [**55:**11.4.3.2.3]

**14.3.2.2.2.4** A minimum distance of 1 ft (0.3 m), shell to shell, shall be maintained between adjacent underground tanks. [**55:**11.4.3.2.4]

**14.3.2.2.3 Depth, Cover, and Fill.** The tank shall be buried such that the top of the vacuum jacket is covered with a minimum of 1 ft (0.3 m) of earth and with concrete a minimum of 4 in. (101 mm) thick placed over the earthen cover. [**55:**11.4.3.3.1]

**14.3.2.2.3.1** The concrete shall extend a minimum of 1 ft (0.3 m) horizontally beyond the footprint of the tank in all directions. [**55:**11.4.3.3.2]

**14.3.2.2.3.2** Underground tanks shall be set on foundations constructed in accordance with the building code and surrounded with not less than 6 in. (152 mm) of noncorrosive inert material. [**55:**11.4.3.3.3]

**14.3.2.2.3.3** The vertical extension of the vacuum jacket required for service connections shall be allowed to extend above grade. [**55:**11.4.3.3.4]

**14.3.2.2.4 Anchorage and Security.** Tanks and systems shall be secured against accidental dislodgment due to seismic events or flooding. [**55:**11.4.3.4]

**14.3.2.2.5 Venting of Underground Tanks.** Vent pipes for underground storage tanks shall be in accordance with 14.8.1.5. [**55:**11.4.3.5]

**14.3.2.2.6 Underground Liquid Hydrogen Piping.** Underground liquid hydrogen piping shall be vacuum jacketed. [**55:**11.4.3.6.1]

**14.3.2.2.6.1** Unjacketed piping shall not be buried and shall exit the tank annular space above grade. [**55:**11.4.3.6.2]

**14.3.2.2.7 Overfill Protection and Prevention Systems.** An approved means or method shall be provided to prevent the overfilling of storage tanks. [**55:**11.4.3.7]

**14.3.2.2.8 Vacuum Level Monitoring.** An approved monitoring method shall be provided to indicate vacuum degradation within the vacuum jacket(s). [**55:**11.4.3.8]

**14.3.2.2.9 Physical Protection.** Piping and control equipment ancillary to the underground tank located above ground shall be protected from physical damage in accordance with 14.8.1.6. [**55:**11.4.3.9]

**14.3.2.2.10 Tanks Not in Service.** Tanks not in service shall be maintained in accordance with 14.3.2.2.10.1. [**55:**11.4.3.10]

**14.3.2.2.10.1** Corrosion protection shall be maintained in operation. [**55:**11.4.3.10.1]

**14.3.2.2.11 Underground Systems. (Reserved)**

**14.3.2.3*** According to Table 11.3.2.2 of NFPA 55, hydrogen systems shall not be located beneath or where exposed by failure of the following:

(1) Electric power lines as follows:
   (a) Not less than 50 ft (15.2 m) from the vertical plane below the nearest overhead wire of an electric trolley, train, or bus line
   (b) Not less than 5 ft (1.5 m) from the vertical plane below the nearest overhead electrical wire
(2) Piping containing other hazardous materials

**Table 14.3.2.1.1 Minimum Distance from Liquefied Hydrogen Systems to Exposures**

| | Total Liquefied Hydrogen Storage | | | | | |
|---|---|---|---|---|---|---|
| | 39.7 gal to 3500 gal | 150 L to 13,250 L | 3501 gal to 15,000 gal | 13,251 L to 56,781 L | 15,001 gal to 75,000 gal | 56,782 L to 283,906 L |
| Type of Exposure | ft | m | ft | m | ft | m |
| 1. Building or structure | | | | | | |
| (a) Wall(s) adjacent to system constructed of noncombustible or limited-combustible materials | | | | | | |
| (1) Sprinklered building or structure or unsprinklered building or structure having noncombustible contents | 5[a] | 1.5 | 5[a] | 1.5 | 5[a] | 1.5 |
| (2) Unsprinklered building or structure with combustible contents | | | | | | |
| (i) Adjacent wall(s) with fire resistance rating less than 3 hours | 25 | 7.6 | 50 | 15 | 75 | 23 |
| (ii) Adjacent wall(s) with fire resistance rating of 3 hours or greater[b] | 5 | 1.5 | 5 | 1.5 | 5 | 1.5 |
| (b) Wall(s) adjacent to system constructed of combustible materials | | | | | | |
| (1) Sprinklered building or structure | 50 | 15 | 50 | 15 | 50 | 15 |
| (2) Unsprinklered building or structure | 50 | 15 | 75 | 23 | 100 | 30.5 |
| 2. Wall openings | | | | | | |
| (a) Operable | 75 | 23 | 75 | 23 | 75 | 23 |
| (b) Inoperable | 25 | 7.6 | 50 | 15 | 50 | 15 |
| 3. Air compressor intakes or inlets for air-conditioning or ventilating equipment | 75 | 23 | 75 | 23 | 75 | 23 |
| 4. All classes of flammable and combustible liquids (above ground and vent or fill openings if below ground)[c] | 50 | 15 | 75 | 23 | 100 | 30.5 |
| 5. Between stationary liquefied hydrogen containers | 5 | 1.5 | 5 | 1.5 | 5 | 1.5 |
| 6. Flammable gas storage other than hydrogen | 50 | 15 | 75 | 23 | 75 | 23 |
| 7. Liquid oxygen storage and other oxidizers | 75 | 23 | 75 | 23 | 75 | 23 |
| 8. Combustible solids | 50 | 15 | 75 | 23 | 100 | 30.5 |
| 9. Open flames and welding | 50 | 15 | 50 | 15 | 50 | 15 |
| 10. Places of public assembly | 75 | 23 | 75 | 23 | 75 | 23 |
| 11. Public ways, railroads, and property lines | 25 | 7.6 | 50 | 15 | 75 | 23 |
| 12. Inlet to underground sewers | 5 | 1.5 | 5 | 1.5 | 5 | 1.5 |
| 13. Encroachment by overhead power lines | | | | | | |
| (a) Horizontal distance from the vertical plane below the nearest overhead wire of an electric trolley, train, or bus line | 50 | 15 | 50 | 15 | 50 | 15 |
| (b) Horizontal distance from the vertical plane below the nearest overhead electrical wire | 25 | 7.5 | 25 | 7.5 | 25 | 7.5 |
| (c) Piping containing other hazardous materials | 15 | 4.6 | 15 | 4.6 | 15 | 4.6 |

[a] Portions of wall less than 10 ft (3.1 m) (measured horizontally) from any part of a system shall have a fire resistance rating of not less than 1 hour.
[b] Exclusive of windows and doors.
[c] The separation distances for Class IIIB combustible liquids shall be permitted to be reduced to 15 ft (4.6 m).
[**55:**Table 11.3.2.2]

**14.3.2.4** The grade for a distance of not less than 50 ft (15.2 m) from where cryogenic fluid storage or delivery systems are installed shall be higher than the grade on which flammable or combustible liquids are stored or used. [**55:**8.13.2.6.4 ]

**14.3.2.4.1*** Where the grade differential between the storage or delivery system and the flammable or combustible liquids storage or use area is not in accordance with 14.3.2.4, diversion curbs or other means of drainage control shall be used to divert the flow of flammable or combustible liquids away from the cryogenic system. [**55:**8.13.2.6.4.1(A)]

**14.3.2.4.2** The means of drainage control shall prevent the flow of flammable or combustible liquid to a distance not less than 50 ft (15.2 m) from all parts of the delivery system. [**55:**8.13.2.6.4.1(B)]

**14.3.2.5** Vaulted or underground installations shall be deemed to provide engineered protection from overhead power lines.

**14.3.2.6** Points of transfer shall be located not less than 25 ft (7.6 m) from the nearest important building not associated with the $LH_2$ facility, from the line of adjoining property that can be built upon, or from fixed sources of ignition. Points of transfer shall also include the maximum length of the refueling hose, off-loading $LH_2$ bulk supply tanker, and off-loading hoses.

**14.3.3 Spill Containment.** Diking shall not be used to contain a liquid hydrogen spill. [**55:**11.3.1.2]

**14.3.4 Indoor Fueling.** Indoor $LH_2$ fueling shall not be permitted.

**14.4 Cargo Transport Unloading.** Bleed or vent connections shall be provided so that loading arms and hoses can be drained and depressurized prior to disconnection if necessary.

**14.4.1** When transfers are made into fueling facility containers, the $LH_2$ shall be transferred at a pressure that shall not overpressurize the receiving tank.

**14.4.2** The transfer piping shall be equipped with a check valve to prevent backflow from the container being filled to the transport vehicle.

**14.4.3** Stationary storage containers shall be located so that they are accessible from mobile supply equipment. [**55:**11.3.1.1]

**14.4.3.1** When the fueling facility tank or transfer equipment is located in an area below grade, operating status indicators, such as those that indicate container level, shall be provided in the unloading area.

**14.4.4** A qualified person shall be in attendance at all times cryogenic fluid is transferred from mobile supply units to a storage system. [**55:**8.14.1.2]

**14.4.5** Sources of ignition shall not be permitted in the unloading area while transfer is in progress.

**14.4.6** Bleed or vent connections shall be provided so that loading arms and hoses can be drained and depressurized prior to disconnection if necessary. The connections for $LH_2$ shall be piped to a vent stack in accordance with Section 5.5.

**14.4.7** Prior to connection, a cargo transport vehicle's wheels shall be rendered immobile.

**14.4.8** The cargo transport vehicle's engine shall be shut off while the transfer hose or piping is being connected or disconnected. If required for $LH_2$ trailer pumping transfer, the engine pump drive motor shall be permitted to be started and used during the liquid transfer operations.

**14.5 $LH_2$ Vehicle Fuel Dispensing Systems.**

**14.5.1** $LH_2$ fueling facilities shall be designed so that, in the event of a power or equipment failure, the system shall go into a fail-safe condition.

**14.5.2** The dispensing device shall be protected from vehicle collision damage.

**14.5.3** An emergency shutdown system (ESD) shall be provided that includes a shut-off valve, which shall be provided within 10 ft (3.1 m) of the dispenser, for stopping liquid supply and shutting down transfer equipment. An actuator for the valve, distinctly marked for easy recognition with a permanently affixed, legible sign, shall be provided with a shutdown control point located near the dispenser and another shutdown control point located at a safe, remote location.

**14.5.4** The maximum delivery pressure at the vehicle tank inlet shall not exceed the maximum allowable pressure of the vehicle fuel tanks.

**14.5.5** Hose and arms shall be equipped with a shut-off valve at the fuel end and a breakaway device to minimize release of liquid and vapor in the event that a vehicle pulls away while the hose remains connected. Such a device shall be installed and maintained in accordance with the manufacturer's instructions.

**14.5.6** When not in use, hose shall be secured to protect it from damage.

**14.5.7** Where a hose or arm of nominal 3 in. (76 mm) diameter or larger is used for liquid transfer or where one of nominal 4 in. (100 mm) diameter or larger is used for vapor transfer, an emergency shut-off valve shall be installed in the piping of the transfer system within 10 ft (3.0 m) from the nearest end of the hose or arm.

**14.5.7.1** Where the flow is away from the hose, a check valve shall be permitted to be used as the shut-off valve.

**14.5.7.2** Where either a liquid or vapor line has two or more legs, an emergency shut-off valve shall be installed either in each leg or in the feed line before the legs.

**14.5.8** Bleed or vent connections shall be provided so that loading arms and hose can be drained and depressurized prior to disconnection if necessary. These bleed or vent connections shall lead to a safe point of discharge.

**14.5.9** A fueling connector and mating vehicle receptacle shall be used for reliable, safe, and secure transfer of $LH_2$ or gas vapor to or from the vehicle with minimal leakage.

**14.5.10** The fueling connector either shall be equipped with an interlock device that prevents release while the line is open or shall have self-closing ends that automatically close upon disconnection.

**14.5.11** The transfer of $LH_2$ into vehicular onboard fuel supply containers shall be performed in accordance with the manufacturer's instructions. The dispenser manufacturer's instructions shall be posted at the dispensing device.

**14.5.12** The provisions of Section 14.5 shall not apply to dispensing from vehicle-mounted tanks located at commercial and industrial facilities used in connection with their business where the following conditions are met:

(1) An inspection of the premises and operations has been made and approval granted by the authority having jurisdiction. All dispensing of $LH_2$, including mobile refueling, into vehicle onboard fuel systems shall comply with the requirements of a permanent $LH_2$ refueling installation at the point of dispensing fuel.
(2) The vehicle-mounted container shall comply with the requirements of DOT.
(3) The dispensing hose shall not exceed 50 ft (15 m) in length.
(4) Nighttime deliveries shall be made only in lighted areas.
(5) Mobile refueling units shall meet the site requirements of a permanent refueling station at the point of dispensing and if left on site.

**14.6 Piping, Tubing, and Fittings. (Reserved)**

**14.7 Piping Systems and Components.** Piping shall be in accordance with ANSI/ASME B31.3, *Process Piping*.

**14.8 Pressure Relief Devices.**

**14.8.1 General. [55:8.2.5.1]**

**14.8.1.1** Pressure-relief devices shall be provided to protect containers and systems containing cryogenic fluids $LH_2$ from rupture in the event of overpressure. [**55:**8.2.5.1.1]

**14.8.1.2** Pressure relief devices shall be designed in accordance with CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*, and CGA S-1.2, *Pressure Relief Device Standards — Part 2 — Cargo and Portable Tanks for Compressed Gases*, for portable tanks; and CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Stationary Storage Containers for Compressed Gases*, for stationary tanks. [**55:**8.2.5.1.2]

**14.8.1.3 Equipment Other than Containers.** Heat exchangers, vaporizers, insulation casings surrounding containers, vessels, and coaxial piping systems in which liquefied cryogenic fluids could be trapped due to leakage from the primary container shall be provided with a pressure-relief device. [**55:**8.2.5.3]

**14.8.1.4** Pressure relief devices serving stationary containers shall be in accordance with the provisions of 14.8.4.1 and arranged to discharge unobstructed to the outdoors. [**55:**11.2.2.1]

**14.8.1.5** Hydrogen venting systems discharging to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*. [**55:**11.2.2.2]

**14.8.1.6 Physical Protection.** Containers, piping, valves, pressure-relief devices, regulating equipment, and other appurtenances shall be protected against physical damage and tampering. [**55:**8.6.5]

**14.8.2 Sizing. [55:8.2.5.4]**

**14.8.2.1** Pressure relief devices shall be sized in accordance with the specifications to which the container was fabricated. [**55:**8.2.5.4.1]

**14.8.2.2** The pressure relief device shall have the capacity to prevent the maximum design pressure of the container or system from being exceeded. [**55:**8.2.5.4.2]

**14.8.3 Accessibility.** Pressure relief devices shall be located such that they are accessible for inspection and repair. [**55:**8.2.5.5]

**14.8.4 Arrangement. [55:8.2.5.6]**

**14.8.4.1 Pressure Relief Devices.** Pressure relief devices shall be arranged to discharge unobstructed to the open air in such a manner as to prevent impingement of escaping gas on personnel, containers, equipment, and adjacent structures or its entrance into enclosed spaces. [**55:**8.2.5.6.1]

**14.8.5 Shutoffs Between Pressure Relief Devices and Containers. [55:8.2.5.7]**

**14.8.5.1 General.** Shutoff valves installed between pressure relief devices and containers shall be in accordance with 14.8.5. [**55:**8.2.5.7.1]

**14.8.5.2 Location.** Shutoff valves shall not be installed between pressure relief devices and containers unless the valves or their use meet the requirements of 14.8.5.3 or 14.8.5.4. [**55:**8.2.5.7.2]

**14.8.5.3 Security.** Shutoff valves shall be of a locking type, and their use shall be limited to service-related work performed by the supplier under the requirements of the ASME *Boiler and Pressure Vessel Code*. [**55:**8.2.5.7.2.1]

**14.8.5.4 Multiple Pressure Relief Devices.** Shutoff valves controlling multiple pressure relief devices on a container shall be installed so that either the type of valve installed or the arrangement provides the full required flow through the minimum number of required relief devices at all times. [**55:**8.2.5.7.2.2]

**14.8.6 Temperature Limits.** Pressure relief devices shall not be subjected to cryogenic fluid temperatures except when operating. [**55:**8.2.5.8]

**14.8.7 Signage.** Stationary containers shall be provided with a sign, placed in proximity to the primary tank pressure relief valve vent stack, that warns against spraying water on or into the vent opening. [**55:**11.2.2.3]

**14.9* Corrosion Control.**

**14.9.1 Corrosion Protection.** Aboveground piping that is subject to corrosion shall be protected against corrosion. [**55:**8.14.8.1]

**14.9.2** Belowground piping shall be protected against corrosion. [**55:**8.14.8.2]

**14.9.3*** Insulation on piping systems used to convey cryogenic fluids shall be of noncombustible material and shall be designed to have a vaportight seal in the outer covering to prevent the condensation of air and subsequent oxygen enrichment within the insulation. [**55:**11.2.3.6.1]

**14.9.4 Cathodic Protection.** Where required, cathodic protection shall be in accordance with 14.9.3. [**55:**8.14.9]

**14.9.4.1 Operation.** Where installed, cathodic protection systems shall be operated and maintained to continuously provide corrosion protection. [**55:**8.14.9.1]

**14.9.4.2 Inspection.** Container systems equipped with cathodic protection shall be inspected for the intended operation by a cathodic protection tester. [**55:**8.14.9.2.1]

**14.9.4.2.1** The cathodic protection tester shall be certified as being qualified by the National Association of Corrosion Engineers, International (NACE). [**55:**8.14.9.2.2]

**14.9.4.3 Impressed Current Systems.** Systems equipped with impressed current cathodic protection systems shall be inspected in accordance with the requirements of the design and 14.9.4.2. [**55:**8.14.9.3.1]

**14.9.4.3.1** The design limits shall be available to the AHJ upon request. [**55:**8.14.9.3.2]

**14.9.4.3.2** The system owner shall maintain records to demonstrate that the cathodic protection is in conformance with the requirements of the design:

(1) The results of inspections of the system
(2) The results of testing that has been completed [**55:**8.14.9.3.3]

**14.9.4.4** Repairs, maintenance, or replacement of a cathodic protection system shall be under the supervision of a corrosion expert certified by NACE. [**55:**8.14.9.4]

**14.9.4.4.1** The corrosion expert shall be certified by NACE as a senior corrosion technologist, a cathodic protection specialist, or a corrosion specialist or shall be a registered engineer with registration in a field that includes education and experience in corrosion control. [**55:**8.14.9.4.1]

**14.10 Stationary Pumps and Compressors.**

**14.10.1** Valves shall be installed such that each pump or compressor can be isolated for maintenance. [**55:**11.2.8.1.1]

**14.10.1.1** Where pumps or compressors are installed for operation in parallel, each discharge line shall be equipped with a check valve to prevent the backflow of liquid from one system to the other. [**55:**11.2.8.1.2]

**14.10.2** Foundations used for supporting pumps and equipment shall be designed and constructed to prevent frost heaving. [**55:**11.2.8.2.1]

**14.10.2.1** The structural aspects of such foundations shall be designed and constructed in accordance with the provisions of the building code. [**55:**11.2.8.2.2]

**14.10.3** When an emergency shutdown (ESD) is required, activation of the ESD shall shut down operation of all pumps and compressors. [**55:**11.2.8.3]

**14.10.4** Each pump or compressor shall be provided with a vent or relief device that will prevent overpressurizing of the pump under normal or upset conditions. [**55:**11.2.8.4.1]

**14.10.4.1** Pressure relief devices used to serve pumps or compression equipment shall be connected to a vent pipe system in accordance with Section 5.4. [**55:**11.2.8.4.2]

**14.10.5 Pressure Monitoring.** Pressure on each pump and compressor discharge shall be monitored by the control system. [**55:**11.2.8.5]

**14.10.5.1 Pressure Monitoring.** A means to determine pressure shall be installed on each pump and compressor discharge.

**14.10.5.2*** Pressure monitoring systems or indicating devices shall have a design safety factor of at least 1.2 times the system MAWP.

**14.10.6** Transfer piping, pumps, and compressors shall be protected from vehicular damage. [**55:**11.2.8.6]

**14.11 Vaporizers.**

**14.11.1*** Heat supplied to a liquefied hydrogen vaporizer shall be by indirect means utilizing a transfer medium. [**55:**11.2.5.1]

**14.11.2*** A low-temperature shutoff switch or valve shall be provided in the vaporizer discharge piping to prevent flow of liquefied hydrogen downstream of the vaporizer in the event that liquid is discharged from the vaporizer. [**55:**11.2.5.2]

**14.11.2.1** The discharge from pressure relief devices serving the vaporizer system shall be connected to a vent pipe system.

**14.11.2.2** Hydrogen venting systems discharging to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*. [**55:**11.2.2.2]

**14.12 $LH_2$ to $GH_2$ Systems.**

**14.12.1** The requirements of Chapter 14 shall be applicable to $LH_2$ systems only. When $LH_2$ is converted to $GH_2$, those portions of the system utilized for $GH_2$ shall be in accordance with Chapter 9.

**14.12.2** In addition to the emergency shutdown systems described in Section 14.5, the emergency shutdown system also shall shut off the liquid supply and power to the $LH_2$ transfer equipment necessary for producing $GH_2$ from $LH_2$.

**14.13 Instrumentation.**

**14.13.1 Emergency Shutdown Device (ESD).** All ESDs shall be of a type requiring that they be manually reset.

**14.13.2 Emergency Shutdown System.**

**14.13.2.1 Emergency Shutdown System.** An ESD system shall be provided at the bulk source to stop the flow of liquid when actuated. [**55:**11.2.9]

**14.13.2.2** The ESD system shall be operated by a remotely located, manually activated shutdown control located not less than 15 ft (4.5 m) from the source of supply. [**55:**11.2.9.1]

**14.13.2.3** Reactivation of the system after emergency shutdown shall require that the ESD system be manually reset. [**55:**11.2.9.2]

**14.13.2.4** The ESD system shall be identified by means of a sign. [**55:**11.2.9.3]

**14.14 Electrical Equipment.**

**14.14.1** If commercially available equipment is used, it shall meet the following requirements:

(1) Purged or ventilated in accordance with NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*
(2) Intrinsically safe
(3) Approved for Class I, Group B atmospheres

**14.14.2 Bonding and Grounding.** The $LH_2$ container and associated piping shall be electrically bonded and grounded.

**14.14.3** Electrical equipment and wiring shall be as specified by and shall be installed in accordance with *NFPA 70, National Electrical Code*, and shall meet the requirements of Class I, Group B, Division or Zone as specified in Table 14.14.3.

*Exception: Electrical equipment on internal combustion engines installed in accordance with NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.*

**14.14.4** Static protection shall be required when $LH_2$ cargo transport vehicles are unloaded, except where cargo transport vehicles or marine equipment are loaded or unloaded by conductive or nonconductive hose, flexible metallic tubing, or pipe connections through or from tight (top or bottom) outlets where both halves of metallic couplings are in contact.

**Table 14.14.3 $LH_2$ Fueling Facility Electrical Area Classification**

| Part | Location | Class I, Group B Division or Zone[a] | Extent of Classified Area[b] |
|---|---|---|---|
| A | **$LH_2$ Fueling Facility Container Area** | | |
| | Indoors[c] | | See 14.3.4. |
| | Outdoor, belowground containers | 1 | See Part E below. |
| | | 2 | See Part E below. |
| B | **$LH_2$ Process Areas Containing Pumps, Compressors, Heat Exchangers, Piping, Connections Vessels, etc.** | | |
| | Indoors | | See 14.3.4. |
| | Outdoors in open air at or above grade | 2 | Within 15 ft (4.6 m) in all directions from this equipment |
| C | **Pits, Trenches, or Sumps Located in or Adjacent to Division 1 or 2 Areas** | 1 | Entire pit, trench, or sump |
| D | **Discharge from Relief Valves, Drains** | 1 | Within 5 ft (1.5 m) from point of discharge |
| | | 2 | Beyond 5 ft (1.5 m) but within 15 ft (4.6 m) in all directions from point of discharge |
| E | **Vehicle/Cargo Transfer Area** | | |
| | Indoors with adequate ventilation[d] | 1 | Within 3 ft (1 m) of connection |
| | Points where connections to the hydrogen system are regularly made and disconnected[e] | 2 | Between 3 ft (1 m) and 25 ft (7.6 m) of connection |
| | Outdoors in open air at or above grade | 1 | Within 3 ft (1 m) of connection |
| | Points where connections to the hydrogen system are regularly made and disconnected[e] | 2 | Between 3 ft (1 m) and 25 ft (7.6 m) of connection |

[a]See Article 500, "Hazardous (Classified) Locations," in NFPA 70, *National Electrical Code*, for definitions of classes, groups, and divisions.
[b]The classified area not to extend beyond an unpierced wall, roof, or solid vaportight partition.
[c]Indoor fueling with $LH_2$ is not permitted. See 14.3.4.
[d]Ventilation is considered adequate when provided in accordance with the provisions of this code.
[e][**55:**11.2.6]

**14.14.5** Each interface between a flammable fluid system and an electrical conduit or wiring system, including process instrumentation connections, integral valve operators, foundation heating coils, canned pumps, and blowers, shall be sealed or isolated to prevent the passage of flammable fluids or gases to another portion of the electrical installation.

**14.14.6** Each seal, barrier, or other means used to comply with 14.14.7 shall be designed to prevent the passage of flammable fluids or gases through the conduit, stranded conductors, and cables.

**14.14.7** A primary seal shall be provided between the flammable fluid system and the electrical conduit wiring system. If the failure of the primary seal would allow the passage of flammable fluids to another portion of the conduit or wiring system, an additional approved seal, barrier, or other means shall be provided to prevent the passage of the flammable fluid beyond the additional device or means in the event that the primary seal fails.

**14.14.7.1** Each primary seal shall be designed to withstand the maximum allowable service conditions to which it is expected to be exposed.

**14.14.7.2** Each additional seal or barrier and interconnecting enclosure shall meet the pressure and temperature requirements of the condition to which it could be exposed in the event of failure of the primary seal, unless other approved means are provided to accomplish this purpose.

**14.14.8** Unless specifically designed and approved for the purpose, the seals specified in 14.14.7 through 14.14.9 are not intended to replace the conduit seals required by 501.15(A) through 501.15(D) of *NFPA 70, National Electrical Code*.

**14.14.9** Where primary seals are installed, drains, vents, or other devices shall be provided for monitoring purposes to detect flammable fluids and leakage.

**14.15 Maintenance.**

**14.15.1** Maintenance shall be performed based on the OEM component manufacturer's recommendations and not less than every 6 months. Maintenance records shall be made available upon demand.

**14.15.1.1** The refueling site shall have a written maintenance program or process safety analysis program in place. A written record of the required maintenance shall be maintained by the operator.

**14.15.1.2** Records of required maintenance shall be provided to the authority having jurisdiction upon request.

**14.15.1.3** Fueling facilities shall be free within 25 ft (7.6 m) from rubbish, debris, weeds, and other material that present a fire hazard.

**14.15.1.4** Grass areas on the $LH_2$ fueling facility grounds shall be maintained in a manner that does not present a fire hazard.

**14.15.2** A preventive maintenance program shall be in place and shall include a schedule of written procedures for test and inspection of facility systems and equipment.

**14.15.3** Each component in service, including its support system, shall be maintained in a condition that is compatible with its operation or safety purpose by repair, replacement, or other means.

**14.15.4** If a safety device is taken out of service for maintenance, the component being served by the device shall be taken out of service unless the same safety function is provided by an alternative means.

**14.15.5** If the inadvertent operation of a component taken out of service could cause a hazardous condition, the system shall be shut down until the component is replaced.

**14.15.5.1** All maintenance and servicing shall be done in accordance with 29 CFR 1910 for energy control.

• **14.15.6** Safety, gas detection, and fire protection equipment shall be tested or inspected at intervals not to exceed 6 months.

**14.15.7** Maintenance activities on fire control equipment shall be scheduled so that a minimum of equipment is taken out of service at any one time and fire prevention safety is not compromised.

**14.15.8** Fire department access to outdoor storage areas where bulk systems are installed shall be provided and maintained in accordance with NFPA 1, *Fire Code*. [**55:**11.3.2.5]

**14.16 Out-of-Service Stationary Bulk Gas Systems.** Installed bulk gas systems no longer in use that remain in place shall be removed from service by the supplier or shall be safeguarded in accordance with the following:

(1) Required permits shall be maintained.
(2) The source and fill valves shall be closed to prevent the intrusion of air or moisture.
(3) Cylinders, containers, and tanks shall be maintained in a serviceable condition.
(4) Security shall be maintained in accordance with 9.2.5.[**55:**4.4]

**14.17 Refueling from Transport Vehicles.** Mobile refueling vehicles, temporary trailers (with or without tractors), and other means of providing vehicle refueling or onsite storage shall be subject to the same requirements as a permanent refueling or storage installation.

**14.17.1** The dispensing of $LH_2$ in the open from a transport vehicle to a motor vehicle located at a separate fleet fueling area in connection with commercial, industrial, governmental, or manufacturing establishments and intended for fueling vehicles used in connection with their businesses shall be permitted if all the requirements of 14.17.1 through 14.17.9 have been met.

**14.17.2** The AHJ shall be notified before commencing operations, and permitting sought if required, under Section 14.17.

**14.17.3** The transport vehicle shall comply with U.S. DOT requirements for the transportation of $LH_2$.

**14.17.4** Smoking materials, including matches, lighters, and other sources of ignition, including torches, shall not be used within 20 ft (6.1 m) of the dispensing of $LH_2$ in the open from a transport vehicle to a motor vehicle.

**14.17.5** Each area where dispensing of $LH_2$ in the open from a transport vehicle to a motor vehicle shall be provided with one or more listed fire extinguishers that have a minimum capability of 40-B:C.

**14.17.5.1** The fire extinguishers shall be within the dispensing operation.

**14.17.5.2** Fire extinguishers shall be inspected and maintained under NFPA 10, *Standard for Portable Fire Extinguishers*.

**14.17.6** Transport vehicle brakes shall be set, and chock blocks shall be in place.

**14.17.7** Persons performing dispensing operations shall be qualified to deliver and dispense $LH_2$ fuels. Operators of transport vehicles used for mobile fueling operations shall have access on site or be in possession of an emergency communications device to notify the authorities in the event of an emergency.

**14.17.8** The transport vehicles shall be positioned with respect to vehicles being fueled to prevent traffic from driving over the delivery hose and between the transport vehicle and the motor vehicle being fueled. The dispensing hose shall be properly placed on an approved reel or in an approved compartment before the transport vehicle is moved.

**14.17.9 Additional Requirements.** The transfer area shall meet the requirements of 9.13.3.

## Chapter 15 LNG Fire Protection

**15.1 Application.** This chapter applies to LNG fire protection, personnel safety, security, LNG fueling facilities and training for LNG vehicles, and warning signs.

**15.2 Fire Protection, Safety, and Security.**

**15.2.1** Fire protection shall be provided for all LNG fueling facilities.

**15.2.1.1** The extent of such protection shall be determined by an evaluation based on sound fire protection and methane detection engineering principles, analysis of local conditions, vehicle operations, hazards within the facility, exposure to or from other property, and the size of the LNG containers.

**15.2.1.2** Guidance factors for making such an evaluation include the following:

(1) Type, quantity, and location of equipment necessary for the detection and control of fires, leaks, and spills of LNG, flammable refrigerants, and flammable gases or liquids
(2) Methods necessary for the protection of vehicles, equipment, and structures from the effects of fire exposure
(3) Equipment and processes to be incorporated within the ESD system
(4) Type, quantity, and location of sensors necessary to initiate automatic operation of the ESD system
(5) Availability and duties of individual facility personnel and the availability of external response personnel during an emergency
(6) Protective equipment and special training required by personnel for emergency duties

**15.2.2** The planning for emergency response measures shall be coordinated with the appropriate local emergency agencies.

**15.2.3*** An emergency response plan shall be prepared to cover the potential emergency conditions that can develop.

**15.2.4** The fire protection and methane detection equipment shall be maintained in accordance with the manufacturer's instructions and the AHJ.

**15.3 Ignition Source Control.**

**15.3.1** Smoking and ignition sources shall be prohibited, except in accordance with 15.3.2.

**15.3.2** Welding, oxygen–acetylene cutting, and similar operations shall be conducted only when and where specifically authorized and in accordance with the provisions of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

**15.3.3** Vehicles and other mobile equipment that constitute a potential ignition source shall be prohibited except where specifically authorized and under constant supervision or when at a transfer point specifically for the purpose of transfer.

**15.3.4** Vehicles delivering LNG to the facility or vehicles being fueled from the facility shall not be considered sources of ignition.

**15.3.5** Vehicles containing fuel-fired equipment (e.g., recreational vehicles and catering trucks) shall be considered a source of ignition unless all sources of ignition such as pilot lights, electric igniters, burners, electrical appliances, and engines located on the vehicle being refueled are shut off completely before entering an area where ignition sources are prohibited.

**15.4* Personnel Safety and Training.**

**15.4.1 Qualification of Personnel.** All persons employed in handling and dispensing LNG shall be trained in proper handling and operating duties and procedures.

**15.4.2** Protective clothing, face shield/goggles, and gloves shall be provided for all operators dispensing and handling LNG.

*Exception: Where equipment is demonstrated to operate without release of LNG or cold gases.*

**15.4.3*** Training shall be conducted upon employment and every 2 years thereafter.

**15.4.4** Training shall include the following:

(1) Information on the nature, properties, and hazards of LNG in both the liquid and gaseous phases
(2) Specific instructions on the facility equipment to be used
(3) Information on materials that are compatible for use with LNG
(4) Use and care of protective equipment and clothing
(5) Standard first aid and self-aid instruction
(6) Response to emergency situations such as fires, leaks, and spills
(7) Good housekeeping practices
(8) Emergency response plan as required in 15.2.3
(9) Evacuation and fire drills

**15.4.5** Each operator shall provide and implement a written plan of initial training to instruct all designated operating and supervisory personnel in the characteristics and hazards of LNG used or handled at the site, including low LNG temperature, flammability of mixtures with air, odorless vapor, boil-off characteristics, and reaction to water and water spray; the potential hazards involved in operating activities; and how to carry out the emergency procedures that relate to personnel functions and to provide detailed instructions on mobile LNG operations.

**15.5 Security.**

**15.5.1** The LNG fueling facility shall provide protection to minimize unauthorized access and damage to the facility.

**15.5.2** Security procedures shall be posted in readily visible areas near the fueling facility.

**15.6 Hazard Detection.** Gas leak detection and fire detection shall be installed based on the evaluation required in 15.2.1.1.

**15.7 Parking of LNG Vehicles.** LNG vehicles shall be permitted to be parked indoors, provided such facilities or vehicles are equipped to prevent an accumulation of gas in a combustible mixture or the onboard fuel storage tank and fuel system are drained of LNG and purged with inert gas or depressurized.

**15.8 Warning Signs.** For all LNG fueling facilities, the following signs shall be displayed in bright red letters on a white background, with letters not less than 6 in. (152 mm) high:

(1) "No Smoking" or "No Smoking within 25 ft (7.6 m)"
(2) "Stop Motor"
(3) "No Open Flames Permitted"
(4) "Cryogenic Liquid or Cold Gas"
(5) "Flammable Gas"
(6) "Unodorized Gas"

## Chapter 16 Installation Requirements for ASME Tanks for LNG

**16.1* Application.** This chapter provides requirements for the installation, design, fabrication, and siting of LNG containers of 70,000 gal (265,000 L) capacity and less and their associated equipment for use in applications such as vehicle refueling facilities and dedicated fuel supply for commercial and industrial applications, which are designed and constructed in accordance with ASME *Boiler and Pressure Vessel Code*.

**16.2 General.** Storage and transfer equipment at unattended facilities shall be secured to prevent tampering. [**59A**:13.2.3]

**16.3 Containers.**

**16.3.1** All piping that is part of an 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 ANSI/ASME B31.3, *Process Piping*. [**59A:**13.3.1]

**16.3.2** Compliance with 16.3.1 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." [**59A:**13.3.2]

**16.3.3** Internal piping between the inner tank and the outer tank within the insulation space shall be designed for the maximum allowable working pressure of the inner tank, with allowance for the thermal stresses. [**59A:**13.3.3]

**16.3.4** Bellows shall not be permitted within the insulation space. [**59A:**13.3.4]

**16.3.5** Containers shall be double-walled, with the inner tank holding LNG surrounded by insulation contained within the outer tank. [**59A:**13.3.5]

**16.3.6** The inner tank shall be of welded construction and in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, and shall be ASME-stamped and registered with the

National Board of Boiler and Pressure Vessel Inspectors or other agency that registers pressure vessels. [**59A:**13.3.6]

**16.3.7** The inner tank supports shall be designed for shipping, seismic, and operating loads. [**59A:**13.3.7]

**16.3.8** The support system to accommodate the expansion and contraction of the inner tank shall be designed so that the resulting stresses imparted to the inner and outer tanks are within allowable limits. [**59A:**13.3.8]

**16.3.9** The outer tank shall be of welded construction using any of the following materials:

(1) Any of the carbon steels in Section VIII, Part UCS of the ASME *Boiler and Pressure Vessel Code* at temperatures at or above the minimum allowable use temperature in Table 1A of the ASME *Boiler and Pressure Vessel Code,* Section II, Part D
(2) Materials with a melting point below 2000°F (1093°C) where the container is buried or mounded [**59A:**13.3.9]

**16.3.10** Where vacuum insulation is used, the outer tank shall be designed by either of the following:

(1) The ASME *Boiler and Pressure Vessel Code*, Section VIII, Parts UG-28, UG-29, UG-30, and UG-33, using an external pressure of not less than 15 psi (100 kPa)
(2) Paragraph 3.6.2 of CGA 341, *Standard for Insulated Cargo Tank Specification for Cryogenic Liquids* [**59A:**13.3.10]

**16.3.11** Heads and spherical outer tanks that are formed in segments and assembled by welding shall be designed in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, Parts UG-28, UG-29, UG-30, and UG-33, using an external pressure of 15 psi (100 kPa). [**59A:**13.3.11]

**16.3.12** Any portion of the outer tank surface that could be exposed to LNG temperatures shall be suitable for such temperatures or protected from the effects of such exposure.

**16.3.13** The outer tank shall be equipped with a relief device or other device to release internal pressure. [**59A:**13.3.12]

**16.3.13.1** The discharge area shall be at least 0.00024 in.$^2$/lb (0.34 mm$^2$/kg) of the water capacity of the inner tank, but the area shall not exceed 300 in.$^2$ (0.2 m$^2$). [**59A:**13.3.12.1]

**16.3.13.2** The relief device shall function at a pressure not exceeding the internal design pressure of the outer tank, the external design pressure of the inner tank, or 25 psi (172 kPa), whichever is least. [**59A:**13.3.12.2]

**16.3.14** Thermal barriers shall be provided to prevent the outer tank from going below its design temperature. [**59A:**13.3.13]

**16.3.15 Container Seismic Design.** Shop-built containers designed and constructed in accordance with the ASME *Boiler and Pressure Vessel Code*, and their support system, shall be designed for the dynamic forces outlined in *NFPA 5000, Building Construction and Safety Code,* as follows:

(1) Horizontal force:

$$V = Z_c \times W$$

where:
$Z_c$ = seismic coefficient from Table 16.3.15
$W$ = total weight of the container and its contents

(2) Design vertical force:

$$P = \frac{2}{3} \times Z_c \times W$$

where:
$Z_c$ = seismic coefficient from Table 16.3.15
$W$ = total weight of the container and its contents

(3) The seismic coefficient shall be permitted to be calculated in accordance with the nonbuilding structures provisions of the ICBO *Uniform Building Code,* using an Importance Factor *I* of 1.25. The minimum coefficient from Table 16.3.15 shall be used if the natural period of vibration *T* is less than 0.3 second.

**Table 16.3.15 Seismic Coefficient for Shop-Built Containers**

| Zone | Coefficient ($Z_c$) | Effective Peak Horizontal Acceleration (EPA) (% G) |
|---|---|---|
| 1 | 0.09 | 7.5 |
| 2A | 0.16 | 16.0 |
| 2B | 0.23 | 20.0 |
| 3 | 0.34 | 30.0 |
| 4 | 0.46 | 40.0 |

Notes:
(1) From UBC Seismic Zone Map, *Uniform Building Code,* 1997.
(2) The EPA (% G) is equivalent to the seismic zones and can be used to determine $Z_c$ in areas where seismic zones are not available.

**16.3.15.1** The container and its supports shall be designed for the resultant seismic forces in combination with the operating loads, using the allowable stresses increase shown in the code or standard used to design the container or its supports. [**59A:**13.3.14.3]

**16.3.15.2** The requirements of 16.3.15 shall apply to ASME containers built prior to July 1, 1996, when reinstalled. [**59A:**13.3.14.4]

**16.3.16** Each container shall be identified by the attachment of a nameplate(s) in an accessible location marked with the information required by the ASME *Boiler and Pressure Vessel Code* and the following:

(1) Builder's name and date container was built
(2) Nominal liquid capacity
(3) Design pressure at the top of the container
(4) Maximum permitted liquid density
(5) Maximum filling level
(6) Minimum design temperature [**59A:**13.3.15]

**16.3.17** All penetrations of storage containers shall be identified. [**59A:**13.3.16]

**16.3.18** Markings shall be legible under all conditions.

**16.4 Container Foundations and Supports.**

**16.4.1** LNG container foundations shall be designed and constructed in accordance with recognized structural and geotechnical engineering practices including provisions for seismic loading as specified in 16.3.15.

**16.4.1.1** Saddles and legs shall be designed in accordance with recognized structural engineering practice, including for shipping loads, erection loads, wind loads, and thermal loads.

**16.4.1.2** Foundations and supports in excess of 18 in. (460 mm) above grade shall be protected to have a fire resistance rating of not less than 2 hours.

**16.4.1.3** If insulation is used to achieve this requirement, it shall be resistant to dislodgment by fire hose streams.

**16.4.2** Where the LNG storage container is installed in an area subject to flooding, the container shall be secured in a manner that will prevent release of LNG or flotation of the container in the event of a flood.

**16.5 Container Installation.**

**16.5.1** The minimum separation distance between LNG containers and exposures shall be in accordance with Table 16.5.1.

*Exception: With the approval of the authority having jurisdiction, such equipment shall be permitted to be located at a lesser distance from buildings or walls constructed of concrete or masonry, but at least 10 ft (3.0 m) from any building openings.*

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

**16.5.3** Where heating systems are used, they shall be installed such that any heating element or temperature sensor used for control can be replaced. [**59A:**13.6.5]

**16.5.4** All buried or mounded components in contact with the soil shall be constructed from material resistant to soil corrosion or protected to minimize corrosion. [**59A:**13.6.6]

**16.5.5** A clear space of at least 3 ft (0.9 m) shall be provided for access to all isolation valves serving multiple containers. [**59A:**13.6.7]

**16.5.6** LNG containers of greater than 40 gal (151 L) capacity shall not be located in buildings. LNG containers of any size shall not be permanently installed in buildings.

*Exception: LNG vehicle fuel tanks permanently installed on vehicles.*

**16.6 Product Retention Valves.**

**16.6.1** All liquid and vapor connections, except relief valve and instrument connections, shall be equipped with automatic failsafe product retention valves. [**59A:**13.7.1]

**16.6.2** Automatic failsafe product retention valves shall be designed to close on the occurrence of any of the following conditions:

(1) Fire detection or exposure
(2) Uncontrolled flow of LNG from the container
(3) Manual operation from a local and remote location [**59A:**13.7.2]

**16.6.3** Connections used only for flow into the container shall be equipped with either two backflow valves, in series, or an automatic failsafe product retention valve. [**59A:**13.7.3]

**16.6.4** Appurtenances shall be installed as close to the container as practical so that a break resulting from external strain shall occur on the piping side of the appurtenance while maintaining intact the valve and piping on the container side of the appurtenance. [**59A:**13.7.4]

**16.7 Inspection.**

**16.7.1** Prior to initial operation, containers shall be inspected to ensure compliance with the engineering design and material, fabrication, assembly, and test provisions of the chapter. The operator shall be responsible for this inspection.

**16.7.2** Performance of any part of the inspection shall be permitted to be delegated to inspectors who are employees of the operator's own organization, an engineering or scientific organization, or a recognized insurance or inspection company. Inspectors shall be qualified in accordance with the code or standard applicable to the container and as specified in NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

**16.8 Testing and Purging of LNG Containers.**

**16.8.1** LNG containers shall be leak-tested in accordance with the governing construction code or standard. All leaks shall be repaired.

**16.8.1.1** Testing shall be performed in accordance with the ASME *Boiler and Pressure Vessel Code*.

**16.8.1.2** Shop-built containers shall be pressure tested by the manufacturer prior to shipment to the installation site. The inner tank shall be tested in accordance with the ASME *Boiler and Pressure Vessel Code*. The outer tank shall be leak-tested. Piping shall be tested in accordance with Chapter 9 of NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

**Table 16.5.1 Distances from Impounding Areas to Buildings, Property Lines**

| Individual Container Water Capacity | | Minimum Distance from Edge of Impoundment or Container Drainage System to Buildings, Property Lines | | 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 | 3.0 | 3 | 1.0 |
| 501–2,000 | 1.9–7.6 | 15 | 4.6 | 5 | 1.5 |
| 2,001–15,000 | 7.6–56.8 | 25 | 7.6 | 5 | 1.5 |
| 15,001–30,000 | 56.8–114 | 50 | 15.0 | 5 | 1.5 |
| 30,001–70,000 | 114–265 | 75 | 23.0 | ¼ of the sum of the diameters of adjacent containers [5 ft (1.5 m) min.] | |

**16.8.1.3** Containers and associated piping shall be leak tested prior to filling with LNG. [**59A:**13.12.1]

**16.8.1.4** Containers shall be shipped under a minimum internal pressure of 10 psi (69 kPa) inert gas. [**59A:**13.11]

**16.8.2** After acceptance tests are completed, there shall be no field welding on the LNG containers. [**59A:**13.12.2]

**16.8.3** Retesting by a method appropriate to the repair or modification shall be required only where the repair or modification is of such a nature that a retest actually tests the element affected and is necessary to demonstrate the adequacy of the repair or modification. [**59A:**13.13.3]

**16.8.3.1** Field welding shall be done only on saddle plates or brackets provided for the purpose. [**59A:**13.13.1]

**16.8.3.2** Where repairs or modifications incorporating welding are required, they shall comply with the code or standard under which the container was fabricated. [**59A:**13.13.2]

**16.8.4 Container Purging Procedures.** Prior to placing an LNG container into or out of service, the container shall be inerted by an approved inerting procedure.

**16.9 Piping.**

**16.9.1** All piping that is part of an LNG container and facility associated with the container for handling cryogenic liquid or flammable fluid shall be in accordance with ANSI/ASME B31.3, *Process Piping*.

**16.9.2** Type F piping, spiral-welded piping, and furnace butt-welded steel products shall not be permitted.

**16.9.3** All welding or brazing shall be performed by personnel qualified to the requirements of ASME *Boiler and Pressure Vessel Code*, Section IX.

**16.9.4** Oxygen–fuel gas welding shall not be permitted.

**16.9.5** Brazing filler metal shall have a melting point exceeding 1000°F (538°C).

**16.9.6** All piping and tubing shall be austenitic stainless steel for all services below −20°F (−29°C).

**16.9.7** All piping and piping components shall have a minimum melting point of 1500°F (816°C).

*Exception No. 1: Gaskets, seats, and packing.*

*Exception No. 2: Aluminum shall be permitted to be used downstream of a product retention valve in vaporizer service.*

**16.9.8** Compression-type couplings shall not be used where they will be subjected to temperatures below −20°F (−29°C) unless they meet the requirements of Section 318 of ANSI/ASME B31.3, *Process Piping*.

**16.9.9** Stab-in branch connections shall not be permitted.

**16.9.10** Extended bonnet valves shall be used for all cryogenic liquid service. The valves shall be installed such that the bonnet is at an angle of not more than 45 degrees from the upright vertical position.

**16.9.11** The level of inspection of piping shall be specified. [**59A:**13.14.2]

**16.10 Container Instrumentation.**

**16.10.1 General.** Instrumentation for LNG facilities shall be designed so that, in the event of power or instrument air failure, the system will go into a failsafe condition that can be maintained until the operators can take action to reactivate or secure the system. [**59A:**13.15.1]

**16.10.2 Level Gauging.** LNG containers shall be equipped with two independent liquid level devices. One shall be a fixed-length dip tube, and the other shall be a continuous indication from full to empty and shall be maintainable or replaceable without taking the container out of service.

*Exception: Containers smaller than 1000 gal (3.8 $m^3$) shall be permitted to be equipped with a fixed-length dip tube only.*

**16.10.3 Pressure Gauging.**

**16.10.3.1** Each container shall be equipped with a pressure gauge connected to the container at a point above the maximum liquid level that has a permanent mark indicating the maximum allowable working pressure (MAWP) of the container. [**59A:**13.15.3.1]

**16.10.3.2** Vacuum-jacketed equipment shall be equipped with instruments or connections for checking the pressure in the annular space. [**59A:**13.15.3.2]

**16.11 Pressure Control.**

**16.11.1** Safety relief valves shall be provided to maintain the internal pressure of LNG containers in accordance with the ASME *Boiler and Pressure Vessel Code*, including under conditions resulting from operational upset, vapor displacement, and flash vaporization during filling; flash vaporization resulting from pump recirculation; and fire.

**16.11.1.1** Pressure relief valves shall communicate directly with the atmosphere. [**59A:**13.15.4]

**16.11.1.2** The valves shall be sized in accordance with 7.9.5 of NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, or CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Compressed Gas Storage Containers*. [**59A:**13.15.5].

**16.11.2** Each pressure- and vacuum-safety relief valve for LNG containers shall be able to be isolated from the container for maintenance or other purposes by means of a manual fully-opening stop valve.

**16.11.2.1** The stop valve shall be lockable or sealable in the fully open position. [**59A:**13.15.6.1]

**16.11.2.2** Sufficient pressure and vacuum relief valves shall be installed on the LNG container to allow each relief valve to be isolated individually for testing or maintenance while maintaining the full capacities determined in 7.9.5 of NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

**16.11.2.3** When only one pressure relief valve is required, either a full-port-opening three-way valve used under the relief valve and its required spare or individual valves beneath each pressure relief valve shall be installed. [**59A:**13.15.6.3]

**16.11.3** Stop valves under individual safety relief valves shall be locked or sealed when opened and shall not be opened or closed except by an authorized person. [**59A:**13.15.7]

**16.11.4** 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, if arranged to discharge directly into the atmosphere, shall discharge vertically upward. [**59A:**13.15.8]

# Chapter 17 LNG and CNG on Commercial Marine Vessels and Pleasure Craft

## 17.1 Application.

**17.1.1** This chapter applies to all commercial marine vessels and pleasure craft operating on LNG or CNG, including new and retrofit construction.

**17.1.2** Chapters 11, 12, and 15 of this code apply to commercial marine vessels and pleasure craft operating on LNG.

**17.1.3** The requirements in 11.12.1.2, 11.12.1.4, 11.12.1.4.1, 11.12.1.7, 11.12.1.8, 11.12.2, 11.12.3.4, 11.12.3.5, and 11.12.8 and all subparts are not applicable to commercial marine vessels and pleasure craft operating on LNG.

## 17.2 Installation of Fuel Supply Containers.

**17.2.1** Fuel supply containers on marine vessels shall be permitted to be located on the weather deck, above accommodation and service space, or below deck adjacent to accommodation and service space, provided all connections to the containers are external to or sealed and vented from these spaces.

**17.2.1.1** Containers on the weather deck shall be protected with a housing to prevent damage that can occur due to loading, unloading, direct sunlight, and the general use of the vessel.

**17.2.1.2** The housing shall be installed to prevent contact of the housing with the container(s) and to prevent entrapment of materials that could damage the container(s) or its coating.

**17.2.1.3** The shelter(s) for storing the containers on the weather deck shall be an enclosure that is constructed of noncombustible or limited-combustible materials and has at least one side predominantly open, facing outboard, and a roof designed for ventilation and dispersal of escaped gas.

**17.2.2 Position.**

**17.2.2.1** Each fuel supply container shall be mounted in a location that minimizes damage from collision.

**17.2.2.2** No part of a container or its appurtenances on the weather deck shall protrude beyond the sides or top of the vessel at the point where it is installed.

**17.2.2.3** No portion of a fuel supply container or container appurtenances shall protrude beyond the bow or the stern of the vessel.

**17.2.2.4** Container valves shall be protected from physical damage using the vessel structure, valve protectors, or a suitable metal shield.

**17.2.3** Each container cradle shall be secured to the vessel frame, either above or below or both, to prevent damage from slippage, loosening, or rotation using a method capable of withstanding a static force in the six principal directions of at least four times the weight of the fully pressurized container(s) or greater as is appropriate for the vessel.

**17.2.4** Each fuel supply container in the rack shall be secured to its cradle in such a manner that it is capable of withstanding a static force applied in the six principal directions of four times the weight of the fully pressurized container with a maximum displacement of 0.5 in. (13 mm).

**17.2.4.1** Metal clamping bands and their supports shall not be in direct contact with a container.

**17.2.4.2** A resilient gasket that does not retain water shall be installed between the clamping bands and their supports and the container.

**17.2.5** The container weight shall not be supported by outlet valves, manifolds, or other fuel connections.

**17.2.6** Fuel supply containers located less than 18 in. (460 mm) from the exhaust system shall be shielded against direct heat.

**17.2.7** The mounting system shall minimize fretting corrosion between the container and the mounting system.

**17.2.8** Fuel supply containers shall not be installed so as to adversely affect the balance of the marine vessel.

**17.2.9** A container, where located in a below-deck tank room or tank compartment that is capable of accumulating natural gas, shall be installed so that the pressure relief device for the protection of the container is installed in the same space as the container and the discharge from the pressure relief device is as follows:

(1) Vented to the outside through a metallic tube (vent mast) or hose no smaller than the outlet diameter of the relief device, secured at 12 in. (305 mm) intervals where the tube exceeds 24 in. (610 mm) in length and having a minimum burst pressure of at least one and one-half times the service pressure of the container at 400°F (204°C)
(2) Located so that the vent opening is not blocked by debris or otherwise affected by the elements

**17.2.10** An LNG container located in a below-deck tank room or compartment shall be enclosed in a space constructed of materials approved for cryogenic service.

**17.2.11** The enclosure shall be capable of containing leakage from the fuel tank.

## 17.3 Installation of Pressure Gauges.

**17.3.1** A pressure gauge located within the wheelhouse (bridge) or accommodation or service space shall be installed in such a manner that no gas flows through the gauge in the event of failure.

**17.3.2** A pressure gauge installed in the engine room/compartment, fuel tank room/compartment, or other gas-dangerous space shall be equipped with a limiting orifice, a shatterproof dial lens, and a body relief.

## 17.4 Labeling.

**17.4.1** Each marine vessel or pleasure craft shall be identified with weather-resistant, diamond-shaped labels located on an exterior vertical surface or near-vertical surface, at a location, as near to eye level as possible, where the vessel is routinely boarded, both port and starboard.

**17.4.2** Depending on the size of the vessel, other labels shall be placed at logical locations to alert persons not familiar with the vessel, such as fire fighters or service personnel, as to the nature of the vessel.

**17.4.3** The label shall be a minimum of 4.72 in. (120 mm) long by 3.27 in. (83 mm) high.

**17.4.4** The marking shall consist of a border and the letters “CNG” or “LNG” as appropriate [1 in. (25 mm) minimum height centered in the diamond] of silver or white reflective luminous material on a blue background.

**17.5 Operation.**

**17.5.1** Where natural gas is being transferred to or from a marine vessel, the engines shall be turned off.

*Exception: Engine operation shall be permitted when necessary to hold the vessel in position while refueling or when, in the opinion of the master, the safety of the vessel is at issue. The master shall be permitted to also elect to operate generators during refueling.*

**17.5.2** A warning sign with the words "Stop Engines," "No Smoking," and "Flammable Gas" shall be posted at dispensing stations and compressor areas where it is possible to secure a vessel to a dock or anchor buoys.

**17.5.2.1** Otherwise, a sign shall be posted with the words "No Smoking" and "Flammable Gas."

**17.5.2.2** The location of signs shall be determined by local conditions, but the lettering shall be large enough to be visible and legible from each point of transfer.

**17.6 Fire Protection for Vessels.**

**17.6.1** Fire protection for vessels shall be in accordance with NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft.*

**17.6.2** The following paragraphs of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, shall be revised as follows when used for LNG fuel systems:

(1) Paragraph 4.5.3.5(2) of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, covering blower intake duct openings, shall be revised to change the blower inlet duct opening location from the lower one-third of the compartment to the upper one-third of the compartment.
(2) Subsection 6.1.1 of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, general requirements for engine exhaust systems, shall be revised by expanding the exception to make the paragraph not applicable to exhaust cooling water in addition to engine-cooling water.

**17.7* Installation of Powered Ventilation.**

**17.7.1** Blower(s) capacity shall be selected in accordance with the blower capacity curve in Figure 4.5.3.1 of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft.* More than one blower shall be permitted.

**17.7.2** As installed, the blower system(s) shall exhaust air from the boat at a rate in accordance with the system performance curve in Figure 4.5.3.1 of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, when the engine is not operating and the blower is operating at the electrical system's nominal voltage.

**17.7.3** Blowers shall be mounted above the normal level of accumulated bilge water.

*Exception: Submersible blower motors.*

**17.7.4** Blowers shall be installed with ducts having intake openings that are as follows:

(1) Permanently secured
(2) Located in the upper one-third of the compartment
(3) Located above the normal level of accumulated bilge water
(4) Located as near below the engine(s) that they serve as practicable

**17.7.5** Electrical wiring shall be installed in accordance with Chapter 9 or Chapter 10 of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft.*

**17.7.6** Each boat that requires a powered ventilation system shall display a warning label that provides the information that follows, located in plain view of the operator, and located as close as practicable to each ignition switch (including auxiliary equipment).

**17.7.7** The powered ventilation label shall read as follows:

**WARNING:** Gas Can Explode
Before Starting Engine:
1. Check Engine Compartment for Gasoline, Gas, or Vapors
2. Operate Blower for 4 Minutes

**17.7.8*** Exhaust systems shall conform to the following:

(1) Be gastight to hull interiors
(2) Have all connections accessible
(3) Be supported to minimize failure from vibration, shock, expansion, and contraction
(4) Have no threaded fittings into nonmetallic exhaust system components
(5) Have no discharge from other devices into the exhaust

*Exception: Engine-cooling water or exhaust-cooling water.*

**17.7.9** In case of conflict, this code shall have precedence over the requirements of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft.*

**17.8 Fueling Systems.**

**17.8.1** LNG fueling systems shall be in accordance with NFPA 303, *Fire Protection Standard for Marinas and Boatyards.*

**17.8.2** The following paragraphs of NFPA 303, *Fire Protection Standard for Marinas and Boatyards*, shall be revised as follows when using LNG as a fuel:

(1) Subsection 8.3.2 of NFPA 303, covering all boat fueling operations, shall be revised by adding reference to NFPA 52, *Vehicular Gaseous Fuel Systems Code.*
(2) Subsection 8.3.5 of NFPA 303, covering securing of fuel storage tanks, shall be revised by adding reference to NFPA 52.
(3) Subsection 8.3.10 of NFPA 303, covering dispensing of fuels, shall be revised by adding reference to NFPA 52.

**17.9* Storage and Handling of Fuels.**

**17.9.1** The fueling station shall be located to minimize the exposure of all other plant facilities.

**17.9.2** All fueling stations shall be accessible by boat without entering or passing through the main berthing area.

*Exception: Where inside fueling stations are made necessary by prevailing sea conditions (wake, surge, tide, etc.), such stations shall be located near an exit by water from the berthing area or at some other location from which, in case of fire aboard a boat alongside, the stricken craft can be quickly removed without endangering other boats nearby.*

**17.9.3** All boat fueling operations shall be carefully accomplished in accordance with NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, and this code, at the fueling station or other specifically designated remote location.

**17.9.4** No tank barge or other fuel supply boat shall be permitted within the berthing area.

**17.9.5** Outside berths and connections shall be provided for the use of tank barges or fuel supply boats.

**17.9.6** Fuel storage tanks shall be installed in accordance with NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*, and this code.

**17.9.7** Fuel storage tanks shall be securely anchored where they are located subject to flooding or tidal conditions, and the applicable precautions outlined in Chapter 4 of NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*, shall be observed.

**17.9.8** Fuel storage tanks and pumps, other than those integral to approved dispensing units supplying gasoline or Class I or Class II flammable liquids at marine service stations, shall be located only on shore or, with the express permission of the authority having jurisdiction, on a pier of solid-fill type.

**17.9.9** Approved dispensing units with or without integral pumps shall be permitted to be located on shore, on piers of solid-fill type, or on open piers, wharves, or floating piers.

• **17.9.10** Pumps that are not a part of the dispensing unit shall be located adjacent to the tanks.

**17.9.11** Fuel pipelines shall be installed in accordance with the provisions of NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*.

**17.9.12** Dispensing units for transferring fuels from storage tanks shall be in accordance with the provisions of NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*, and this code.

• **17.9.12.1** In the construction of the fuel hose assembly, provision shall be made so the fuel delivery nozzle is properly bonded to the shore electric grounding facilities.

**17.9.13** Gasoline and other flammable liquids stored in drums or cans shall be kept separate from other plant facilities and stored and dispensed in accordance with applicable requirements of NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*.

• **17.10 Marine Service Stations.**

**17.10.1** Marine service stations for fueling natural gas–powered marine vessels shall be in accordance with NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*.

**17.11 Engine Rooms or Compartments.**

**17.11.1** In engine rooms and engine compartments, all fuel lines shall be mounted in the overhead to provide the shortest route for leaking gas to flow to the exterior.

**17.11.2** The pressure in the fuel lines passing through the engine room or engine compartment shall not exceed the pressure required to operate the engines.

**17.11.3** All pressure regulators, except those mounted on the engine(s), shall be located in a tank room or tank compartment.

**17.11.4 Ventilation.** Engine rooms or compartments shall be provided with positive pressure and passive ventilation. Positive pressure ventilation shall provide a minimum of 30 volumetric exchanges per hour.

**17.11.4.1** The ventilation system shall be capable of handling a combustible mixture, if necessary.

**17.11.4.1.1** The ventilation fans shall take air from the weather deck and discharge it to the weather deck through ducts that shall have a maximum separation from the fans.

**17.11.4.1.2** Multiple discharge ducts shall be used, if practical, to enhance ventilation.

**17.11.4.2** If engine combustion air is taken from the engine room (compartment), the 30 volumetric exchanges per hour shall be in excess of the maximum air volume per hour required by the engines.

**17.11.5 Engines.**

**17.11.5.1 Blowout Plugs.**

**17.11.5.1.1** Since LNG/CNG engines have a natural gas atmosphere in the crankcase, they shall be provided with blowout plugs to relieve pressure in the event of a crankcase explosion.

**17.11.5.1.2** Blowout plugs shall be located so as to limit risk to the crew.

**17.11.5.2** Vessels having the capability shall be permitted to switch to another fuel to maintain power.

**17.11.5.3** Engines shall be permitted to be located on the weather deck.

**17.11.5.4** Engines on the weather deck shall be protected with a housing to prevent damage that can occur due to loading, unloading, or the general use of the vessel.

**17.11.5.5** Shelters for engines installed on the weather deck shall be enclosures constructed of noncombustible or limited-combustible materials that have at least one side predominantly open, facing outboard, and roofs designed for dispersal of escaped gas.

**17.11.5.6** An engine or engines on the weather deck shall be mounted in a location to minimize damage from collision.

**17.11.5.7** No part of an engine or its appurtenances shall protrude beyond the sides or top of the vessel at the point where it is installed.

**17.11.5.8** No portion of an engine on the weather deck shall protrude beyond the bow or stern of the vessel.

**17.11.6 Natural Gas Monitoring.**

**17.11.6.1 Engine Rooms.** Engine rooms shall have at least two natural gas detectors placed in the overhead at the fore and aft locations.

**17.11.6.2** Monitoring stations shall be located in the engine room, in the wheelhouse (bridge), and in an accommodation or service space, such as a galley, where crew are likely to congregate.

**17.11.6.3** When no gas is detected, the monitoring stations shall show a green light.

**17.11.6.4** At one-tenth of the LFL of the concentration, power ventilation shall activate simultaneously along with a flashing yellow light at each monitoring station accompanied by a klaxon.

**17.11.6.5** Should the monitoring system detect a concentration of one-fifth of the LFL, a flashing red light shall activate at each monitoring station accompanied by a siren.

**17.11.6.5.1** When the one-fifth LFL is detected and the alarm system activated, an emergency fuel shutoff shall be activated simultaneously, terminating the flow of natural gas to the engine room.

**17.11.6.5.2** Vessels having the capability shall be permitted to switch to another fuel.

**17.11.6.6** A manual override switch shall be mounted in the engine room so that the crew can turn off the alarm and restore natural gas to the engines in the event of a false alarm or other contingency.

**17.11.6.7** When the natural gas fuel supply is shut down due to loss of ventilation or detection of gas, the master shall ensure that the natural gas fuel supply is not used until the leak or other cause of the shutdown is found and corrected.

**17.11.7 Engine Compartments.**

**17.11.7.1** Engine compartments shall be equipped with natural gas detection and intervention equipment in a fashion similar to engine rooms, except that a monitoring station shall be placed only at the wheelhouse (bridge).

**17.11.7.2** If the vessel is large enough to make a fuel alarm inaudible if no one is manning the wheelhouse (bridge), then a monitoring station shall also be placed in the accommodation or service space.

**17.11.8 Fire Equipment and Systems.** LNG/CNG-powered marine vessels of all sizes shall carry fire equipment and systems normally required by U.S. Coast Guard, and meet all of the criteria in 17.11.8.1 through 17.11.8.4.

**17.11.8.1** In addition, engine rooms and engine compartments shall have a 150°F (66°C) thermal switch that shall activate fire-fighting equipment.

**17.11.8.1.1** When the thermal switch is activated, a flashing red light and an audible alarm in the engine room wheelhouse (bridge) and other accommodation space or service space where crew are likely to congregate, such as a galley, shall activate, signaling the possible presence of a fire.

**17.11.8.2** There shall be a 1-minute time delay, after which the engine room or compartment shall be flooded with $CO_2$ (or other USCG-approved inert gas) for 2 minutes.

**17.11.8.2.1** Simultaneously, the ventilation fans shall be cut off for 2 minutes and then reactivated. Sufficient $CO_2$ (or other USCG-approved inert gas) should be provided for two cycles.

**17.11.8.3** A manual override switch shall be provided in the engine room or near the engine compartment to allow the response to be terminated in the event of false alarm or other contingency.

**17.11.8.4** Controls shall be provided to allow manual activation of the $CO_2$ (or other USCG-approved inert gas) system without a delay.

**17.12 Tank Rooms or Compartments.**

**17.12.1** Tank rooms and tank compartments shall be airtight as well as watertight, with appropriate fittings used to seal penetrations through the bulkheads for wire or pipes passing through the tank rooms.

**17.12.2** The tank rooms shall be provided with positive pressure and passive ventilation.

**17.12.3** Ventilation of the tank rooms (compartments) shall be provided at 30 volumetric exchanges per hour minimum.

**17.12.4** Air shall be taken from the weather deck and discharged to the weather deck through ducts that have a maximum separation from the fans.

**17.12.5** The fans shall be capable of handling a combustible mixture, if necessary.

**17.12.6** Multiple discharge ducts shall be used, if practical, to enhance ventilation.

**17.12.7 Natural Gas Monitoring.**

**17.12.7.1** Tank rooms or compartments shall have at least two natural gas sensors placed at or near the ceiling at fore and aft locations.

**17.12.7.2** When no gas is detected, the monitoring stations shall show a green light.

**17.12.7.3** Two levels of alarm shall be used for signaling the need for intervention.

**17.12.7.4** An alarm shall activate when one-tenth of the LFL is detected by a monitor.

**17.12.7.4.1** A flashing yellow light and a klaxon shall be activated in the engine room and in the wheelhouse (bridge), as well as in an accommodation or service space, such as a galley, where crew are likely to congregate.

**17.12.7.4.2** Simultaneously, power ventilation shall activate.

**17.12.7.4.3** On vessels with a tank compartment, a flashing yellow light and an audible signal shall activate in the wheelhouse (bridge).

**17.12.7.4.4** If the vessel is large enough to cause the alarm to be inaudible if no one is manning the wheelhouse (bridge), a second warning station shall activate in an accommodation or service space where crew are likely to congregate.

**17.12.7.5** At one-fifth of LFL, a second alarm shall activate, utilizing a flashing red light and a siren.

**17.12.7.5.1** These monitoring stations shall be located as are the monitoring stations for the one-tenth LFL.

**17.12.7.5.2** When the one-fifth LFL warning is activated, an automatic fuel shut-off valve will terminate flow of natural gas from the tank room or compartment, ventilation shall terminate, $CO_2$ (or other USCG-approved inert gas) shall flood the tank room, and a water deluge system shall be activated.

**17.12.7.5.3** Vessels having the capability shall be permitted to switch to another fuel.

**17.12.7.6** A tank compartment shall be permitted to omit a deluge system if a vessel is too small to accommodate the equipment. The judgment shall be made by the AHJ.

**17.12.7.7** When the LNG fuel supply is shut down due to loss of ventilation or detection of gas, the master shall ensure that the LNG fuel supply is not used until the leak or other cause of the shutdown is found and corrected.

**17.12.8** Tank rooms and compartments shall have manual drains to remove the water produced by the deluge system.

**17.12.9** A labeled override switch shall be available in a readily accessible location to turn off the tank room or compartment warning system in the event of a false alarm or other contingency and to shut down the $CO_2$ (or other USCG-approved inert gas) and deluge.

**17.12.10 Fire-Fighting Equipment.**

**17.12.10.1** Tank rooms and compartments shall have a 150°F (66°C) thermal switch, which will activate automatic fire-fighting equipment.

**17.12.10.2** When the switch is activated, a red flashing light and an audible alarm shall activate on a fire alarm panel in the wheelhouse (bridge) and in an accommodation or service space (such as a galley) where crew are likely to congregate.

**17.12.10.3** Since the tank rooms or compartments are unmanned spaces, alarms shall not be required in those spaces.

**17.12.10.4** Ventilation in the tank rooms or compartments shall be terminated simultaneously with the activation of the fire alarm.

**17.12.10.4.1** One minute after the fire alarm is activated, the tank room or compartment shall be flooded with $CO_2$ (or other USCG-approved inert gas).

**17.12.10.4.2** A deluge system shall activate to keep the tanks cool and to assist in terminating fire.

**17.12.10.5** The tank room or compartment shall be provided with a readily accessible override switch that will allow the crew to terminate the fire-fighting system in the event of a false alarm or other contingency.

**17.12.10.6** A deluge system shall be permitted to be omitted from tank compartments on vessels too small to accommodate them. This determination shall be made by the AHJ.

**17.12.11 Lighting.**

**17.12.11.1** Tank rooms shall have at least two explosionproof lighting fixtures.

**17.12.11.2** Switches and overcurrent protective devices for lighting in the tank room(s) shall be in a gas-safe space.

**17.13 Vent Masts.**

**17.13.1** All crankcases on natural gas–powered engines shall have a closed crankcase ventilation system or be vented to a vent mast.

**17.13.2** Vessels having more than one engine shall be permitted to utilize a manifold.

**17.13.3** Relief valves or common vent headers from relief valves shall discharge to a vent mast.

**17.13.4** Vent masts shall have the following features:

(1) Vertically upward discharge
(2) Rain cap or other means of preventing the entrance of rain or snow
(3) Height of at least 10 ft (3 m) above the highest working level on the vessel

**17.13.5** Relief valve vent masts and engine ventilation vent masts shall not be connected but shall be permitted to terminate at the same location.

**17.14 Deluge Systems.**

**17.14.1** Each deluge system that protects more than one area shall have at least one isolation valve at each branch connection and at least one isolation valve downstream from each branch connection to isolate damaged sections.

**17.14.2** Each valved cross connection from the deluge system to the fire main shall be outside of the tank room or compartment.

**17.14.3** Each pipe, fitting, and valve for the deluge system shall be made of fire-resistant and corrosion-resistant materials such as galvanized steel or galvanized iron pipe.

**17.14.4** Each deluge system shall have a means of drainage to prevent corrosion of the system and freezing of the accumulated water in subfreezing temperatures.

**17.14.5** Each deluge system shall have a dirt strainer that is located at the deluge system manifold or pump.

**17.14.6** Water to the deluge system shall be supplied by a pump that is reserved for the use of the system.

**17.15 Alarm Systems.**

**17.15.1** Alarm systems shall have a means of indicating which natural gas sensor has been activated.

**17.15.2** The fire alarm systems shall have a means of indicating which thermal switch has been activated.

**17.15.3** Each audible alarm shall have an arrangement that allows it to be turned off after sounding. For remote group alarms, this arrangement shall not interrupt the alarm's actuation by other faults.

**17.15.4** Each visual alarm shall be of the type that can be turned off only after the actuating is corrected.

**17.15.5** Each vessel shall have means for testing each alarm.

**17.15.6** Gas-safe spaces adjacent to gas-dangerous spaces such as engine rooms and tank compartments shall have positive pressure ventilation systems capable of 30 volumetric exchanges an hour. Their ventilation shall activate whenever an alarm is activated.

**17.16 Safety Equipment.**

**17.16.1** Marine vessels with tank rooms and engine rooms shall have the following:

(1) Three self-contained, pressure demand–type, air-breathing apparatus approved by the Mine Safety and Health Administration (MSHA) or the National Institute for Occupational Safety and Health (NIOSH), each having at least a 30-minute capacity
(2) Three spare bottles of air for the self-contained air-breathing apparatus, each having at least a 30-minute capacity
(3) Three explosionproof flashlights
(4) Three helmets that meet ANSI Z89.1, *Personal Protection — Protective Headwear for Industrial Workers — Requirements*
(5) Three sets of goggles that meet the specification ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*
(6) An air compressor to recharge the bottles for the air-breathing apparatus
(7)*Portable handheld natural gas detectors provided to aid in evaluating alarms and for making a survey of the vessel

**17.16.1.1** Portable handheld natural gas detectors shall allow locating specific leaks at very low levels of detection and shall be carried by personnel working in a compartment containing gas storage or transmission equipment.

**17.16.1.2** A vessel with a tank room shall have at least two of the sensors described in 17.16.1.1.

**17.16.2** Vessels having engine rooms and tank rooms shall have a portable analyzer that measures oxygen levels in an inert atmosphere.

**17.16.3** Before allowing anyone to enter a space that has had a gas leak and repair, the master shall ensure that the space has an oxygen concentration of at least 19.5 percent oxygen by volume and is free of natural gas.

**17.16.4** The master shall ensure that the compressed air-breathing equipment is inspected at least once a month by a licensed officer and that the date of inspection and condition of the equipment is placed in the vessel's log.

**17.17 Safety Training.**

**17.17.1** A written safety guide for the vessel and for the safety equipment and procedures shall be provided.

**17.17.2** The safety guide shall outline all safety systems and equipment and their operation.

**17.17.3** Crews shall be trained to operate the LNG/CNG-powered vessel and perform repairs.

**17.17.4** Training drills shall be conducted monthly.

## Chapter 18 Reserved

## Chapter 19 Reserved

## Chapter 20 Reserved

## Chapter 21 Reserved

## Annex A Explanatory Material

*Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.*

**A.1.1** Natural gas is a flammable gas. It is colorless, tasteless, and nontoxic. It is a light gas, weighing about two-thirds as much as air. As used in the systems covered by this standard, it tends to rise and diffuses rapidly in air when it escapes from the system.

Natural gas burns in air with a luminous flame. At atmospheric pressure, the ignition temperature of natural gas–air mixtures has been reported to be as low as 900°F (482°C). The flammable limits of natural gas–air mixtures at atmospheric pressure are about 5 percent to 15 percent by volume natural gas.

Natural gas is nontoxic but can cause anoxia (asphyxiation) when it displaces the normal 21 percent oxygen in air in a confined area without adequate ventilation.

Hydrogen is a colorless gas with no odor. It is not toxic; the immediate health hazard is that it can cause thermal burns. It is flammable and can form mixtures with air that are flammable or explosive. Hydrogen can react violently if combined with oxidizers, such as air, oxygen, and halogens. Hydrogen is an asphyxiant and can displace oxygen in a workplace atmosphere. The concentrations at which flammable or explosive mixtures form are much lower than the concentration at which asphyxiation risk is significant.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, rating is as follows:

(1) Health — 0
(2) Flammability — 4
(3) Reactivity — 0
(4) Special — None

Hydrogen is not toxic by any route. Asphyxia can result if the oxygen concentration is reduced to below 18 percent by displacement. None of the available data indicate toxicity for exposures of any duration. Asphyxiation is the primary health risk. No detrimental effects of skin contact or eye contact have been reported. Ingestion is not an observed route of exposure to gaseous hazardous materials.

**Hydrogen Data and Physical Properties.** The following information provides basic physical property data and regulatory guidance:

(1) Flash point: Not applicable (This material is a gas.)
(2) Flammability limits in air: 4.0 percent to 75.0 percent
(3) Autoignition temperature: 932°F (500°C)
(4) Flammability classification (per 29 CFR 1910.1200): Flammable gas
(5) Known or anticipated hazardous products of combustion: None

Cryogenic fluids are gases that have been liquefied by having their temperature brought below –130°F (–90°C). They are typically stored at low pressures in vacuum jacketed containers. Some of the potential hazards of cryogenic fluids are the following:

(1) Extreme cold that freezes or damages human skin on contact and can embrittle metals
(2) Extreme pressure resulting from rapid vaporization of the fluid during a leak or release of the cryogenic fluid
(3) Asphyxiation resulting from a release of the cryogenic fluid that vaporizes and displaces air

Personnel handling cryogenic fluids should use the protective clothing proscribed on the material safety data sheet (MSDS). This clothing typically includes heavy leather gloves, aprons, and eye protection.

**A.3.2.1 Approved.** The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

**A.3.2.2 Authority Having Jurisdiction (AHJ).** The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

**A.3.2.3 Code.** The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

**A.3.2.5 Listed.** The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

**A.3.3.4.1 Important Building.** Examples of important buildings include occupied buildings where egress within 2 minutes cannot be reasonably expected and control buildings that require presence of personnel for orderly shutdown of important or hazardous processes. Important buildings can also include unprotected storage where products from fire can harm the community or the environment or buildings that contain high-value contents or critical equipment or supplies. [**30,** 2008]

**A.3.3.6 Cathodic Protection.** This protection renders a metallic container or piping system or component negatively charged with respect to its surrounding environment. [**55,** 2010]

**A.3.3.16 Dew Point (at Container Pressure).** Where stating or referencing dew point, the value is given in terms of the container pressure [e.g., −4°F (−20°C) dew point at 3600 psi (24.8 MPa)].

**A.3.3.33 Installation.** Where filling containers or transferring natural gas or hydrogen directly from distribution lines by means of a compressor, an installation includes the compressor and all piping and piping components beyond the shutoff valve between the distribution system and the compressor.

**A.3.3.34.1 Saturated LNG Gas.** Saturation reduces the initial weight and BTU content and forms a pressurized gas when released.

**A.3.3.36.2 Limited-Combustible Material.** For further information, see NFPA 259, *Standard Test Method for Potential Heat of Building Materials.*

**A.3.3.42 Original Equipment Manufacturer (OEM).** Additional information regarding DOT classifications for companies that manufacture, modify, or repair vehicles is provided on the DOT web site.

**A.3.3.47.3.1 Maximum Operating Pressure.** The maximum operating pressure should not exceed the allowable working pressure, and it is usually kept at a suitable level below the setting of pressure-limiting/relieving devices to prevent their frequent functioning.

**A.3.3.57.1 Bulk Hydrogen Compressed Gas System.** The bulk system terminates at the source valve, which is the point where the gas supply, at service pressure, first enters the supply line, or at a piece of equipment that utilizes the hydrogen gas, such as a hydrogen dispenser. The containers are either stationary or movable, and the source gas for the system is stored as a compressed gas.

Bulk hydrogen compressed gas systems can include a bulk storage source, transfer piping and manifold system, compression system, and other components. The gaseous source can include a tube trailer, tube bank, or other high pressure storage vessels used to serve the piping system that transports hydrogen to the end user. Compressors can be installed downstream of the storage supply to boost the pressure of the source gas, and intermediate high pressure storage might be present. This is done where the end use requires hydrogen at a pressure higher than that of the bulk supply. In these instances, there may be intermediate storage vessels used to store the gas at elevated pressures. It is not uncommon for the bulk supply as delivered to be furnished at nominal gauge pressure of 3000 psi (20,684 kPa), and the intermediate high pressure storage to be stored at gauge pressures up to 15,000 psi (103,421 kPa). See Figure A.3.3.57.1(a) through Figure A.3.3.57.1(f).

**A.3.3.57.2 Bulk Liquefied Hydrogen Gas System.** The bulk system terminates at the source valve, which is commonly the point where the gas supply, at service pressure, first enters the supply line or a piece of equipment that utilizes the gas or the liquid, such as a hydrogen dispenser. The containers are either stationary or movable, and the source gas for the system is stored as a cryogenic fluid.

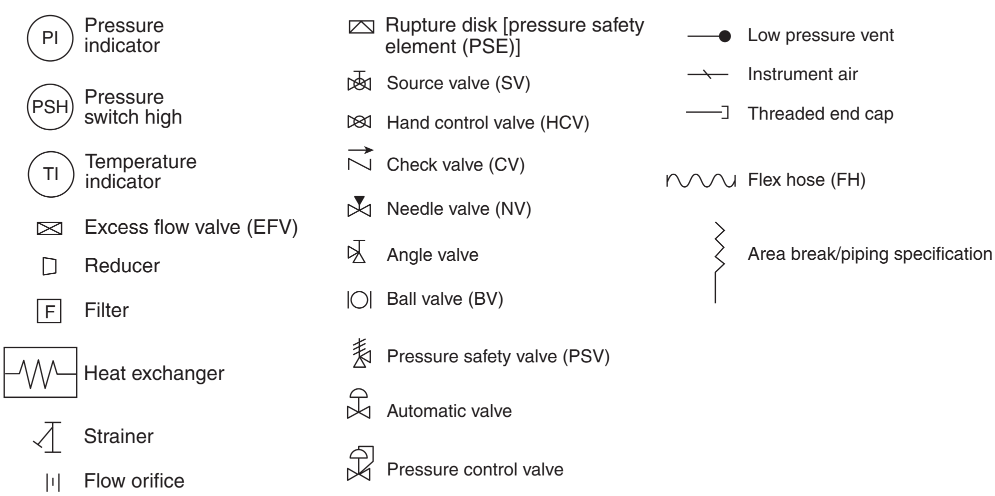



**FIGURE A.3.3.57.1(a) Symbol Legend for Figure A.3.3.57.1(b) through Figure A.3.3.57.1(f). [55:Figure A.3.3.12(a)]**

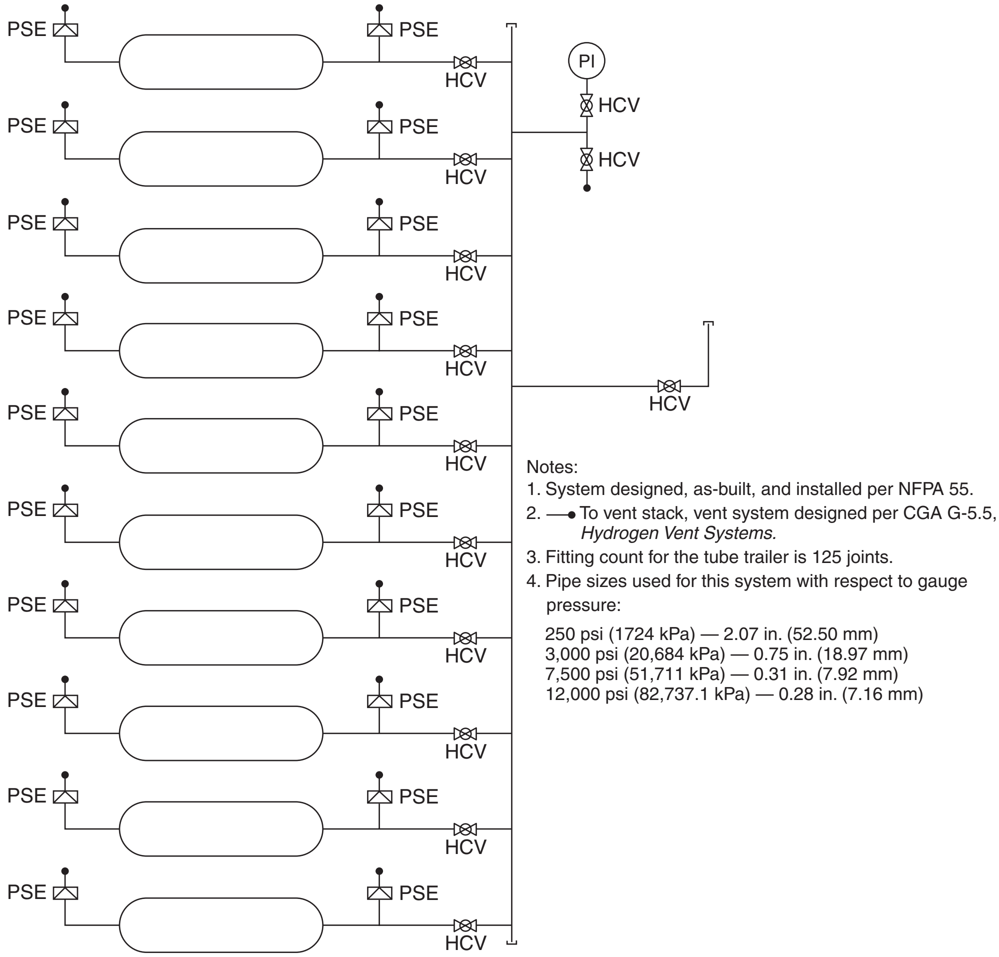



**FIGURE A.3.3.57.1(b) Typical Tube Trailer. [55:Figure A.3.3.12(b)]**

A bulk liquefied hydrogen gas system can include a liquid source where the liquid is vaporized and subsequently compressed and transferred to storage in the compressed gaseous form. It is common for liquid hydrogen systems to be equipped with vaporizers that are used to gasify the cryogen for ultimate use in the compressed state; however, there are also systems that can be used to transfer liquid in the cryogenic state. Bulk liquefied hydrogen gas systems can be either in an all-liquid state or in a hybrid system that can consist of storage containers for gas in the liquid state and other containers for gas in the compressed state. For the purposes of the application of the code, a hybrid system is viewed as a bulk liquefied hydrogen gas system. [**55,** 2010]

**A.3.3.57.7 Piping System.** Equipment such as a compressor or an intermediate storage vessel should be considered individual pieces of equipment. The equipment is not piping within the context of the definition of a piping system. [**55,** 2010]

**A.3.3.62.2 Source Valve.** The source valve is located at a point downstream of a bulk gas supply system and used as the defined point of termination of the bulk supply. It is a point that differentiates between the "supplier" side of the system and what is commonly referred to as the "user" or customer side of the system. [**55,** 2010]

**A.4.1** A typical vehicle fuel system consists of one or more fuel supply containers (if more than one, the containers are manifolded together) holding CNG or $GH_2$ at high pressure and fitted with the following:

(1) Pressure relief devices and manual shut-off valves
(2) A filling connection with a check valve to prevent gas from flowing back out of the connection
(3) A manual valve downstream from the container valve or valves
(4) A valve that automatically closes if the engine stops for any reason
(5) A pressure regulator to reduce the fuel supply container pressure to a low engine service pressure
(6) A gas–air mixer to produce a flammable mixture
(7) A pressure gauge to indicate the fuel supply container pressure

Systems are designed to operate at fuel supply container pressures of 2400 psi, 3000 psi, or 3600 psi (7.5 MPa, 20.7 MPa, or 25 MPa). Fueling connections are designed to accommodate compatible filling nozzles suitable only for the proper pressure.

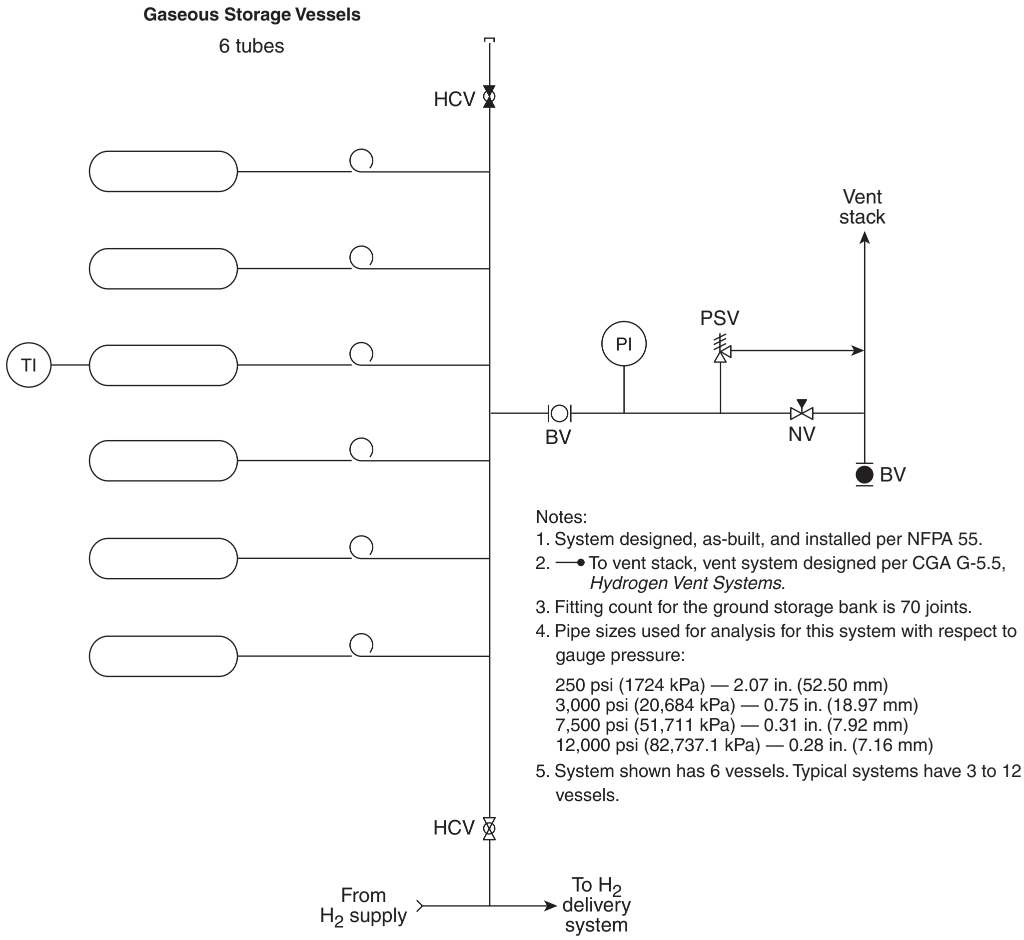



**FIGURE A.3.3.57.1(c) Typical Bulk Compressed Gaseous Storage System. [55:Figure A.3.3.12(c)]**

Fuel supply containers are installed on either the outside or the inside of the vehicle. If installed on the inside, all connections to the containers are either external to a driver or passenger compartment or inside a compartment that is gastight with respect to a driver or passenger compartment. The compartment is vented to the outside of the vehicle. *(See Figure A.4.1.)*

**A.4.2** For additional information on gas quality, see SAE J1616, *Recommended Practice for Compressed Natural Gas Vehicle Fuel*, and CGSB 3.513, *Natural Gas for Vehicles*.

**A.4.4** Containers are described by their liquid capacity and their design and allowable service pressures. The liquid capacity [$ft^3$ ($m^3$) of water] is the volume of liquid that is required to fill the container. The gas storage capacity can be calculated from the liquid capacity and allowable service pressure.

The amount of gas stored in a container can be estimated by using the information in Table A.4.4 referenced to 70°F (21°C). The gas quantity, in standard cubic feet (scf), can be estimated by multiplying the container water capacity [scf ($m^3$)] by the stored volume [scf/$ft^3$ ($scm^3/m^3$)] factor at a given pressure. One scf of natural gas weighs approximately 0.0456 lb (0.0207 kg) and has an energy content of about 930 Btu (2725 W) (on a lower heating value basis).

**A.4.4.4** Current DOT and TC specifications, exemptions, and specified permits do not address the use of cylinders that are approved for the transportation of natural gas to be used in CNG service.

The following Compressed Gas Association publications are relevant cylinder inspection standards:

(1) CGA C-6, *Standards for Visual Inspection of Steel Compressed Gas Cylinders*
(2) CGA C-6.1, *Standards for Visual Inspection of High Pressure Aluminum Compressed Gas Cylinders*
(3) CGA C-6.2, *Guidelines for Visual Inspection and Requalification of Fiber Reinforced High Pressure Cylinders*
(4) CGA C-10, *Recommended Procedures for Changes of Gas Service for Compressed Gas Cylinders*

The following Compressed Gas Association publication is specified in ANSI/ISA NGV2, *Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers*, as appropriate for CNG container inspection:

CGA C-6.4, *Methods of External Visual Inspection of Natural Gas Vehicle (NGV) Fuel Containers and Their Installations*

Notes:
1. System designed, as-built, and installed per NFPA 55.
2. —• To vent stack, vent system designed per CGA G-5.5, *Hydrogen Vent Systems.*
3. Fitting count for the pressure control manifold is 111 joints.
4. Fitting count for the stanchion is 29 joints.
5. Pipe sizes used for analysis for this system with respect to gauge pressure:
   250 psi (1724 kPa) — 2.07 in. (52.50 mm)
   3,000 psi (20,684 kPa) — 0.75 in. (18.97 mm)
   7,500 psi (51,711 kPa) — 0.31 in. (7.92 mm)
   12,000 psi (82,737.1 kPa) — 0.28 in. (7.16 mm)

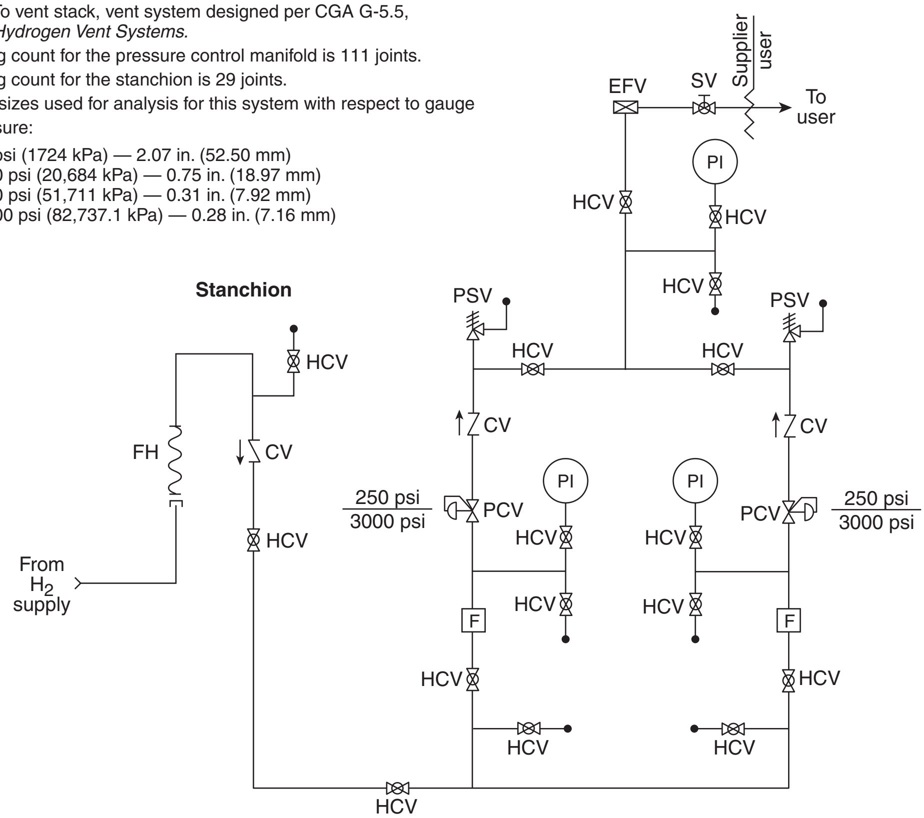



**FIGURE A.3.3.57.1(d) Typical Tube Trailer Discharge Stanchion and Pressure Control Manifold. [55:Figure A.3.3.12(d)]**

**A.4.4.4.2** Current copies of exemptions and special permits can be found at http://hazmat.dot.gov/sp_app/special_permits/exe_0000.htm.

**A.4.4.5.3** The service life of an ASME container is determined by the designer. Requirements of federal, state, or local entities vary with respect to the requirements for inspection of pressure vessels as well as the standards that are to be used when in-service inspections are performed. Various standards can be referenced for inspection purposes including, but not limited to, NB-23, *National Board Inspection Code*, 2004 edition, published by the National Board of Boiler and Pressure Vessel Inspectors, provides rules and guidelines for in-service inspection of boilers, pressure vessels, piping, and pressure relief valves. Other standards, including those published by the American Petroleum Institute, such as API 510, *Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration*, can be applicable.

**A.5.1** A typical $GH_2$ fueling system consists of one or more compressors taking suction from a natural gas or hydrogen transmission or distribution pipeline, or from a building piping system connected to a transmission or distribution pipeline with the compressor discharging into either one or more storage containers or to a dispensing system, along with a dispensing system consisting of a hose and nozzle and, sometimes, a meter. Where a storage container is present, it discharges into a dispensing system.

Where storage containers are used, the system is known as a fast-fill system with a vehicle-filling time of about 3 to 5 minutes. Where storage containers are not used, the system is known as a slow-fill system, with filling times that can last several hours.

The suction pressure for compressors ranges from approximately 2 psi to 500 psi (13.7 kPa to 3.4 MPa), with the suction pressure for most compressors under 60 psi (414 kPa). The delivery pressure is more than the vehicle system pressure but less than 5000 psi (35 MPa), with most at approximately 4500 psi (31 MPa).

CNG or $GH_2$ is stored in two types of storage systems: bulk storage and cascade storage. They differ in the manner in which the CNG or $GH_2$ is withdrawn.

Hydrogen embrittlement is a potential problem, particularly at elevated temperatures in ferritic materials. Special precautions should be taken in hydrogen service and can include increasing the safety factor particularly in areas where residual stresses could be present (bending, swaging, welding, etc.). Information on material considerations for hydrogen service is contained in Annex E.

**A.5.3** The amount of gas stored in a container can be estimated by using the information in Table A.4.4 referenced to 70°F (21°C). The gas quantity, in standard cubic feet, can be estimated by multiplying the container water capacity [scf ($m^3$)] by the stored volume [scf/ft$^3$ (scm/$m^3$)] factor at a

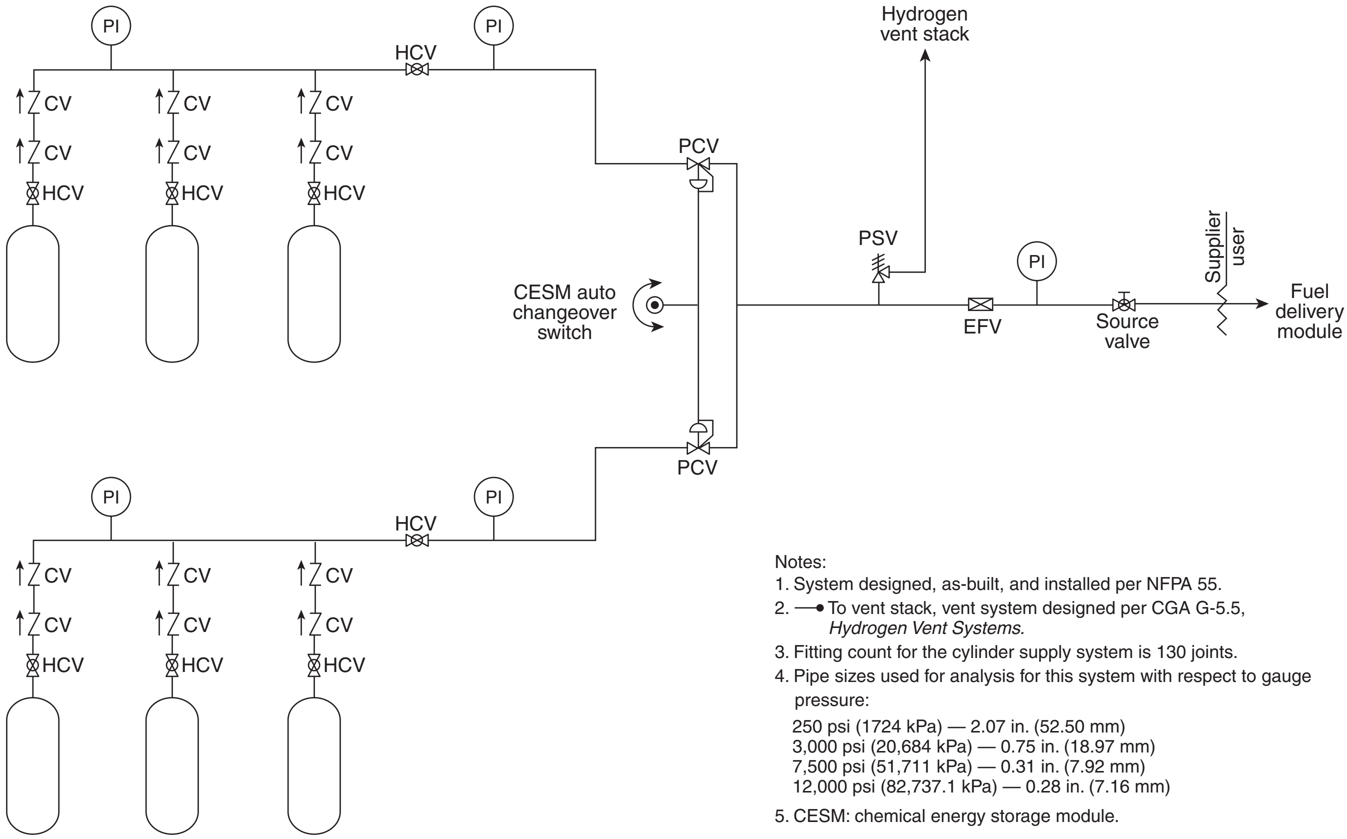



**FIGURE A.3.3.57.1(e) Typical Chemical Energy Storage Module (CESM). [55:Figure A.3.3.12(e)]**

given pressure. One scf of hydrogen gas weighs approximately 0.0052 lb (0.0024 kg). See Table A.5.3(a) and Table A.5.3(b).

**A.5.4** See Table A.5.3(b).

**A.5.8.3** The following are examples of materials and components that should not be used for gaseous $GH_2$ service:

(1) Gray, ductile, or cast iron
(2) Certain stainless steels
(3) Nickel and its alloys such as Inconel and Monel
(4) Nickel steels such as 2.25, 3.5, and 9 percent Ni

**A.6.1** A typical fueling system consists of one or more compressors taking suction from a natural gas or hydrogen transmission or distribution pipeline or a building piping system connected to a transmission or distribution pipeline, with the compressor discharging into either one or more storage containers or to a dispensing system, along with a dispensing system consisting of a hose and nozzle and, sometimes, a meter. Where a storage container is present, it discharges to a dispensing system.

Where storage containers are used, the system is known as a fast-fill system, with a vehicle-filling time of about 3 to 5 minutes. Where storage containers are not used, the system is known as a slow-fill system, with filling times that can last several hours.

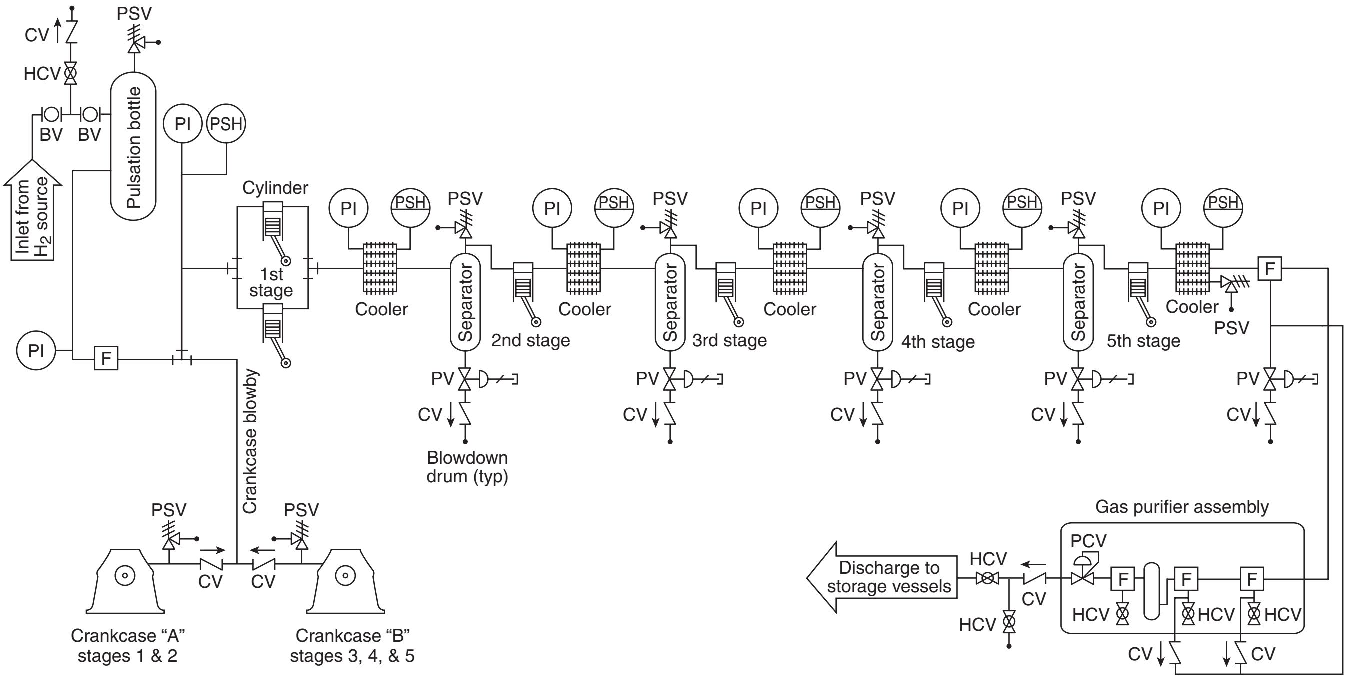
The suction pressure for compressors ranges from approximately 2 psi to 500 psi (13.7 kPa to 3.4 MPa), with the suction pressure for most compressors under 60 psi (414 kPa). The delivery pressure is more than the vehicle system pressure but less than 5000 psi (35 MPa), with most at approximately 4500 psi (31 MPa).

CNG or $GH_2$ is stored in two types of storage systems: bulk storage and cascade storage. They differ in the manner in which the CNG or $GH_2$ is withdrawn.

**A.6.1.2** Due to the large degree of variation possible in fuel and gaseous detection system configurations and component specifications, information regarding the content of these systems should be documented/validated by OEM chassis, engine, fuel system container/component supplier, gaseous detection supplier, and so forth, to be included by the FSVIM in an operating manual. The operating manual content described should be presented in sufficient depth and clarity so as to provide a basic understanding of these systems unique to a gaseous fuel–powered vehicle. Furthermore, the FSVIM has the responsibility for documentation, collection, and consolidation of the OEM gaseous fuel system and detection-related components as well as operating and maintenance documentation for the end user.

**A.6.1.2.1** Therefore, the FSVIM is responsible for providing systems' (fuel and gas detection) validation of the following:

(1) Engineering
(2) Integration
(3) Installation
(4) Regulatory validation
(5) Performance
(6) Durability




Notes:
1. System designed, as-built, and installed per NFPA 55.
2. —• To vent stack, vent system designed per CGA G-5.5, *Hydrogen Vent Systems*.
3. Fitting count for the compression system is 225 joints.
4. Pipe sizes used for analysis for this system with respect to gauge pressure:

250 psi (1724 kPa) — 2.07 in. (52.50 mm)
3,000 psi (20,684 kPa) — 0.75 in. (18.97 mm)
7,500 psi (51,711 kPa) — 0.31 in. (7.92 mm)
12,000 psi (82,737.1 kPa) — 0.28 in. (7.16 mm)

**FIGURE A.3.3.57.1(f) Typical Compressor Module. [55:Figure A.3.3.12(f)]**

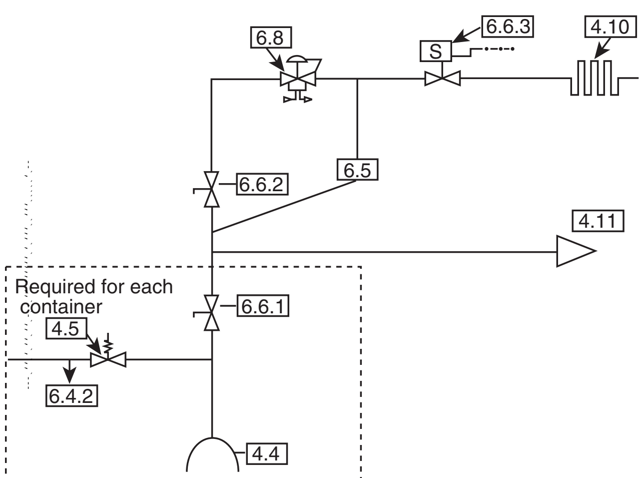



**FIGURE A.4.1 Typical Vehicular Fuel System Components.**

**A.6.4** GRI-02/0013, *Reference Guide for Integration and Use of Natural Gas Vehicle Fuel Systems*, gives information on how to prevent blockages in the vent line.

**A.6.4.1** The vent outlet is not permitted to be terminated in the engine compartment.

**A.6.6.4** Electronic fuel injectors are considered to be automatic valves.

**A.6.12.1** WARNING: The use of compressed air for system or container leak testing can result in a hazardous combustible mixture in the fuel supply container, with a high risk of severe injury or death.

**A.6.12.4** The following practices should be followed:

(1) Before a CNG or $GH_2$ vehicle is returned to service following an accident that caused damage or dislocation to the CNG or $GH_2$ fuel system, or following the repair or replacement of any part of a CNG or $GH_2$ fuel system that is subject to container pressure, the system should be tested in accordance with Section 5.11.

**Table A.4.4 Natural Gas Storage Volume**

| Pressure | | Stored Volume Ratio |
|---|---|---|
| psi | MPa | (Volume/Volume) |
| 200 | 1.38 | 15 |
| 400 | 2.76 | 29 |
| 600 | 4.14 | 45 |
| 800 | 5.52 | 61 |
| 1000 | 6.89 | 78 |
| 1200 | 8.27 | 96 |
| 1400 | 9.65 | 114 |
| 1600 | 11.03 | 133 |
| 1800 | 12.41 | 152 |
| 2000 | 13.79 | 171 |
| 2200 | 15.17 | 189 |
| 2400 | 16.55 | 206 |
| 2600 | 17.93 | 223 |
| 2800 | 19.31 | 238 |
| 3000 | 20.68 | 252 |
| 3200 | 22.06 | 265 |
| 3400 | 23.44 | 278 |
| 3600 | 24.82 | 289 |
| 3800 | 26.20 | 299 |
| 4000 | 27.58 | 309 |
| 4200 | 28.96 | 318 |
| 4400 | 30.34 | 327 |
| 4600 | 31.72 | 335 |
| 4800 | 33.09 | 342 |
| 5000 | 34.47 | 349 |

Note: The above values can differ slightly for different gas compositions.

(2) Prior to maintenance or repair of a CNG or $GH_2$ fuel system, the following should be performed:

(a) Before commencing the work, the supply of CNG or $GH_2$ should be shut off by closing the shut-off valves and operating the engine until the engine stops running, and it should be ensured that the valves remain shut off throughout the inoperative period.

(b) CNG or $GH_2$ should be vented outdoors to a safe location and should not be vented indoors.

(c) Upon completion of the work, the CNG or $GH_2$ fuel system should be leak tested in accordance with the requirements of Section 5.11.

(3) Prior to making repairs to gasoline-related equipment on a CNG or $GH_2$ vehicle, other than to the CNG or $GH_2$ fuel system, the following should be performed:

(a) Prior to removal of the natural gas mixer, the supply of CNG or $GH_2$ should be shut off by closing the shutoff valves and operating the engine until the engine stops running, and it should be ensured that the valves remain off throughout the inoperative period.

(b) Upon completion of the work, the natural gas mixer should be placed in its original location without any change or adjustment before the CNG or $GH_2$ shutoff valves are reopened.

**Table A.5.3(a) Gaseous Hydrogen, Pressure Range 0–6400 psi (0–44 MPa)**

| Gauge Pressure | | Stored Volume Ratio |
|---|---|---|
| psi | MPa | |
| 0 | 0 | 1 |
| 200 | 1.38 | 14 |
| 400 | 2.76 | 28 |
| 600 | 4.14 | 41 |
| 800 | 5.52 | 54 |
| 1000 | 6.89 | 66 |
| 1200 | 8.27 | 79 |
| 1400 | 9.65 | 91 |
| 1600 | 11.03 | 103 |
| 1800 | 12.41 | 115 |
| 2000 | 13.79 | 126 |
| 2200 | 15.17 | 138 |
| 2400 | 16.55 | 149 |
| 2600 | 17.93 | 160 |
| 2800 | 19.31 | 171 |
| 3000 | 20.68 | 182 |
| 3200 | 22.06 | 192 |
| 3400 | 23.44 | 203 |
| 3600 | 24.82 | 213 |
| 3800 | 26.20 | 223 |
| 4000 | 27.58 | 233 |
| 4200 | 28.96 | 243 |
| 4400 | 30.34 | 252 |
| 4600 | 31.72 | 262 |
| 4800 | 33.09 | 271 |
| 5000 | 34.47 | 280 |
| 5200 | 35.85 | 289 |
| 5400 | 37.23 | 298 |
| 5600 | 38.61 | 307 |
| 5800 | 39.99 | 315 |
| 6000 | 41.37 | 324 |
| 6200 | 42.75 | 332 |
| 6400 | 44.13 | 340 |

(4) Prior to making collision repairs on a CNG or $GH_2$ vehicle, other than to the CNG or $GH_2$ fuel system, the following should be performed:

(a) The shut-off valve at the outlet of the CNG or $GH_2$ container should be closed before commencing the work, and it should be ensured that the valve remains off throughout the inoperative period.

(b) The CNG or $GH_2$ vehicle owner or operator should be instructed to take the vehicle to a vehicle conversion center for inspection of the CNG or $GH_2$ fuel system before the shutoff valve described in A.6.12.4(4)(a) is reopened.

**A.7.1** Bulk storage of CNG or $GH_2$ can be accomplished using one large container or a number of smaller containers manifolded together. As vehicles draw CNG or $GH_2$ from bulk storage, all containers draw down (reduce in pressure) at the same rate. Bulk storage provides less "available" CNG or $GH_2$ storage than the cascade system.

**Table A.5.3(b) Gaseous Hydrogen, Pressure Range 0–14,504 psi (0–100 MPa)**

| Gauge Pressure | | Stored Volume Ratio |
|---|---|---|
| psi | MPa | |
| 0 | 0 | 1 |
| 725 | 5 | 49 |
| 1,450 | 10 | 94 |
| 2,176 | 15 | 136 |
| 2,901 | 20 | 176 |
| 3,626 | 25 | 214 |
| 4,351 | 30 | 249 |
| 5,076 | 35 | 283 |
| 5,802 | 40 | 314 |
| 6,527 | 45 | 344 |
| 7,252 | 50 | 372 |
| 7,977 | 55 | 399 |
| 8,702 | 60 | 425 |
| 9,427 | 65 | 449 |
| 10,153 | 70 | 472 |
| 10,878 | 75 | 495 |
| 11,603 | 80 | 516 |
| 12,328 | 85 | 536 |
| 13,053 | 90 | 556 |
| 13,779 | 95 | 575 |
| 14,504 | 100 | 593 |

Storage containers arranged in a cascade can provide more "available" CNG or $GH_2$ volume from storage than a bulk system for the same size containers. A brief description of the operation of a typical cascade system is as follows:

A cascade is usually arranged in at least three banks of containers with the containers in any one bank manifolded together so that each bank acts as one large container. The banks are separated by automatic switching valves. The valve sequencing is controlled automatically by a sequencing control panel.

The cascade banks are initially filled with CNG or $GH_2$ in sequence by the compressor to the normal service pressure of the system. The highest pressure bank is refilled first (bank 1 — high bank), followed by successively lower pressure banks (bank 2 — medium bank, bank 3 — low bank, etc.). This sequence is called priority fill.

Vehicles can then be fueled from the cascade, beginning with bank 3 (for a three-bank cascade).

If there is insufficient CNG or $GH_2$ in bank 3 to pressurize the vehicle fuel supply container(s), bank 3 is valved off and bank 2 "tops up" the vehicle container(s). Successive vehicles draw from banks 3 and 2, as previously described, until bank 1 has to top up the vehicle container(s). When bank 1 pressure is reduced to a preset value, the compressor bypasses the cascade and fills the vehicle directly. At the completion of the last vehicle fill, the compressor continues running and refills the cascade by priority fill.

Cascade valving can be arranged to provide more available storage than the system described.

**A.7.1.2** Due to the large degree of variation possible in fuel and gaseous detection system configurations and component specifications, information regarding the content of these systems should be documented and validated, to be included by the FSVIM in an operating manual, according to each of the following:

(1) OEM chassis
(2) Engine
(3) Fuel system container/component supplier
(4) Gaseous detection supplier, and so forth

The operating manual content described should be presented in sufficient depth and clarity so as to provide a basic understanding of these systems unique to a gaseous fuel powered vehicle. Furthermore, the FSVIM has the responsibility for documentation, collection and consolidation of the OEM gaseous fuel system and detection-related components, and operating and maintenance documentation for the end user.

**A.7.1.2.1** Therefore, the FSVIM is responsible for providing systems' (fuel and gas detection) validation of the following:

(1) Engineering
(2) Integration
(3) Installation
(4) Regulatory validation
(5) Performance
(6) Durability

**A.7.2.1** See SAE J2578, *Recommended Practice for General Fuel Cell Safety*, for additional information on the design of fuel supply containers.

**A.8.3.3** Methanol injection systems are not an approved control device.

Many insulating materials that have had prolonged exposure to natural gas or methane retain appreciable quantities of the gas within their pores or interstitial spaces.

**A.8.3.12** Aftercoolers and automatic condensate systems frequently are used to remove liquid so that it is not carried over into the storage system.

**A.8.4.3.3** For information on venting of explosions, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

**A.8.4.3.5.5** This corresponds to five air changes per hour.

**A.8.5.1** Where space is at a premium or is not available, consideration should be given to installation of compressors, dryers, and storage containers on a roof made of noncombustible material at fueling stations.

**A.8.9.1** For information on corrosion protection of underground pipe, see NACE RP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*.

**A.8.12** See Figure A.8.12 for an illustration of classified areas in and around dispensers.

The electrical classification specified in Table 8.4.2.9 can be permitted to be reduced, or hazardous areas limited or eliminated, by adequate positive pressure ventilation from a source of clean air or inert gas in conjunction with effective safeguards against ventilator failure by purging methods recognized in NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*. Such changes should be subject to approval by the AHJ.

**A.8.13.1** See API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*.

**A.8.13.2** See NFPA 77, *Recommended Practice on Static Electricity*, and API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*, for additional information.

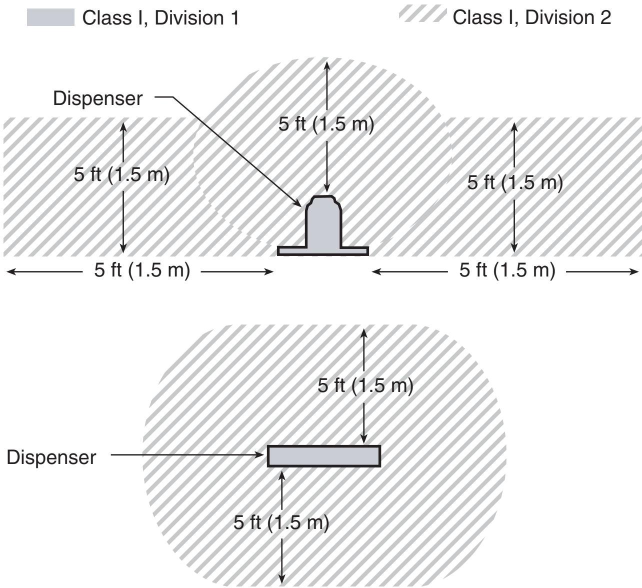



**FIGURE A.8.12 Classified Areas in and Around Dispensers as Detailed in Table 8.4.2.9.**

**A.8.14.12** The flyer shown in Figure A.8.14.12 is recommended to be made available by CNG dispensing facilities. The page is designed to be photocopied and cut into three sections for ease of distribution.

**A.8.16** The Uniform Boiler and Pressure Vessel Laws Society, Inc., publishes a synopsis detailing boiler and pressure vessel laws, rules, and regulations relating to construction, installation, and inspection in the various states, provinces, territories, counties, and cities of the United States and Canada.

**A.8.16.6** As a precaution to keep pressure relief devices in reliable operating condition and to avoid damage, care should be taken in the handling or storage of CNG or hydrogen containers. Care also should be exercised to avoid plugging by paint or other dirt accumulation in pressure relief device channels or other parts that could interfere with the functioning of the device.

**A.9.2.1** The systems referred to are those that consume natural gas from the public utility. For example, a reformer process that is used to generate hydrogen.

**How to Tell If Your Compressed Natural Gas (CNG) Fuel Cylinders Have Been Inspected**

The Department of Transportation requires this statement on the label of all CNG cylinders used on motor vehicles:

**THIS CONTAINER SHOULD BE VISUALLY INSPECTED AFTER A MOTOR VEHICLE ACCIDENT OR FIRE AND AT LEAST EVERY 36 MONTHS OR 36,000 MILES, WHICHEVER COMES FIRST, FOR DAMAGE AND DETERIORATION**

Evidence that your cylinders have been inspected could be one of the following:

1. A readily visible inspection label on the cylinder:

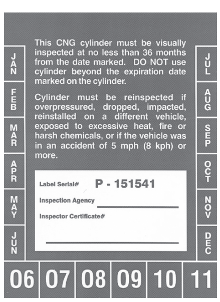



*Image Courtesy of CSA America*

2. An inspection form/report provided by inspector (perhaps kept in glove box with insurance, registration papers).
3. Other: sticker on windshield, doorpost, fueling receptacle area, etc.

**How to Tell If Your Compressed Natural Gas (CNG) Fuel Cylinders Have Been Inspected**

The Department of Transportation requires this statement on the label of all CNG cylinders used on motor vehicles:

**THIS CONTAINER SHOULD BE VISUALLY INSPECTED AFTER A MOTOR VEHICLE ACCIDENT OR FIRE AND AT LEAST EVERY 36 MONTHS OR 36,000 MILES, WHICHEVER COMES FIRST, FOR DAMAGE AND DETERIORATION**

Evidence that your cylinders have been inspected could be one of the following:

1. A readily visible inspection label on the cylinder:

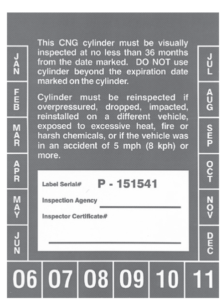


*Image Courtesy of CSA America*

2. An inspection form/report provided by inspector (perhaps kept in glove box with insurance, registration papers).
3. Other: sticker on windshield, doorpost, fueling receptacle area, etc.

**How to Tell If Your Compressed Natural Gas (CNG) Fuel Cylinders Have Been Inspected**

The Department of Transportation requires this statement on the label of all CNG cylinders used on motor vehicles:

**THIS CONTAINER SHOULD BE VISUALLY INSPECTED AFTER A MOTOR VEHICLE ACCIDENT OR FIRE AND AT LEAST EVERY 36 MONTHS OR 36,000 MILES, WHICHEVER COMES FIRST, FOR DAMAGE AND DETERIORATION**

Evidence that your cylinders have been inspected could be one of the following:

1. A readily visible inspection label on the cylinder:

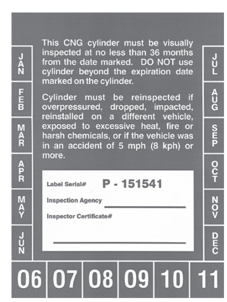


*Image Courtesy of CSA America*

2. An inspection form/report provided by inspector (perhaps kept in glove box with insurance, registration papers).
3. Other: sticker on windshield, doorpost, fueling receptacle area, etc.

**FIGURE A.8.14.12 CNG Inspection Flyer.**

**A.9.2.3** A hazard(s) analysis can be performed by a number of methods where the end result can be achieved through the use of more than one method. Several of the more common methods employed by those involved in systems safety today include, but are not limited to, hazard and operability studies (HAZOPs), failure modes effects and criticality analysis (FMECA), preliminary hazards analysis (PHA), fault tree analysis (FTA), and event tree analysis. Standard designs that have been analyzed by recognized methodology need not be studied each and every time such an installation occurs. Rather, site-specific elements that are unique to the installation should be reviewed in concert with the analysis performed on the standard system to ensure that the standard design has not been altered in a way that would negatively affect the hazard analysis.

The reviews conducted frequently involve a series of meetings between members of a multidisciplinary team that methodically "brainstorms" the system design, following a structure provided by study format and the team leader's experience. Members of the team can include engineers as well as other personnel skilled in the application of a systems safety approach.

**A.9.2.4** Out-of-service systems should not be abandoned in place. Systems that remain out of service should be maintained in a usable condition to ensure that the appropriate safeguards are in place. Permits should be maintained in a current state so that the AHJ remains aware of the installation until such time as the system is removed. [**55:** A.4.4]

**A.9.3.1.3.1.2** The following is a sample calculation for separation distances using ¼ in. ID tubing at gauge pressure of 250–3000 psi:

(1) Determine internal diameter (ID) where ID = OD − (2 × wall thickness); wall thickness = 0.049 in. (known); outside diameter (OD) = 0.250 in.:
ID = $d$ = 0.250 −(2 × 0.049) = 0.152 in. = 3.86 mm
To use the equations in Table 9.3.1.3.1.2 the ID values (the value of $d$ in the equation) to be used must be expressed in millimeters.

(2) Next, determine separation distance(s). The separation distances $D_a$, $D_b$, etc., are calculated in meters to two significant places after the decimal. To convert meters to feet, multiply meters by 3.281 and round off to the nearest 5 ft.
For example, assuming the 250–3000 psi pressure range (second column), calculations for separation distance for the Table 9.3.1.3.1.2 footnotes (a) through (e) are as follows.

*Where:*
$D_{a,\ b,\ c,\ d,\ e}$ = calculated separation distance for $D_a$, $D_b$, etc.
$e$ = 2.71828 ..., the base of natural logarithms
*Then:*

(a) $D_a = 0.74d^{0.99962}$
$D_a = 0.74(3.86^{0.99962})$
$D_a = 0.74(3.858) = 2.85 \text{ m} = 9.4 \text{ ft} \rightarrow 10 \text{ ft}$

(b) $D_b = 0.37d^{1.1152} + e^{-0.10771d}\ (0.19d^{1.2531} - 0.37d^{1.1152})$
$D_b = 0.37(3.86^{1.1152}) + e^{-(0.10771)(3.86)}$
$[(0.19)(3.86^{1.2531}) - (0.37)(3.86^{1.1152})]$
$D_b = 0.37(4.51) + e^{-0.4158}[(0.19)(5.43) - (0.37)(4.51)]$
$D_b = 1.67 + 0.66(1.03 - 1.67)$
$D_b = 1.67 - 0.42$
$D_b = 1.25 \text{ m} = 4.1 \text{ ft} \rightarrow 5 \text{ ft}$

(c) $D_c = 0.29d^{1.092} + e^{-0.10392d}\ (0.19d^{1.1795} - 0.29d^{1.092})$
$D_c = 0.29(3.86^{1.092}) + e^{-(0.10392)(3.86)}$
$[(0.19)(3.86^{1.1795}) - (0.29)(3.86^{1.092})]$
$D_c = 0.29(4.37) + e^{-0.4011}[(0.19)(4.92)$
$-(0.29)(4.37)]$
$D_c = 1.27 + 0.67(0.94 - 1.27)$
$D_c = 1.27 - 0.22$
$D_c = 1.05 \text{ m} = 3.45 \text{ ft} \rightarrow 5 \text{ ft}$

(d) $D_d = 0.31d^{0.99962}$
$D_d = 0.31(3.86^{0.99962})$
$D_d = 0.31(3.84) = 1.19 \text{ m} = 3.9 \text{ ft} \rightarrow 5 \text{ ft}$

(e) $D_e = 0.31d^{0.99962}$
$D_e = 0.31(3.86^{0.99962})$
$D_e = 0.31(3.84) = 1.19 \text{ m} = 3.9 \text{ ft} \rightarrow 5 \text{ ft}$

The subscripts to *D, a, b, c, d,* and *e*, relate to notes (a) through (e), respectively, in Table 9.3.1.3.1.2. To convert the distance in meters to feet, multiply by 3.2808. The resultant distance in feet is then rounded off to the nearest 5 foot dimension. For example, a distance of 5.2 ft would be rounded down to 5 ft. A distance of 7.6 ft would be rounded up to 10 ft. [**55:** A.10.3.2.2.1.1(B)]

**A.9.3.1.3.1.5** Systems that employ compressors downstream of a bulk supply typically operate at higher pressures than that of the bulk supply. As a result, the diameter of the piping system can vary with the pressure. The use of a higher pressure rating or variation of internal diameters is not warranted unless there is a storage component with a hydrogen content that exceeds 400 scf (11.3 $m^3$) located downstream of the primary storage source and upstream of the source valve. The volume of gas contained within the piping system is not included in determining the quantity in storage.

For example, a 3000 psi (20,684 kPa) storage system that supplies a 6000 psi (41,369 kPa) compressor that directly feeds a process with less than 400 scf (11.3 $m^3$) of intervening storage at a pressure of 6000 psi (41,369 kPa) or less is considered a 3000 psi (20,684 kPa) system. Conversely, a system with the primary storage of 3000 psi (20,684 kPa) might supply a compressor that in turn delivers hydrogen to intermediate storage with a quantity of greater than 400 scf (11.3 $m^3$). (Note: Pressures given are gauge pressures.) The piping serving the intermediate storage system from a point of discharge on the compressor can have an internal diameter of less than that serving the primary storage system upstream of the compressor. Accordingly, each portion of the system must be analyzed with respect to the tabular distances. See the typical P&IDs shown in Figure A.3.3.57.1(a) through Figure A.3.3.57.1(f) for additional information in this regard.

The use of Table 9.3.1.3.1.2 is based on the maximum internal diameter of the piping system over the range of pressures specified. In practice, it is common to maintain a consistent size of piping throughout the system; however, there might be cases where the ID of the piping system varies. In such cases, the piping with the largest internal diameter in the system is used to establish the system pipe size for the purposes of using the table, regardless of the length of the piping. It is not uncommon for portions of the system equipped with pressure gauges, pressure transducers, or other instrumentation to be served by small-diameter piping systems. However, the maximum internal diameter of the piping system will control the establishment of distance for the exposures indicated.

Pipe sizes are typically expressed in nominal terms as illustrated in Table A.9.3.1.3.1.5 below. This is compared with tubing in which the outside diameter (OD) is expressed in exact terms. Designers commonly use pipe schedule to specify the wall thickness for a given material based on the design conditions. Typical pipe sizes found in commerce include those shown in Table A.9.3.1.3.1.5.

**Table A.9.3.1.3.1.5 Typical Pipe Sizes**

| Nominal Pipe Size (in.) | O.D. (in.) | Pipe Schedules — Wall Thickness (in.) | | | |
|---|---|---|---|---|---|
| | | 40 | 80 | XH | XXH |
| ¼ | 0.540 | 0.088 | 0.119 | 0.119 | — |
| ⅜ | 0.675 | 0.091 | 0.126 | 0.126 | — |
| ½ | 0.840 | 0.109 | 0.147 | 0.147 | 0.294 |
| ¾ | 1.050 | 0.113 | 0.154 | 0.154 | 0.308 |
| 1 | 1.315 | 0.133 | 0.179 | 0.179 | 0.358 |
| 1¼ | 1.660 | 0.140 | 0.191 | 0.191 | 0.382 |
| 1½ | 1.900 | 0.145 | 0.200 | 0.200 | 0.400 |
| 2 | 2.375 | 0.154 | 0.218 | 0.218 | 0.436 |
| 2½ | 2.875 | 0.203 | 0.276 | 0.276 | 0.552 |
| 3 | 3.500 | 0.216 | 0.300 | 0.300 | 0.600 |
| 3½ | 4.000 | 0.226 | 0.318 | 0.318 | 0.636 |
| 4 | 4.500 | 0.237 | 0.337 | 0.337 | 0.674 |

XH = extra heavy; XXH = extra extra heavy.
Note: Standard pipe schedule or pipe size as listed by ANSI/ASME B36.10M, *Welded and Seamless Wrought Steel Pipe*, and API Spec 5L, *Specification for Line Pipe*.

To determine internal diameter (ID) of a selected pipe size, multiply by 2 the wall thickness for the selected schedule and subtract the result from the outside diameter (OD):

ID = OD −(2 × wall thickness)

For example, for 2 in. Schedule 40 pipe:

Wall thickness = 0.154 in.; OD = 2.375 in.

Then:

ID = 2.375 −(2 × 0.154) = 2.067 in.

When tubing is used in lieu of pipe, the OD of the tubing is designated in inches (e.g., ¼, ⅜, ½, 1, 1¼, 1½, 2), and the tubing is manufactured to those specific dimensions. Tube wall thickness is determined based on the working pressure and materials of construction. The calculation of internal diameter is the same as that used for conventional pipe:

ID = OD −(2 × wall thickness)

For example, for ¼ in. OD tubing, if the wall thickness is 0.049 in. and the OD is 0.250 in.,

then:

ID = 0.250 −(2 × 0.049) = 0.152 in.

[**55:** A.10.3.2.2.1.1(E)]

**A.9.3.1.3.1.6** Portions of a system might operate at higher pressures than the bulk supply; however, those portions of the system do not require the use of a pressure rating higher than that of the bulk supply unless there is a storage component exceeding 400 scf (11.3 $m^3$) downstream of the primary storage source and upstream of the source valve. The volume of gas contained within the piping system is not included when the quantity in storage is determined. For example, a 3000 psi (20,684 kPa) storage system that supplies a 6000 psi (41,369 kPa) compressor that directly feeds a process with less than 400 scf (11.3 $m^3$) of intervening storage at a pressure of 6000 psi (41,369 kPa) or less is considered a 3000 psi (20,684 kPa) system. [**55:** A.10.3.2.2.1.1(F)]

**A.9.3.1.3.2** Distances to assumed lot lines established for the purpose of determining exterior wall and opening protection should not be confused with lot lines that are property lines in the true sense of the definition, and distances to assumed lot lines can be disregarded in the application of Table 9.3.1.3(a) and Table 9.3.1.3(b). The lot lines specified in 9.3.1.3.2 are property lines used to separate one lot from another or to separate a property from a street or other public space.

A permit holder cannot exercise any right of control over the property of others, whether the ownership is public or private. In cases where the permit holder owns an adjacent lot or parcel, the separation from property lines assumes that the permit holder could transfer ownership of the adjacent property at some point, and therefore the requirements for property line separation should be observed. [**55:** A.10.3.2.2.2]

**A.9.3.1.3.3** The code has historically recognized that, in certain instances, fire barrier walls can serve as a means to reduce the limits of unacceptable consequences due to the release of hydrogen from high-pressure equipment. Testing other than that related to establish fire resistance of the fire barrier walls has not been documented. Researchers at Sandia National Laboratories have been investigating the use of fire barrier walls as a means of mitigation in the establishment of distances related to the installation of bulk gaseous hydrogen systems, and a technical paper has been presented detailing the early findings.

As stated by Houf, Schefer, and Evans in "Analysis of Barriers for Mitigation of Unintended Releases of Hydrogen," the purpose of the Sandia study was to extend the available database on barrier walls as a hazard mitigation strategy and to provide technical data for risk-informed decisions in hydrogen codes and standards regarding barrier wall design and implementation. The focus of the research included testing to assess the effectiveness of various barrier designs in terms of the following:

(1) Deflecting jet flames
(2) Reducing the extent of the flammable cloud resulting from an unignited release
(3) Reducing the magnitude of the radiative heat flux produced by a jet flame from an ignited release
(4) Minimizing the amount of ignition overpressure produced from the barrier confinement

When the work is concluded, it is expected that the results will likely provide the basis for criteria for the proper configuration, design, and construction of such barriers in order that the walls do not create other hazards. The work to date has been limited; however, the results have been promising. Houf, Schefer, and Evans have determined that for the conditions investigated, 2000 psi (13.79 MPa) source pressure and a ⅛ in. (3.175 mm) diameter round leak, the barrier configurations studied were found to (1) reduce horizontal jet flame impingement hazard by deflecting the jet flame, (2) reduce radiation hazard distances for horizontal jet flames, and (3) reduce horizontal unignited jet flammability hazard distances. For the one-wall vertical barrier and the three-wall barrier configurations examined in the tests, the simulations of the peak overpressure hazard from ignition were found to be approximately 5.8 psi (40 kPa) on the release side of the barrier and approximately 0.73 psi to 0.44 psi (5 kPa to 3 kPa) on the downstream side of the barrier.

Investigation is continuing into the parameters for the construction of fire barrier walls. In the interim, a risk-informed approach to the establishment of distance has been introduced into Chapter 9 of this code. The Industrial and Medical Gases Technical Committee recognizes that previous editions of the code have allowed the use of fire barrier walls as a mitigation method. Until such time as the investigation by Sandia National Laboratories or others has been completed, 9.3.1.3.3 provides for the use, in limited cases, of fire barrier walls to mitigate effects on the downstream side of the wall by allowing a reduction of one-half of the separation distance otherwise required through the use of the risk-informed tables.

The resultant distances should be measured from a point on the unexposed (or downstream side) of the fire-barrier wall to the exposure. For example, the 45 ft (14.0 m) distance to lot lines shown for a 3,000 psi gauge (20,684 kPa gauge) system using piping with a maximum internal diameter (ID) of 0.747 in. (18.97 mm) can be reduced to 22.5 ft (7.0 m) between the property line and the fire barrier wall.

The concept of limiting the use of barrier walls is an interim determination that augments the requirements now found in the risk-informed approach to the establishment of separation distances. The outcome of the scientific research underway will measure the effect of the mitigation provided by the walls and will bring a firmness to the fire barrier requirements. The importance of completing the research is that all the factors integral to the construction of fire barrier walls will have been established through the scientific process. The use of the scientific process is a fundamental precept established in the acceptance of the risk-informed approach. [**55:** A.10.3.2.2.3]

**A.9.3.2.1.1** Hydrogen is not considered an "explosive or detonable" material per se and item (3) of these provisions extracted from *NFPA 5000, Building Construction and Safety Code,* is intended to be limited to explosives per se. NFPA 1, *Fire Code,* NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* and *NFPA 5000, Building Construction and Safety Code,* all contain similar provisions.

**A.9.3.3.2** NFPA 55, *Compressed Gases and Cryogenic Fluids Code* provides regulation for bulk $GH_2$ storage systems to be located within buildings. Section 10.4 of NFPA 55, *Compressed Gases and Cryogenic Fluids Code* provides requirements for detached buildings in 10.4.4 and for hydrogen gas rooms in 10.4.5. Requirements for ventilation, electrical classification, explosion control, and so forth, are provided. The requirements for dispensing and generation systems involving construction features and engineering controls do not supersede requirements for the storage system.

**A.9.3.3.9** The extent of the classified area from active sources can be determined through the use of NFPA 497 Figure 5.9.8(b), Gaseous Hydrogen Storage Located Outdoor, or Indoors in an Adequately Ventilated Building. This figure is applicable to gaseous hydrogen systems only. Where a distance of 15 ft (4.5 m) is required, the distance can be subject to increase if the room height is greater than 15 ft (4.5 m). The classified zone can extend to the outdoors to a point 15 ft (4.5 m) from the point at which the ventilation system provided exits the building. See NFPA 497 for additional information.

**A.9.4.3.2.1** A maximum fueling event is that amount of fuel that is dispensed in a single operation of the dispenser. The fueling event begins when fuel begins to flow to the vehicle, and is terminated when the flow of fuel is terminated or when the vehicle being fueled has been filled to capacity.

**A.9.4.3.2.3** For example, if the maximum fueling event for a single dispenser is 1.8 lb (0.8 kg) based on a minimum room volume of 35,000 scf (1000 $m^3$), the addition of a single additional dispenser will require that the minimum room volume be not less than 71,000 scf (2000 $m^3$).

**A.9.9.2** Vent locations should be designed such that if the safety valve is relieving at capacity and ignited, radiated heat felt by an individual who can be present at grade will not exceed 500 $Btu/hr{\cdot}ft^2$ (5.68 $MJ/hr{\cdot}m^2$). This does not apply to locations where access is restricted to personnel with appropriate protection.

**A.9.10.1** Either the media used for leak testing should be compatible with all equipment according to the manufacturer's instructions or the equipment should be isolated during the test. It is not necessary to pressure test equipment that has already been pressure tested before installation. If a pressure test is required on a system or portion of a system that includes previously tested equipment, either the testing media should be compatible with the previously tested equipment according to the manufacturer's instructions or the equipment should be isolated during the test.

**A.9.13.1** See API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.*

**A.9.13.3.2** Motor vehicles can acquire an electrostatic charge while traveling. The resistance offered by the tires through an uncoated concrete surface is low enough that this charge dissipates to ground very quickly (seconds or less). However, under dry conditions, an asphalt surface can offer sufficient resistance that the charge will not dissipate in a timely manner. A small number of incidents have occurred in Europe where a nonabsorbent polymer having unusually high resistance was used at service stations to prevent soil contamination from gasoline spills. Therefore, paved surfaces that result in a resistance greater than 1 megohm should not be used. Transfer surface materials meeting the criteria specified will provide for the dissipation of static charge built up on the vehicle before the driver opens the door to initiate refueling. The 1 megohm criterion is cited from API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.* Measurement of the resistivity of the vehicle fueling pad can be conducted using BS EN 1081: *Determination of Electrical Resistance — Resilient Floor Coverings.*

**A.9.15** The purpose of the extinguisher is to extinguish not a gas fire but other fires in the area. Gas fires should be extinguished by shutting off the source of the gas.

**A.9.16.4** See A.8.16.6.

**A.10.2.2** For information on standards for listing fueling appliances, see AGA publication, *Requirements for Natural Gas Vehicle (NGV) Fueling Appliances.*

**A.10.4.2.2** An RFF-CNG that is listed can utilize a combination of ventilation and gas detection to ensure that the room is maintained at a level below one-fifth of the LFL of natural gas. This is deemed to be equivalent to a gas detector located within 6 in. (150 mm) of the ceiling or the highest point in the room.

**A.11.3.4** Shut-off valves should be located as close as practical to the tank outlets and should be protected from damage from collision to the extent possible. Due to the potential for collision damage and fire, the use of design features, such as automatic shut-off valves, shut-off valves located inside the tank assembly, and high G and excess flow shutoffs for such valves, should be considered.

**A.12.2.3.3** The potential spill from a fixed container equipped with the valves discussed in Section 15.6 is limited to the volume of the piping system. For transfer operations where the source of a spillage is from a truck unloading, the spill volume is either the 10-minute flow from the truck, assuming design flow, or a lower volume if the truck is equipped with automatic shutoff.

The facility can be arranged so that the container and transfer areas' spill containment can be a common impounding area. In this case, the volume determined by 12.2.3.3 will usually satisfy both requirements.

**A.12.2.3.5** The potential spill from a fixed container equipped with the valves discussed in Section 12.6 is limited to the volume of the piping system. For transfer operations where the source of a spillage is from a truck unloading, the spill volume is either the 10-minute flow from the truck, assuming design flow, or a lower volume if the truck is equipped with automatic shutoff.

The facility can be arranged so that the container and transfer areas' spill containment can be a common impounding area. In this case, the volume determined by 12.2.3.5 will usually satisfy both requirements.

**A.12.2.4.2** For information on venting of explosions, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. Snow loads should be considered where applicable.

**A.12.2.4.2.6** This rate corresponds to five air changes per hour.

**A.12.12.4** Examples of such other means might include a physical interruption of the conduit run and of the stranded conductor(s) through the use of an adequately vented junction box containing terminal strip or busbar connections; an exposed section of MI cable using suitable fittings; or an exposed section of single conductor(s) incapable of transmitting gases or vapors. *[See Sections 505.16(A) through 505.16(E) of NFPA 70, National Electrical Code.]*

**A.12.13** For more information on maintenance of LNG equipment, see AGA publication *LNG Preventive Maintenance Guide*.

**A.14.3.1.3.1** The lighting should be designed to provide illumination of the dispensing apparatus and dispensing area, such that all controls including emergency shutdown devices are visible to the operator.

**A.14.3.2.3** When locating liquefied hydrogen storage containers in proximity to all classes of aboveground flammable and combustible liquid storage or liquid oxygen storage, the liquefied hydrogen container should be on ground higher than all classes of flammable and combustible liquid storage or liquid oxygen storage, as spilled material will quickly vaporize, thereby mitigating the potential exposure hazard to the other fluids. [**55:** A.11.3.1.2]

**A.14.3.2.4.1** The intent of these provisions is to make certain that the cryogenic installation is not exposed to the potential of a pool fire from the release of flammable or combustible liquids. $LH_2$ are not diked in order that they are allowed to dissipate should leakage occur. Studies conducted by NASA (NSS 1740.16, *Safety Standard for Hydrogen and Hydrogen Systems*, 1997) show that the use of dikes around liquid hydrogen storage facilities serves to prolong ground-level flammable cloud travel and that the dispersion mechanism is enhanced by vaporization-induced turbulence. The travel of spilled or leaked $LH_2$ to distances greater than a few feet (meters) from the source given the nature of the typical leak is considered to be implausible due to the character of $LH_2$ and their ability to quickly absorb heat from the surrounding environment. [**55:** A.8.13.2.6.4.1]

**A.14.9** Corrosion characteristics of hydrogen, as well as other corrosives to which components may be exposed, should be accounted for in the specification of materials and the design and installation of components and systems.

**A.14.9.3** Recommended practices of the National Association of Corrosion Engineers (NACE) can be used as guidance for the design and installation of protections systems. See NACE Standard RP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, for additional information. Corrosion protection of all other materials should be in accordance with the requirements of Steel Structures Painting Council Specifications SSPC-PA 1, *Shop, Field and Maintenance Painting*; SSPC-PA 2, *Measurement of Dry Paint Thickness with Magnetic Gages*; and SSPC-SP 6, *Commercial Blast Cleaning*.

Stainless steel systems can still require protection when the potential exists for corrosion from exposure to atmospheric contamination, which includes chlorides, sulfur compounds, and salt water. Tape and packing materials are not considered suitable protection against corrosion.

**A.14.10.5.2** Although pressure gauges can be used to determine system pressure, pressure transducers are commonly used to monitor pressure and are typically designed to withstand and indicate 20 percent or greater than the maximum system pressure.

**A.14.11.1** To be indirect, heat must be transferred by a transfer medium, such as air, steam, water, oil, or comparable heat sources. The use of direct-heat transfer media including electrical sources or flame, presents a potential hazard should the system overheat, resulting in damage to the wall of the tubing used to construct the vaporizer. [**55:** A.11.2.5.1]

**A.14.11.2** The loss of heat or the withdrawal of hydrogen at a rate exceeding the design capacity of the vaporizer presents a circumstance where cryogenic fluid is transported into portions of the piping system that have been designed to contain gaseous — not liquid — hydrogen. Such an event is able to result in brittle failure of the piping system downstream of the vaporizer. The potential to trap liquid in parts of the system that have not been designed to accommodate liquid can result in a loss of hydrogen and the generation of hazardous conditions. [**55:** A.11.2.5.2]

**A.15.2.3** The emergency response plan should be kept readily available, and it should be updated as necessary to include changes in personnel, equipment, or procedures. The response plan should include, but not be limited to, the following:

(1) The use of an emergency shutdown system to isolate various portions of the equipment and other applicable measures to ensure that the escape of liquid or gas is cut off promptly or reduced as much as possible
(2) Use of fire protection systems
(3) Notification of public authorities and neighboring properties
(4) First aid
(5) Duties of personnel
(6) An evacuation plan

**A.15.4** For more information on personnel safety, see the AGA publication *Introduction to LNG for Personnel Safety*.

**A.15.4.3** For more information on training personnel, see the AGA publication *LNG Plant Operator Training Guide*.

**A.16.1** For information on on-site storage of LNG in ASME tanks larger than 70,000 gal (265,000 L) and in tanks built to API or other standards, see NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

**A.17.7** Section 17.7 supersedes 4.5.3 of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft.*

**A.17.7.8** Subsection 17.7.8 supersedes 6.1.1 of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft.*

**A.17.9** Section 17.9 supersedes Section 7.3 of NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft.*

**A.17.16.1(7)** Handheld natural gas detectors aid in evaluating alarms and making a survey of the vessel. These instruments will allow for the location of specific leaks at very low levels of detection and can be carried by personnel working in a compartment containing gas storage or transmission equipment.

## Annex B Sample Ordinance Adopting NFPA 52

*This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

**B.1** The following sample ordinance is provided to assist a jurisdiction in the adoption of this [*code, standard*] and is not part of this [*code, standard*].

ORDINANCE NO. ____________

An ordinance of the *[jurisdiction]* adopting the *[year]* edition of NFPA *[document number]*, *[complete document title],* and documents listed in Chapter 2 of that [*code, standard*]; prescribing regulations governing conditions hazardous to life and property from fire or explosion; providing for the issuance of permits and collection of fees; repealing Ordinance No. _______ of the *[jurisdiction]* and all other ordinances and parts of ordinances in conflict therewith; providing a penalty; providing a severability clause; and providing for publication; and providing an effective date.

BE IT ORDAINED BY THE *[governing body]* OF THE *[jurisdiction]*:

SECTION 1 That the *[complete document title]* and documents adopted by Chapter 2, three (3) copies of which are on file and are open to inspection by the public in the office of the *[jurisdiction's keeper of records]* of the *[jurisdiction]*, are hereby adopted and incorporated into this ordinance as fully as if set out at length herein, and from the date on which this ordinance shall take effect, the provisions thereof shall be controlling within the limits of the *[jurisdiction]*. The same are hereby adopted as the [*code, standard*] of the *[jurisdiction]* for the purpose of prescribing regulations governing conditions hazardous to life and property from fire or explosion and providing for issuance of permits and collection of fees.

SECTION 2 Any person who shall violate any provision of this code or standard hereby adopted or fail to comply therewith; or who shall violate or fail to comply with any order made thereunder; or who shall build in violation of any detailed statement of specifications or plans submitted and approved thereunder; or fail to operate in accordance with any certificate or permit issued thereunder; and from which no appeal has been taken; or who shall fail to comply with such an order as affirmed or modified by a court of competent jurisdiction, within the time fixed herein, shall severally for each and every such violation and noncompliance, respectively, be guilty of a misdemeanor, punishable by a fine of not less than $ _____ nor more than $_____ or by imprisonment for not less than ______ days nor more than ______ days or by both such fine and imprisonment. The imposition of one penalty for any violation shall not excuse the violation or permit it to continue; and all such persons shall be required to correct or remedy such violations or defects within a reasonable time; and when not otherwise specified the application of the above penalty shall not be held to prevent the enforced removal of prohibited conditions. Each day that prohibited conditions are maintained shall constitute a separate offense.

SECTION 3 Additions, insertions, and changes — that the *[year]* edition of NFPA *[document number]*, *[complete document title]* is amended and changed in the following respects:

List Amendments

SECTION 4 That ordinance No. _________ of *[jurisdiction]* entitled *[fill in the title of the ordinance or ordinances in effect at the present time]* and all other ordinances or parts of ordinances in conflict herewith are hereby repealed.

SECTION 5 That if any section, subsection, sentence, clause, or phrase of this ordinance is, for any reason, held to be invalid or unconstitutional, such decision shall not affect the validity or constitutionality of the remaining portions of this ordinance. The *[governing body]* hereby declares that it would have passed this ordinance, and each section, subsection, clause, or phrase hereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses, and phrases be declared unconstitutional.

SECTION 6 That the *[jurisdiction's keeper of records]* is hereby ordered and directed to cause this ordinance to be published.

[NOTE: An additional provision may be required to direct the number of times the ordinance is to be published and to specify that it is to be in a newspaper in general circulation. Posting may also be required.]

SECTION 7 That this ordinance and the rules, regulations, provisions, requirements, orders, and matters established and adopted hereby shall take effect and be in full force and effect *[time period]* from and after the date of its final passage and adoption.

## Annex C Pressure Relief Devices (PRDs)

*This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

**C.1** It is recommended that pressure relief devices (PRDs) should be sized to protect ASME pressure vessels against excessive pressure caused by exposure to fire or other sources of external heat, since this is the worst case condition. As noted in the ASME *Boiler and Pressure Vessel Code*, Section VIII, Appendix M, API RP 520, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries*, Part I, is a reference document for sizing of PRDs for fire conditions. Other useful documents include CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*; and CGA S-1.2, *Pressure Relief Device Standards — Part 2 — Cargo and Portable Tanks for Compressed Gases.*

Where tank designs are such that heat conduction from a fire could be insufficient to activate a thermally operated PRD, the use of heat conduction devices or insulating noncombustible materials, or both, should be considered (e.g., a ceramic blanket can prevent rupture of a cylinder due to a localized fire).

Thermally operated PRDs might not activate if the cylinder is in a fire that is localized and some distance away from the PRDs.

It has been demonstrated that a 1 in. (25 mm) ceramic blanket can keep the surface temperature of the container below 392°F (200°C) under fire conditions for 45 minutes.

Manifolded installations of multiple containers or pressure relief vent lines should be designed after taking the following into account:

(1) If fire can be expected to act on some of the containers while others are unaffected, gas could flow through the manifold from the unexposed containers to the containers exposed to fire. This can reduce the rate of pressure relief to an unsafe level. Some considerations in evaluating this risk are as follows:
   (a) The flow capacity of the individual PRDs. High flow devices can safely vent multiple containers through a single device.
   (b) Automatic valves closed by a fire condition or check valves can be used to isolate containers or groups of containers to prevent flow through the manifold.
   (c) Containers distributed over a large vehicle are more susceptible to partial fire exposure.
   (d) Containers mounted in compartments might not be exposed to the same fire conditions as other containers outside of the compartment or in a different compartment.
   (e) Container manufacturer will have data from the required container fire tests that can support the design of the manifolding.
(2) Manifolds for vent lines of multiple PRDs can be designed with a flow capacity less than the sum of the flow capacities of all of the PRDs. The following are some of the conditions in such a design:
   (a) Containers can have PRDs at each end for protection against partial fire exposures. Either PRD will generally have sufficient flow capacity to vent the containers safely.
   (b) Containers protected with high flow PRDs can be expected to vent to a safe pressure level before the fire spreads to containers located elsewhere in the vehicle.
   (c) The individual PRD might have greater capacity than is required to perform safely in the container fire test. The container manufacturer will have data from the required container fire test that can support a manifold design with flow capacity less than the total PRD flow capacities.

## Annex D OSHA Requirements for Hydrogen Systems

*This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

*This annex is extracted from Annex G of NFPA 55, Compressed Gases and Cryogenic Fluids Code.*

**D.1 Introduction.** The Occupational Safety and Health Administration (OSHA) establishes requirements for hydrogen systems in 29 CFR 1910.103. The tabular distances reflect those values published in the July 1, 2006, edition of the CFR. The criteria established in OSHA's tables of distances are based on the 1969 edition of NFPA 50A, which superseded the 1963 edition. Subsequent editions were adopted in 1973, 1978, 1984, 1989, 1994, and 1999. In 2003, the document was integrated into NFPA 55 because the committee believed that one standard covering storage and use of all compressed gases and cryogenic fluids was needed. NFPA 55 was revised in 2005 because the requirements for compressed gases and cryogenic fluids were broadened.

Throughout the eight revision cycles of NFPA 55, the tabular distances were revised as the technology in the use of hydrogen advanced. However, the tabular distances listed in the OSHA tables remain based on the 1969 data. It is important to recognize that the OSHA tables represent the current statutory requirements. While the OSHA tables may, in fact, be accurate, it should also be recognized that the OSHA tables in some cases lack clarity and that, in other cases, hazards recognized by the ongoing evolution of the separation tables have not been acknowledged.

For an example of lack of clarity, consider row 1 of Table D.2(a) (Building or structure). The OSHA table refers to buildings by construction types, including wood frame, heavy timber, ordinary, and fire resistive. Current construction types are now designated as Types I through V, with variations to address the elements of construction, including the supporting structure as well as the construction of the roof and exterior walls. Although one can guess as to the original intent, there is no clear correlation between the construction types designated in the OSHA tables and current editions of either NFPA 220, *Standard on Types of Building Construction*, or *NFPA 5000, Building Construction and Safety Code*.

Other examples where clarity is needed include rows 3, 4, and 5, which specify separation distance from flammable liquids, raising the question as to whether combustible liquids should be considered or ignored. Examples of hazards not addressed include the fact that there are no prescribed distances for separation from property lines, public sidewalks, and parked vehicles. A close comparison between the OSHA tables and the distance tables found in the 2005 edition of NFPA 55 reveals a number of discrepancies.

**D.2 OSHA Tables.** The OSHA tables Table D.2(a) and Table D.2(b)] are provided to inform the code user of the minimum requirements as they currently exist under 29 CFR and the federal OSHA program. It is incumbent on installers and property owners to recognize the limitations of OSHA based on the precedent requirements established with the use of the 1969 edition of NFPA 50A. The use of alternative approaches to distance as now embodied within the body of the code is subject to approval on a location-by-location basis. The typical AHJ traditionally has been a fire official, but that person might not be the only official who exercises regulatory control for installations of this nature.

The evaluation of separation distances for bulk gaseous hydrogen systems was the subject of study of a joint task group that comprised members of NFPA's Hydrogen Technology Technical Committee and the Industrial and Medical Gases Technical Committee. The task of the group was to examine the exposure distances published in Table 10.3.2.2.1 of the 2005 edition of NFPA 55 for the purpose of validation or revision based on a scientific approach that could be substantiated either through testing or through generally accepted scientific means.

The determination of separation distance was initially approached through the use of a consequence-based approach in which the consequences of a release of hydrogen from a system resulted either in ignition and its attendant jet flame or in an envelope of unignited gas, which was subject to dispersion. In each instance, the effects of a release on a receptor were considered within the context of hazard scenarios developed in the performance approach foundational to determining the design scenarios outlined in the performance-based option integral to NFPA 1, *Fire Code*.[1]

Notes for each of the rows found in Table 9.3.1.3(a) and Table 9.3.1.3(b) have been developed to inform the user of the rationale considered for each of the exposures listed in Table D.2(c) and Table D.2(d)). Table D.2(c) is cross-referenced to Table 9.3.1.3(a) and Table 9.3.1.3(b) by row number.

Notes are provided to indicate the specific rationale considered for each of the exposures listed. The notes are then cross-referenced to specific hazard scenarios further defined in Table D.2(d). The performance criteria and design scenarios have been extracted from NFPA 1 as indicated in the extracts provided. In the event alternative materials or methods are to be employed when bulk systems are installed, code users should be aware of the specific hazard scenarios attendant to each exposure.

Studies by Houf and Schefer of Sandia National Laboratories predicted the radiative heat flux at various distances resulting from the ignition of turbulent jet releases of hydrogen from systems at various pressures. In addition, the concentrations of an unignited hydrogen jet in the surrounding air and the envelope of locations where the concentration falls below the lower flammability limit for hydrogen were determined.[2] Understanding the consequences of release in terms of thermal flux or the boundaries of the unignited cloud could then be used to determine distances that were believed to be appropriate based on the consequence of a release. The consequence approach is referred to as a deterministic approach because distances are determined based on consequence alone. Another consequence-based approach, found in a project

**Table D.2(a) OSHA Table: Minimum Distance from Liquefied Hydrogen Systems to Exposure**

| | Size of Hydrogen System | | | | | |
|---|---|---|---|---|---|---|
| | <3,000 scf (85 $m^3$) | | 3,000 to 15,000 scf (85 $m^3$ to 425 $m^3$) | | >15,000 scf (425 $m^3$) | |
| **Type of Outdoor Exposure** | **ft** | **m** | **ft** | **m** | **ft** | **m** |
| 1. Building or structure | | | | | | |
| Wood frame construction[1] | 10 | 3.1 | 25 | 7.6 | 50 | 15.2 |
| Heavy timber, noncombustible, or ordinary construction[1] | 0 | 0 | 10 | 3.1 | 25 | 7.6 |
| Fire resistive construction[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| 2. Wall openings | | | | | | |
| Not above any part of a system | 10 | 3.1 | 10 | 3.1 | 10 | 3.1 |
| Above any part of a system | 25 | 7.6 | 25 | 7.6 | 25 | 7.6 |
| 3. Flammable liquids above ground | | | | | | |
| 0–1000 gal (3785 L) | 10 | 3.1 | 25 | 7.6 | 25 | 7.6 |
| In excess of 1000 gal (3785 L) | 25 | 7.6 | 50 | 15.2 | 50 | 15.2 |
| 4. Flammable liquids below ground — 0–1000 gal (3785 L) | | | | | | |
| Tank | 10 | 3.1 | 10 | 3.1 | 10 | 3.1 |
| Vent of fill opening of tank | 25 | 7.6 | 25 | 7.6 | 25 | 7.6 |
| 5. Flammable liquids below ground, in excess of 1000 gal (3785 L) | | | | | | |
| Tank | 20 | 6.1 | 20 | 6.1 | 20 | 6.1 |
| Vent of fill opening of tank | 25 | 7.6 | 25 | 7.6 | 25 | 7.6 |
| 6. Flammable gas storage, either high pressure or low pressure | | | | | | |
| 0–15,000 scf (425 $m^3$) capacity | 10 | 3.1 | 25 | 7.6 | 25 | 7.6 |
| In excess of 15,000 scf (425 $m^3$) capacity | 25 | 7.6 | 50 | 15.2 | 50 | 15.2 |
| 7. Oxygen storage | | | | | | |
| 12,000 scf (340 $m^3$) or less[4] | | | | - | | |
| More than 12,000 scf (340 $m^3$)[5] | | | | - | | |
| 8. Fast-burning solids such as ordinary lumber, excelsior, paper | 50 | 15.2 | 50 | 15.2 | 50 | 15.2 |
| 9. Slow-burning solids such as heavy timber, coal | 25 | 7.6 | 25 | 7.6 | 25 | 7.6 |
| 10. Open flames and welding | 25 | 7.6 | 25 | 7.6 | 25[2] | 7.6[2] |
| 11. Air compressor intakes or inlets to ventilating or air-conditioning equipment | 50 | 15.2 | 50 | 15.2 | 50 | 15.2 |
| 12. Concentration of people[3] | 25 | 7.6 | 50 | 15.2 | 50 | 15.2 |

[1] Refer to NFPA 220, *Standard on Types of Building Construction*, for definitions of various types of construction (1969).
[2] But not less than one-half the height of adjacent side wall of the structure.
[3] In congested areas such as offices, lunchrooms, locker rooms, time-clock areas.
[4] Refer to NFPA 51, *Gas Systems for Welding, Cutting* (1969).
[5] Refer to NFPA 566, *Bulk Oxygen Systems at Consumer Sites.*

**Table D.2(b) OSHA Table: Minimum Distance (Feet) from Liquefied Hydrogen Systems to Exposure[1,2]**

| | Liquefied Hydrogen Storage | | | | | |
|---|---|---|---|---|---|---|
| | 39.63–3,500 gal (150–13,249 L) | | 3,501–15,000 gal (13,249–56,780 L) | | 15,001–30,000 gal (56,780–113,559 L) | |
| **Type of Outdoor Exposure** | **ft** | **m** | **ft** | **m** | **ft** | **m** |
| 1. Fire resistive building and fire walls[3] | 5 | 1.5 | 5 | 1.5 | 5 | 1.5 |
| 2. Noncombustible building[3] | 25 | 7.6 | 50 | 15.2 | 75 | 22.9 |
| 3. Other buildings[3] | 50 | 15.2 | 75 | 22.9 | 100 | 30.5 |
| 4. Wall openings, air-compressor intakes, inlets for air-conditioning or ventilating equipment | 75 | 22.9 | 75 | 22.9 | 75 | 22.9 |
| 5. Flammable liquids (above ground and vent or fill openings if below ground) (See 513 and 514) | 50 | 15.2 | 75 | 22.9 | 100 | 30.5 |
| 6. Between stationary liquid hydrogen containers | 5 | 1.5 | 5 | 1.5 | 5 | 1.5 |
| 7. Flammable gas storage | 50 | 15.2 | 75 | 22.9 | 100 | 30.5 |
| 8. Liquid oxygen storage and other oxiders (See 513 and 514) | 100 | 30.5 | 100 | 30.5 | 100 | 30.5 |
| 9. Combustible solids | 50 | 15.2 | 75 | 22.9 | 100 | 30.5 |
| 10. Open flames, smoking and welding | 50 | 15.2 | 50 | 15.2 | 50 | 15.2 |
| 11. Air compressor intakes or inlets to ventilating or air-conditioning equipment | 50 | 15.2 | 50 | 15.2 | 50 | 15.2 |
| 12. Concentrations of people[4] | 75 | 22.9 | 75 | 22.9 | 75 | 22.9 |

[1]The distances in Nos. 2, 3, 5, 7, 9 and 12 may be reduced where protective structures such as fire walls equal to the top of the container, to safeguard the liquefied hydrogen storage system, are located between the liquefied hydrogen installation and the exposure.
[2]Where protective structures are provided, ventilation and confinement of product should be considered. The 5 ft (1.5 m) distance in Nos. 1 and 6 facilitates maintenance and enhances ventilation.
[3]Refer to NFPA 220, *Standard on Types of Building Construction*, for definitions of various types of construction (1969).
[4]In congested areas such as offices, lunchrooms, locker rooms, time-clock areas.

sponsored by NFPA's Fire Research Foundation, to determine appropriate separation distances for certain installations of bulk gaseous hydrogen systems was also reviewed by the task group, and comparisons were made to the existing requirements in the 2005 edition of NFPA 55. [3]

As the group evaluated the impact of the deterministic tables, it became apparent that the probability of occurrence of events could have a bearing on determining a reasonable level of safety. NFPA 55 addresses the installation of bulk hydrogen systems used for any application. Whether the installation is to serve an industrial use or an emerging technology that uses hydrogen as an alternative fuel, the installation standards have a common basis in which the safety of the user, employees, and members of the public is of concern. Recent work undertaken by the U.S. Department of Energy to develop a scientific basis for control of this material has resulted in substantial technological advancement in the safety aspects involved in the use of hydrogen as an alternative fuel. Whether the material is used as a vehicle fuel or in classic industrial processes, the hazards of a bulk installation are similar. It was also recognized that use as an alternative fuel would have the impact of increasing the number of installations such that there would be broader exposure to the public at large.

The work of the task group integrated the efforts of Sandia National Laboratories' risk and reliability department. LaChance, in a paper discussing the use of risk in determining acceptable separation distances, explains the focus of ongoing work to provide a defensible analysis strategy for risk and consequence assessment of unintended releases from hydrogen systems, generally referred to as a scientific basis for the establishment of separation distances, and describes the work in pertinent part as follows:

As part of the U.S. Department of Energy Hydrogen, Fuel Cells & Infrastructure Technologies Program, Sandia National Laboratories is developing the technical basis for assessing the safety of hydrogen-based systems for use in the development/modification of relevant codes and standards. The project impacts most areas of hydrogen utilization, including bulk transportation and distribution, storage, production and utilization. Sandia is developing benchmark experiments and a defensible analysis strategy for risk and consequence assessment of unintended releases from hydrogen systems. This work includes experimentation and modeling to understand the fluid mechanics and dispersion of hydrogen for different release scenarios, including investigations of hydrogen combustion and subsequent heat transfer from hydrogen flames. The resulting technical information is incorporated into engineering models that are used for assessment of different hydrogen release scenarios and for input into quantitative risk assessments (QRA) of hydrogen facilities.

The QRAs are used to identify and quantify scenarios for the unintended release of hydrogen, identify the significant risk contributors at different types of hydrogen facilities, and to identify potential accident prevention and mitigation strategies to reduce the risk to acceptable levels. The results of the QRAs are one input into a risk-informed codes and standards development process that can also include other considerations by the code and standard developers. Examples of these

**Table D.2(c) Hazard Scenario**

| Row | Exposure | Hazard Scenario Rationale* |
|---|---|---|
| 1 | Lot lines | 1, 2, 3, 4, 5 |
| 2 | Exposed persons other than those involved in servicing of the system | 4 |
| 3 | Buildings and structures<br>Combustible construction<br>Noncombustible non-fire-rated construction<br>Fire-rated construction with fire resistance rating of not less than 2 hours | 2 |
| 4 | Openings in buildings of fire-rated or non-fire-rated construction (doors, windows, penetrations)<br>Openable<br>Fire-rated or non fire-rated<br>Unopenable<br>Fire-rated or non fire-rated | 1, 2 |
| 5 | Air intakes (HVAC, compressors, other) | 1 |
| 6 | Fire barrier walls or structures used to shield bulk system from exposures | 2, 4 |
| 7 | Unclassified electrical equipment | 2, 5 |
| 8 | Utilities (overhead), including electric power, building services, hazardous materials piping | 2, 10 |
| 9 | Ignition sources such as open flames and welding | 3, 5 |
| 10 | Parked cars | 4 |
| 11 | Flammable gas storage systems, including other hydrogen systems above ground<br>Nonbulk<br>Bulk | 2 |
| 12 | Aboveground vents or exposed piping and components of flammable gas storage systems, including other hydrogen systems below ground<br>Gaseous or cryogenic | 6, 7 |
| 13 | Hazardous materials (other than flammable gases) storage below ground<br>Physical hazard materials or health hazard materials | 6, 7 |
| 14 | Hazardous materials storage (other than flammable gases) above ground<br>Physical hazard materials or health hazard materials | 8, 9 |
| 15 | Ordinary combustibles, including fast-burning solids such as ordinary lumber, excelsior, paper, combustible waste, vegetation other than that found in maintained landscaped areas | 2 |
| 16 | Heavy timber, coal, other slow-burning combustible solids | 2 |

*See Table D.2(d) for explanation of notes.

other considerations can include the results of deterministic analyses of selected accidents scenarios, the need for defense-in-depth for certain safety features (e.g., overpressure protection), the use of safety margins for high-pressure components, and requirements identified from the actual occurrences at hydrogen facilities. [4]

To evaluate risk, the history of leakage data from high pressure compressed gas systems was needed. Hydrogen-specific leak data were provided by one of the major suppliers through the use of a 5-year documented collection of leak data from both industrial and fueling uses. These data were augmented with data from other sources after being reviewed for applicability, and representative values were selected. The source documents considered in augmentation of hydrogen-specific data included the following publications:

(1) "Determination of Safety Distances," European Industrial Gases Association, IGC Doc 75/07/E, 2007
(2) A. W. Cox, F. P. Lees, and M. L. Ang, "Classification of Hazardous Locations," Institution of Chemical Engineers, May 2003
(3) C. H. Blanton and S. A. Eide, "Savannah River Site Generic Data Base Development," WSRC-TR-93-262, Westinghouse Savannah River Company, June 30, 1993
(4) J. Spouge, "New Generic Leak Frequencies for Process Equipment," *Process Safety Progress* (Vol. 24, No. 4), December 2005

A hierarchy was developed that gave hydrogen-specific data the highest priority, followed by non-gas-specific data where available for high pressure components. Piping and instrumentation drawings (P&IDs) were then prepared to define a standard bulk supply system in terms of modules that might be found in the typical system. The P&IDs can be found in A.3.3.57.1. The P&IDs were reviewed by suppliers and the typical nature verified.

Frequency and size of leaks encountered were evaluated across a number of systems, including both industrial and fueling operations. The leak/failure data were then applied to "typical" fitting counts (components) integral to each of the modules identified in the P&IDs for each of the components. The failure data were based on the most recent 5-year history for high pressure systems. Hydrogen-specific data were provided by Compressed Gas Association (CGA) representatives. These data were augmented by failure data from other resources obtained by researchers from Sandia National Laboratories and combined to quantify a probability for failure on a component-by-component basis [hoses (pigtails), valves, elbows, tees, pipe, gauges, etc.]. The analysis resulted in a probability for failure being developed for each component, which could then be wrapped into failures expected across the spectrum of the various modules included in the array of P&IDs developed.

**Table D.2(d) Hazard Scenario Rationale Notes to Table D.2(c)**

| Note Number | Statement | Performance Criteria | Hazardous Materials Design Scenario |
|---|---|---|---|
| 1 | Gas release and subsequent entrainment or accumulation by the receptor | **Explosion Conditions.** The facility design shall provide an acceptable level of safety for occupants and for individuals immediately adjacent to the property from the effects of unintentional detonation or deflagration. [**1:**5.2.2.2] | **Hazardous Materials Design Scenario 1.** Hazardous Materials Design Scenario 1 involves an unauthorized release of hazardous materials from a single control area. This design scenario shall address the concern regarding the spread of hazardous conditions from the point of release. [**1:**5.4.4.1] |
| 2 | Fire spread to or from adjacent equipment or structure | **Property Protection.** The facility design shall limit the effects of all required design scenarios from causing an unacceptable level of property damage. [**1:**5.2.2.4] | **Hazardous Materials Design Scenario 2.** Hazardous Materials Design Scenario 2 involves an exposure fire on a location where hazardous materials are stored, used, handled, or dispensed. This design scenario shall address the concern regarding how a fire in a facility affects the safe storage, handling, or use of hazardous materials. [**1:**5.4.4.2] |
| 3 | Gas explosion hazard on site or affecting adjacent property | **Explosion Conditions.** The facility design shall provide an acceptable level of safety for occupants and for individuals immediately adjacent to the property from the effects of unintentional detonation or deflagration. [**1:**5.2.2.2] | **Hazardous Materials Design Scenario 1.** Hazardous Materials Design Scenario 1 involves an unauthorized release of hazardous materials from a single control area. This design scenario shall address the concern regarding the spread of hazardous conditions from the point of release. [**1:**5.4.4.1] |
| 4 | Threat of injuries on site or adjacent property | **Hazardous Materials Exposure.** The facility design shall provide an acceptable level of safety for occupants and for individuals immediately adjacent to the property from the effects of an unauthorized release of hazardous materials or the unintentional reaction of hazardous materials. [**1:**5.2.2.3] | **Hazardous Materials Design Scenario 2.** Hazardous Materials Design Scenario 2 involves an exposure fire on a location where hazardous materials are stored, used, handled, or dispensed. This design scenario shall address the concern regarding how a fire in a facility affects the safe storage, handling, or use of hazardous materials. [**1:**5.4.4.2] **Hazardous Materials Design Scenario 4.** Hazardous Materials Design Scenario 4 involves an unauthorized discharge with each protection system independently rendered ineffective. This set of design hazardous materials scenarios shall address concern regarding each protection system or protection feature, considered individually, being unreliable or becoming unavailable. [**1:**5.4.4.4.1] |
| 5 | Ignition of an unignited release/vented hydrogen | **Explosion Conditions.** The facility design shall provide an acceptable level of safety for occupants and for individuals immediately adjacent to the property from the effects of unintentional detonation or deflagration. [**1:**5.2.2.2] | **Hazardous Materials Design Scenario 1.** Hazardous Materials Design Scenario 1 involves an unauthorized release of hazardous materials from a single control area. This design scenario shall address the concern regarding the spread of hazardous conditions from the point of release. [**1:**5.4.4.1] |

**Table D.2(d)** ***(Continued)***

| Note Number | Statement | Performance Criteria | Hazardous Materials Design Scenario |
|---|---|---|---|
| 6 | Damage to exposed components of underground system that are exposed above ground | **Property Protection.** The facility design shall limit the effects of all required design scenarios from causing an unacceptable level of property damage. [**1:**5.2.2.4] | **Hazardous Materials Design Scenario 1.** Hazardous Materials Design Scenario 1 involves an unauthorized release of hazardous materials from a single control area. This design scenario shall address the concern regarding the spread of hazardous conditions from the point of release. [**1:**5.4.4.1] |
| 7 | Damage to aboveground system due to function of explosion control system used to vent underground vault or structure | **Property Protection.** The facility design shall limit the effects of all required design scenarios from causing an unacceptable level of property damage. [**1:**5.2.2.4] **Explosion Conditions.** The facility design shall provide an acceptable level of safety for occupants and for individuals immediately adjacent to the property from the effects of unintentional detonation or deflagration. [**1:**5.2.2.2] | **Hazardous Materials Design Scenario 3.** Hazardous Materials Design Scenario 3 involves the application of an external factor to the hazardous material that is likely to result in a fire, explosion, toxic release, or other unsafe condition. This design scenario shall address the concern regarding the initiation of a hazardous materials event by the application of heat, shock, impact, or water onto a hazardous material being stored, used, handled, or dispensed in the facility. [**1:**5.4.4.3] |
| 8 | Fire or explosion in other hazardous materials resulting in release of hydrogen | **Hazardous Materials Exposure.** The facility design shall provide an acceptable level of safety for occupants and for individuals immediately adjacent to the property from the effects of an unauthorized release of hazardous materials or the unintentional reaction of hazardous materials. [**1:**5.2.2.3] | **Hazardous Materials Design Scenario 3.** Hazardous Materials Design Scenario 3 involves the application of an external factor to the hazardous material that is likely to result in a fire, explosion, toxic release, or other unsafe condition. This design scenario shall address the concern regarding the initiation of a hazardous materials event by the application of heat, shock, impact, or water onto a hazardous material being stored, used, handled, or dispensed in the facility. [**1:**5.4.4.3] |
| 9 | Fire or explosion in hydrogen system resulting in release of other hazardous materials | **Hazardous Materials Exposure.** The facility design shall provide an acceptable level of safety for occupants and for individuals immediately adjacent to the property from the effects of an unauthorized release of hazardous materials or the unintentional reaction of hazardous materials. [**1:**5.2.2.3] | **Hazardous Materials Design Scenario 2.** Hazardous Materials Design Scenario 2 involves an exposure fire on a location where hazardous materials are stored, used, handled, or dispensed. This design scenario shall address the concern regarding how a fire in a facility affects the safe storage, handling, or use of hazardous materials. [**1:**5.4.4.2] |
| 10 | Failure of equipment exposing hydrogen system to electrical hazard, physical, or health hazard; failure of system exposing utilities to failure | **Property Protection.** The facility design shall limit the effects of all required design scenarios from causing an unacceptable level of property damage. [**1**:5.2.2.4] **Public Welfare.** For facilities that serve a public welfare role as defined in 4.1.5 of NFPA 1, the facility design shall limit the effects of all required design scenarios from causing an unacceptable interruption of the facility's mission. [**1:**5.2.2.5] | **Hazardous Materials Design Scenario 3.** Hazardous Materials Design Scenario 3 involves the application of an external factor to the hazardous material that is likely to result in a fire, explosion, toxic release, or other unsafe condition. This design scenario shall address the concern regarding the initiation of a hazardous materials event by the application of heat, shock, impact, or water onto a hazardous material being stored, used, handled, or dispensed in the facility. [**1:**5.4.4.3] |

A Bayesian approach to the determination of probability was used in the analysis of data by researchers at Sandia National Laboratories. The technical approach and supporting details can be found in the articles listed in Annex E of NFPA 55 and informational articles found in H.2 of NFPA 55. The advantage of the Bayesian approach is that it can combine data from different sources to include uncertainty. This approach is contrary to what has been done in other sources. For example, judgment can be used as a means to determine risk; however, that method does not provide for uncertainty. Such methods are qualitative at best. By comparison, the use of specific leak data results in a quantitative approach.

The tables developed for inclusion in Chapter 9 are said to be *risk informed*, not *risk based*, the difference being that integral to the risk tables is a series of decisions based on the applicability of various factors. For example, with respect to thermal flux, one could use a series of exposures from *no harm* to *fatality*, and those exposures could then be taken from the point of various receptors (workers, people on the property where the installation is located, people off the property, etc.). One of the primary decisions made by the group was that in the final analysis the risk presented for the typical GH2 installation (either industrial or fueling applications) should present no greater risk to the public in terms of fatalities or injuries than does an existing gasoline service station. The average frequency of a fatality or injury associated with the operation of a single gasoline station has been reported to be approximately 2E-5/yr and 7E-4/yr, respectively.[5] Other key decisions of the group included parameters given in Sections D.3 through D.6.

**D.3 Lower Flammable Limit — 4 Percent $H_2$ by Volume.** In scenarios where the concern is that a plume of unignited GH2 from a release may reach an ignition source, the separation distance was determined using a computational fluid dynamics (CFD) model to determine the distance required to reduce the GH2 concentration to 4 percent by volume. A concentration of 4 percent hydrogen in air has been shown to be the lower bounds of an ignitible mixture under ideal conditions for burning. As such, 4 percent is the established lower flammable limit for hydrogen mixtures in air. In other situations, such as the design of flammable gas detection systems, target concentrations of 2 percent, or 1 percent GH2 by volume, are commonly used to provide a factor of safety and account for uncertainties in the configuration that can affect the detection system. This fact could lead one to conclude that 1 percent or 2 percent should be used as the basis for establishing a separation distance as well. However, the inherent uncertainties associated with detection systems, such as room configuration, ventilation rates, and so forth, that drive conservatism in the design of a hydrogen detection system do not exist in the case of this CFD model, and therefore no additional reduction of the conservative 4 percent value is warranted.

**D.4 Use of 3 Percent of Internal Pipe Diameter (ID) as Leak Size.** The development of separation distances for hydrogen facilities can be determined in several ways. A conservative approach is to use the worst possible accidents in terms of consequences. Such accidents can be of very low frequency such that they likely would never occur. Although this approach bounds separation distances, the resulting distances are generally prohibitive. The current separation distances do not reflect this approach. An alternative deterministic approach that is often utilized by standards development organizations (SDOs) and allowed under some regulations is to select accident scenarios that are more probable but do not provide bounding consequences. In this approach, expert opinion is generally used to select the accidents used as the basis for the prescribed separation distances. Although anecdotal experience often forms the basis for the selection of the accidents, the frequency of accidents can also be used as a selection criterion.

A detailed description of the process used and the results achieved are provided in a technical article included in Annex E of NFPA 55.[6] This process follows guidance by the Fire Protection Research Foundation published in March 2007 that encourages NPFA Technical Committees to use risk concepts in their decision-making process.[7] A risk-informed process, as opposed to a risk-based process, utilizes risk insights obtained from quantitative risk assessments (QRAs) combined with other considerations to establish code requirements. The QRAs are used to identify and quantify scenarios for the unintended release of hydrogen, identify the significant risk contributors at different types of hydrogen facilities, and to identify potential accident prevention and mitigation strategies to reduce the risk to acceptable levels.

The risk-informed approach included two considerations: the frequency of hydrogen system leakage and the risk from leakage events. Unfortunately, hydrogen component leakage data are very limited. Past QRAs of hydrogen facilities have thus been forced to utilize leakage rates based on data from non-hydrogen facilities. The European Industrial Gas Association (EIGA)[8], for example, assessed the frequencies presented in five different sources and then used values that were deemed appropriate for the assessment rather than performing any further analysis.

Rather than selecting a value from different generic sources, a different approach was utilized in this assessment. Data from different sources were collected and combined using Bayesian statistics.[9] This approach has three major advantages over the approach utilized by EIGA and other QRA guidance documents. First, it allows for the generation of leakage rates for different amounts of leakage. Second, it generates uncertainty distributions for the leakage rates that can be propagated through the QRA models to establish the uncertainty in the risk results. Finally, it provides a means for incorporating limited hydrogen-specific leakage data to establish estimates for leakage rates for hydrogen components. Limited hydrogen-specific leakage data were obtained through the efforts of the CGA for use in the Bayesian analysis.

Component leak frequencies as a function of leak size were generated for several hydrogen components. The hydrogen-specific leakage rates were used to estimate the leakage frequency for four example systems used as the basis for the risk evaluation used in the study. The cumulative probability for different leak sizes was then calculated to determine what range of leaks represents the most likely leak sizes. The results of this analysis indicated that leaks less than 0.1 percent of the component flow areas represent 95 percent of the leakage frequency for the example systems. Leak areas less than 10 percent of the flow area are estimated to result in 99 percent of the leaks that could occur based on the results of the analysis.

The risks resulting from different size leaks were also evaluated for four standard gas storage configurations. The risk evaluations indicate that the use of 0.1 percent of the component flow area as the basis for determining separation distances results in risk estimates that significantly exceed the $2 \times 10^{-5}$/yr risk guideline selected by the NFPA separation distance working group, particularly for the 7500 psig and 15,000 psig systems. On the other hand, use of a leak size equal to between 1 percent and 10 percent of the component flow area results in risk estimates that are reasonably close to the risk guideline. The fact that the risk estimates are a factor of 2 higher than the risk guideline for the 7500 psig and 15,000 psig example systems was weighed against the uncertainties in the QRA models, most of which result in conservative risk estimates.

Based on the results of both the system leakage frequency evaluation and the associated risk assessment, a diameter of 3 percent of the flow area corresponding to the largest internal pipe downstream of the highest pressure source in the system is used in the model. The use of a 3 percent leak area results in capturing an estimated 98 percent of the leaks that have been determined to be probable based on detailed analysis of the typical systems employed. Typical systems to include components have been established in the form of P&IDs and incorporated into the work so that the basis for the statistical determinations reached can be documented.

**D.5 Selected Heat Flux Values.** The values for heat flux used in development of the separation distance tables are as follows:

(1) 1,577 W/m$^2$ (500 Btu/hr-ft$^2$)
(2) 4,732 W/m$^2$ (1,500 Btu/hr-ft$^2$)
(3) 20,000 W/m$^2$ (6,340 Btu/hr-ft$^2$)
(4) 25,237 W/m$^2$ (8,000 Btu/hr-ft$^2$)

The basis for using each value is as follows:

(1) 1,577 W/m$^2$ (500 Btu/hr-ft$^2$) is used as the "no harm" value. This heat flux is defined by API 521, *Recommended Practice, Guide for Relieving Depressuring Systems*, as the heat flux threshold to which personnel with appropriate clothing can be continuously exposed.[10] This value is slightly less than what the Society of Fire Protection Engineers determined to be the "no harm" heat flux threshold (540 Btu/hr-ft$^2$), that is, the maximum heat flux to which people can be exposed for prolonged periods of time without experiencing pain.[11]
(2) 4,732 W/m$^2$ (1,500 Btu/hr-ft$^2$) is defined by API 521 as the heat flux threshold in areas where emergency actions lasting several minutes may be required by personnel without shielding but with appropriate clothing.[10] It is also defined by the *International Fire Code* as the threshold for exposure to employees for a maximum of 3 minutes.[12]
(3) 20,000 W/m$^2$ (6,340 Btu/hr-ft$^2$) is generally considered the minimum heat flux for the nonpiloted ignition of combustible materials, such as wood.[13]
(4) 25,237 W/m$^2$ (8,000 Btu/hr-ft$^2$) is the threshold heat flux imposed by the *International Fire Code* for noncombustible materials.[12]

**D.6 Pressure as a Controlling Parameter in Lieu of Volume.** The traditional approach of using volume as a determinant in the establishment of distance was revised in favor of using pressure as the determinate factor. The work of Houf and Schefer demonstrated that the flame radiation heat flux and flame length varied with the pressure of gas released across a given orifice.[2] In cases where the high pressure leak of hydrogen was unignited, a turbulent jet is formed and the area of the flammable envelope can be calculated.

Peak flows were used as a means to determine acceptable distances, and comparisons were made to contents. It was determined that once the threshold for a bulk supply had been exceeded, gas pressure, not volume, was the determining factor in establishing the radiant flux or the unignited jet concentration. Detailed analysis over a series of tank pressures of 18.25 bar (250 psig), 207.85 bar (3000 psig), 518.11 bar (7500 psig), and 1035.21 bar (15,000 psig) over a range of leak diameters were examined.

Transient effects varying the quantity and pressure decay over time were ruled out as controlling parameters. Volume was then considered to be at its worst case, which assumed that pressure was constant due to the volume contained. This is especially true for large systems typically encountered in commercial applications. Small systems using small-diameter tubing are accounted for by the use of tables that allow the user to calculate the benefit from the use of small-diameter systems.

**D.7 References**


(1) NFPA 1, *Fire Code*, 2009 edition, National Fire Protection Association, Quincy, MA, Chapter 5.

(2) W. Houf and R. Schefer, "Predicting Radiative Heat Fluxes and Flammability Envelopes from Unintended Releases of Hydrogen," *International Journal of Hydrogen Energy*, Elsevier Publishing, 2007, Vol. 32, pp. 136–151.

(3) J. Floyd, *Siting Requirements for Hydrogen Supplies Serving Fuel Cells in Non-Combustible Enclosures*, Hughes Associates, Inc., 3610 Commerce Drive, Suite 817, Baltimore, MD 21227, HAI Project #3250-000, November 30, 2006.

(4) J. LaChance, *Risk-Informed Separation Distances for Hydrogen Refueling Stations*, Risk and Reliability Department, Sandia National Laboratories, Albuquerque, NM, May 2007. (Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94-AL85000.)

(5) Ibid, p. 11, reference to *Fires in or at Service Stations and Motor Vehicle Repair and Paint Shops,* NFPA, April 2002.

(6) J. LaChance, W. Houf, B. Middleton (all of Sandia National Laboratories), and L. Fluer (of Fluer, Inc.), "Analyses to Support Development of Risk-Informed Separation Distances for NFPA Hydrogen Codes and Standards," SAND 2009-0874, Sandia National Laboratories, Albuquerque, NM 87185, and Livermore, CA 94550, March 2009.

(7) S. E Rose, S. Flamberg, and F. Leverenz, "Guidance Document for Incorporating Risk Concepts into NFPA Codes and Standards," Fire Protection Research Foundation, March 2007.

(8) "Determination of Safety Distances," European Industrial Gases Association, IGC Doc. 75/07/E, 2007.

(9) C. L. Atwood, J. L. LaChance, H. F. Martz, D. J. Anderson, M. Englehardt, D. Whitehead, and T. Wheeler, "Handbook of Parameter Estimation for Probabilistic Risk Assessment," NUREG/CR-6823, U.S. Nuclear Regulatory Commission, Washington, D.C., 2003.

(10) API Recommended Practice 521, *Guide for Pressure Relieving and Depressuring Systems*, 4th edition, March 1997, API Publishing Services, 1220 L. St. N.W., Washington, DC 20005, Table 8, p. 41.

(11) "Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation," *SFPE Engineering Guide*, Society of Fire Protection Engineers, Bethesda, MD 20814, March 2000, p. 8.

(12) ICC, *International Fire Code*™, 2006 edition, International Code Council, 4051 West Flossmoor Road, Country Club Hills, IL 60478-5795, Table 2209.5.4.3.6(1), p. 210.

(13) V. Babrauskas, "Ignition of Wood: A Review of the State of the Art," Interflam 2001, Interscience Communications Ltd., London, 2001, pp. 71–88.

## Annex E Material Compatibility for Hydrogen Service

*This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

**E.1 Guidance.** Further guidance on hydrogen-assisted corrosion and control techniques can be found through the standards and organizations in E.1.1 through E.1.9.

**E.1.1 American Society for Testing and Materials.**

www.astm.org

ASTM B577-93 01-Apr-1993, *Standard Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper*

ASTM B839-94 01-Nov-1994, *Standard Test Method for Residual Embrittlement in Metallic Coated, Externally Threaded Articles, Fasteners, and Rod-Inclined Wedge Method*

ASTM B849-94 01-Nov-1994, *Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement*

ASTM B850-98 01-Nov-1998, *Standard Guide for Post-Coating Treatments Steel for Reducing the Risk of Hydrogen Embrittlement*

ASTM E781-99 10-Apr-1999, *Standard Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials*

ASTM F1459-93 01-Nov-1993, *Standard Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement*

ASTM F724-00 01-Aug-2000, *Standard Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique*

ASTM F1940-01 01-Nov-2001, *Standard Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners*

ASTM F2078-01 01-Nov-2001, *Standard Terminology Relating to Hydrogen Embrittlement Testing*

ASTM F326-96 01-Nov-1996, *Standard Test Method for Electronic Measurement for Hydrogen Embrittlement from Cadmium-Electroplating Processes*

ASTM F519-97 01-Nov-1997, *Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments*

ASTM G129-00 01-Aug-2000, *Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking*

ASTM G142-98 01-Nov-1998, *Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both*

ASTM G146-01 01-Feb-2001, *Standard Practice for Evaluation of Disbonding of Bimetallic Stainless Alloy/Steel Plate for Use in High-Pressure, High-Temperature Refinery Hydrogen Service*

ASTM G148-97 01-Nov-1997, *Standard Practice for Evaluation of Hydrogen Uptake, Permeation, and Transport in Metals by an Electrochemical Technique*

**E.1.2 The National Association of Corrosion Engineers.**

www.nace.org

NACE TM0177-96 23-Dec-1996, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking in Hydrogen Sulfide ($GH_2S$) Environments*

NACE TM0284-96 30-Mar-1996, *Standard Test Method – Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking*

**E.1.3 The American Petroleum Institute.**

www.api.org

API RP 941 01-Jan-1997, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants.*

API 934 01-Dec-2000, *Materials and Fabrication Requirements for 2-1/4Cr-1Mo & 3Cr-1Mo Steel Heavy Wall Pressure Vessels for High Temperature, High Pressure Hydrogen Service*

**E.1.4 American Welding Society.**

www.aws.org

ANSI/AWS A4.3-93 01-Jan-1993, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

**E.1.5 The American Society of Mechanical Engineers.**

www.asme.org

ASME *Boiler and Pressure Vessel Code*

ASME/ANSI B31.1, *Power Piping*

ASME/ANSI B31.3, *Process Piping*

**E.1.6 ASM International.**

www.asminternational.org

**E.1.7 Society of Automotive Engineers.**

www.sae.org

SAE/AMS 2451/4 01-Jul-1998, *Plating, Brush, Cadmium - Corrosion Protective, Low Hydrogen Embrittlement*

SAE/AMS 2759/9 01-Nov-1996, *Hydrogen Embrittlement Relief (Baking) of Steel Parts*

SAE/USCAR 5 01-Nov-1998, *Avoidance of Hydrogen Embrittlement of Steel*

**E.1.8 International Standards Organization.**

www.iso.ch

ISO 15330 01-Oct-1999, *Fasteners — Preloading test for the detection of hydrogen embrittlement — Parallel bearing surface method*

ISO 15724 01-Jan-2001, *Metallic and other inorganic coatings — Electrochemical measurement of diffusible hydrogen in steels — Barnacle electrode method*

ISO 2626 01-Oct-1973, *Copper — Hydrogen embrittlement test*

ISO 3690 01-Mar-2000, *Welding and allied processes — Determination of hydrogen content in ferritic steel arc weld metal*

ISO 3690 /Amd1 01-Jan-1983, *Amendment 1 — Welding — Determination of Hydrogen in Deposited Weld Metal Arising from the Use of Covered Electrodes for Welding Mild and Low Alloy Steels*

ISO 7539-6 1989, *Corrosion of metals and alloys — Stress corrosion testing* — Part 6: *Preparation and use of pre-cracked specimens*

ISO 9587 01-Oct-1999, *Metallic and other inorganic coatings — Pretreatments of iron or steel to reduce the risk of hydrogen embrittlement*

ISO 9588 01-Oct-1999, *Metallic and other inorganic coatings — Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement*

ISO PDTR 1597 09-May-2002, *Basic considerations for the safety of hydrogen systems*

ISO 11114-4 1997, *Transportable gas cylinders — Compatibility of cylinders and valve materials with gas contents — Part 4: Test methods for hydrogen compatibility with metals*

**E.1.9 European Standards.**

BS 7886 01-Jan-1997, *Method of Measurement of Hydrogen Permeation and the Determination of Hydrogen Uptake and Transport in Metals by an Electrochemical Technique*

**E.1.10** U.S. Department of Transportation website www.fhwa.dot.gov/ contains definitions of the term *OEM* and other classifications of manufacturers

## Annex F Informational References

**F.1 Referenced Publications.** The documents or portions thereof listed in this annex are referenced within the informational sections of this code and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

**F.1.1 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1, *Fire Code*, 2009 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, 2010 edition.

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 2009 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2007 edition.

*NFPA 70®, National Electrical Code®*, 2008 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2007 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 2008 edition.

NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft*, 2010 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 2008 edition.

NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2008 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2007 edition.

*NFPA 5000®, Building Construction and Safety Code®*, 2009 edition.

**F.1.2 Other Publications.**

**F.1.2.1 AGA Publications.** American Gas Association, 400 North Capitol Street, NW, Washington, DC 20001.

*Introduction to LNG for Personnel Safety*, No. X08614 IN1, 1986.

*LNG Plant Operator Training Guide*, No. X01181-IN1, 1982.

*LNG Preventive Maintenance Guide*, No. X01084-IN1, 1984.

*Requirements for Natural Gas Vehicle (NGV) Fueling Appliances*, No. 2-90, 1990.

**F.1.2.2 IHS–CSA America Publication.** International Approval Services, 15 Inverness Way East, Englewood, CO 80112.

ANSI/ISA NGV2, *Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers,* 2000.

**F.1.2.3 API Publications.** American Petroleum Institute, 1220 L Street NW, Washington, DC 20005.

API 510, *Pressure Vessel Inspection Code: In-Service Inspection Rating, Repair, and Alteration*, 9th edition, June 2006.

API RP 520, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries*, Part I, 1993.

API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*, 1991.

API Spec 5L, *Specifications for Line Pipe*, 44th edition, 2009.

**F.1.2.4 ASME Publications.** American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code*, 1992.

ANSI/ASME B36.10M, *Welded and Seamless Wrought Steel Pipe*, 2004.

**F.1.2.5 BSI Publications.** British Standards Institute, 389 Chiswick High Road, London, W4 4AL, United Kingdom.

BS EN 1081, *Determination of Electrical Resistance — Resilient Floor Coverings*, 1998.

**F.1.2.6 CGA Publications.** Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

CGA C-6, *Standards for Visual Inspection of Steel Compressed Gas Cylinders*, 1993.

CGA C-6.1, *Standards for Visual Inspection of High Pressure Aluminum Compressed Gas Cylinders*, 1984.

CGA C-6.2, *Guidelines for Visual Inspection and Requalification of Fiber Reinforced High Pressure Cylinders*, 1988.

CGA C-6.4, *Methods of External Visual Inspection of Natural Gas Vehicle (NGV) Fuel Containers and Their Installations*, 2003.

CGA C-10, *Recommended Procedures for Changes of Gas Service for Compressed Gas Cylinders*, 1993.

CGA G-5.5, *Hydrogen Vent Systems*, 2004.

CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*, 1994.

CGA S-1.2, *Pressure Relief Device Standards — Part 2 — Cargo and Portable Tanks for Compressed Gases*, 1994.

**F.1.2.7 CGSB Publications.** Canadian General Standards Board, Place du Portage III, 6B1, 11 Laurier Street, Gatineau, QC, K1A 5R3, Canada.

CGSB-3.513, *Natural Gas for Vehicles.*

**F.1.2.8 GTI Publications.** Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, IL 60018-1804,

www.gastechnology.org

GRI-02/0013, *Reference Guide for Integration and Use of Natural Gas Vehicle Fuel Systems*, 2002.

**F.1.2.9 NACE Publications.** NACE International, 1440 South Creek Drive, Houston, TX 77084.

RP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, 2002.

**F.1.2.10 NB Publication.** National Board of Boiler and Pressure Vessel Inspectors, 1055 Cripper Avenue, Columbus, OH 43229.

NB-23, *National Board Inspection Code*, 2004.

**F.1.2.11 SAE Publications.** Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

SAE J1616, *Recommended Practice for Compressed Natural Gas Vehicle Fuel*, February 1994.

SAE J2578, *Recommended Practice for General Fuel Cell Safety*, 2002.

**F.1.2.12 SSPC Publications.** Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburg, PA 15222-4656.

Steel Structures Painting Council Specifications:

SSPC-PA 1, *Shop, Field and Maintenance Painting*, 2004.

SSPC-PA 2, *Measurement of Dry Paint Thickness with Magnetic Gages*, 2004.

SSPC-SP 6, *Commercial Blast Cleaning*, 2002.

**F.1.2.13 U.S. Government Publications.** U.S. Government Printing Office, Washington, DC, 20402

Title 29, Code of Federal Regulations, Part 1910.1200.

**F.1.2.14 Other Publications.** National Aeronautics and Space Administration (NASA).

NSS 1740.16, *Safety Standard for Hydrogen and Hydrogen Systems*, 1997.

**F.2 Informational References.** The following documents or portions thereof are listed here as informational resources only. They are not a part of the requirements of this document.

**F.2.1 CGA Publications.** Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

CGA-5-1991, *Hydrogen*, 2002.

**F.2.2 Other Publications.** Idaho National Engineering and Environmental Laboratory (INEEL), *Safety Issues with Hydrogen as a Vehicle Fuel*, Sept. 1999.

National Renewable Energy Laboratories (NREL), Golden, CO, *Sourcebook For Hydrogen Applications* (NREL).

**F.3 References for Extracts in Informational Sections.**

NFPA 1, *Fire Code*, 2009 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2008 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, 2010 edition.

# Index

Cou/D 1 2 3 4 5 6 12 11 10 09

# Sequence of Events Leading to Issuance of an NFPA Committee Document

## Step 1: Call for Proposals

- Proposed new Document or new edition of an existing Document is entered into one of two yearly revision cycles, and a Call for Proposals is published.

## Step 2: Report on Proposals (ROP)

- Committee meets to act on Proposals, to develop its own Proposals, and to prepare its Report.
- Committee votes by written ballot on Proposals. If two-thirds approve, Report goes forward. Lacking two-thirds approval, Report returns to Committee.
- Report on Proposals (ROP) is published for public review and comment.

## Step 3: Report on Comments (ROC)

- Committee meets to act on Public Comments to develop its own Comments, and to prepare its report.
- Committee votes by written ballot on Comments. If two-thirds approve, Report goes forward. Lacking two-thirds approval, Report returns to Committee.
- Report on Comments (ROC) is published for public review.

## Step 4: Technical Report Session

- "*Notices of intent to make a motion*" are filed, are reviewed, and valid motions are certified for presentation at the Technical Report Session. ("Consent Documents" that have no certified motions bypass the Technical Report Session and proceed to the Standards Council for issuance.)
- NFPA membership meets each June at the Annual Meeting Technical Report Session and acts on Technical Committee Reports (ROP and ROC) for Documents with "certified amending motions."
- Committee(s) vote on any amendments to Report approved at NFPA Annual Membership Meeting.

## Step 5: Standards Council Issuance

- Notification of intent to file an appeal to the Standards Council on Association action must be filed within 20 days of the NFPA Annual Membership Meeting.
- Standards Council decides, based on all evidence, whether or not to issue Document or to take other action, including hearing any appeals.

# Committee Membership Classifications

The following classifications apply to Technical Committee members and represent their principal interest in the activity of the committee.

M *Manufacturer:* A representative of a maker or marketer of a product, assembly, or system, or portion thereof, that is affected by the standard.

U *User:* A representative of an entity that is subject to the provisions of the standard or that voluntarily uses the standard.

I/M *Installer/Maintainer:* A representative of an entity that is in the business of installing or maintaining a product, assembly, or system affected by the standard.

L *Labor:* A labor representative or employee concerned with safety in the workplace.

R/T *Applied Research/Testing Laboratory:* A representative of an independent testing laboratory or independent applied research organization that promulgates and/or enforces standards.

E *Enforcing Authority:* A representative of an agency or an organization that promulgates and/or enforces standards.

I *Insurance:* A representative of an insurance company, broker, agent, bureau, or inspection agency.

C *Consumer:* A person who is, or represents, the ultimate purchaser of a product, system, or service affected by the standard, but who is not included in the *User* classification.

SE *Special Expert:* A person not representing any of the previous classifications, but who has a special expertise in the scope of the standard or portion thereof.

NOTES;
1. "Standard" connotes code, standard, recommended practice, or guide.
2. A representative includes an employee.
3. While these classifications will be used by the Standards Council to achieve a balance for Technical Committees, the Standards Council may determine that new classifications of members or unique interests need representation in order to foster the best possible committee deliberations on any project. In this connection, the Standards Council may make appointments as it deems appropriate in the public interest, such as the classification of "Utilities" in the National Electrical Code Committee.
4. Representatives of subsidiaries of any group are generally considered to have the same classification as the parent organization.

# NFPA Document Proposal Form

**NOTE: All Proposals must be received by 5:00 pm EST/EDST on the published Proposal Closing Date.**

**For further information on the standards-making process, please contact the Codes and Standards Administration at 617-984-7249 or visit www.nfpa.org/codes.**

**For technical assistance, please call NFPA at 1-800-344-3555.**

**FOR OFFICE USE ONLY**

Log #:

Date Rec'd:

**Please indicate in which format you wish to receive your ROP/ROC** ☐ **electronic** ☐ **paper** ☒ **download**
**(Note: If choosing the download option, you must view the ROP/ROC from our website; no copy will be sent to you.)**

**Date** April 1, 200X **Name** John J. Doe **Tel. No.** 716-555-1234

**Company** Air Canada Pilot's Association **Email**

**Street Address** 123 Summer Street Lane **City** Lewiston **State** NY **Zip** 14092

******If you wish to receive a hard copy, a street address MUST be provided. Deliveries cannot be made to PO boxes.***

**Please indicate organization represented (if any)**

**1. (a) NFPA Document Title** National Fuel Gas Code **NFPA No. & Year** 54, 200X Edition

**(b) Section/Paragraph** 3.3

**2. Proposal Recommends (check one):** ☐ new text ☒ revised text ☐ deleted text

**3. Proposal (include proposed new or revised wording, or identification of wording to be deleted):** [Note: Proposed text should be in legislative format; i.e., use underscore to denote wording to be inserted (<u>inserted wording</u>) and strike-through to denote wording to be deleted (~~deleted wording~~).]

Revise definition of effective ground-fault current path to read:

3.3.78 Effective Ground-Fault Current Path. An intentionally constructed, permanent, low impedance electrically conductive path designed and intended to carry ~~underground~~ <u>electric</u> fault <u>current</u> ~~conditions~~ from the point of a ground fault on a wiring system to the electrical supply source.

**4. Statement of Problem and Substantiation for Proposal:** (Note: State the problem that would be resolved by your recommendation; give the specific reason for your Proposal, including copies of tests, research papers, fire experience, etc. If more than 200 words, it may be abstracted for publication.)

Change uses proper electrical terms.

**5. Copyright Assignment**

**(a)** ☐ **I am the author of the text or other material (such as illustrations, graphs) proposed in the Proposal.**

**(b)** ☒ **Some or all of the text or other material proposed in this Proposal was not authored by me. Its source is as follows:** (please identify which material and provide complete information on its source)

ABC Co.

*I hereby grant and assign to the NFPA all and full rights in copyright in this Proposal and understand that I acquire no rights in any publication of NFPA in which this Proposal in this or another similar or analogous form is used. Except to the extent that I do not have authority to make an assignment in materials that I have identified in (b) above, I hereby warrant that I am the author of this Proposal and that I have full power and authority to enter into this assignment.*

**Signature (Required)**

**PLEASE USE SEPARATE FORM FOR EACH PROPOSAL**

Mail to: Secretary, Standards Council · National Fire Protection Association
1 Batterymarch Park · Quincy, MA 02169-7471 OR
Fax to: (617) 770-3500 OR Email to: proposals_comments@nfpa.org

6/11/2009

# NFPA Document Proposal Form

**NOTE: All Proposals must be received by 5:00 pm EST/EDST on the published Proposal Closing Date.**

**For further information on the standards-making process, please contact the Codes and Standards Administration at 617-984-7249 or visit www.nfpa.org/codes.**

**For technical assistance, please call NFPA at 1-800-344-3555.**

**FOR OFFICE USE ONLY**

Log #: ____________

Date Rec'd: ____________

**Please indicate in which format you wish to receive your ROP/ROC** ☐ **electronic** ☐ **paper** ☐ **download**
**(Note: If choosing the download option, you must view the ROP/ROC from our website; no copy will be sent to you.)**

**Date** ____________ **Name** ____________________ **Tel. No.** ____________

**Company** ____________________ **Email** ____________

**Street Address** ____________ **City** ____________ **State** ______ **Zip** ______

******If you wish to receive a hard copy, a street address MUST be provided. Deliveries cannot be made to PO boxes.***

**Please indicate organization represented (if any)** ____________________

**1. (a) NFPA Document Title** ____________________ **NFPA No. & Year** ____________

(**b) Section/Paragraph** ____________________

**2. Proposal Recommends (check one):** ☐ new text ☐ revised text ☐ deleted text

**3. Proposal (include proposed new or revised wording, or identification of wording to be deleted):** [Note: Proposed text should be in legislative format; i.e., use underscore to denote wording to be inserted (<u>inserted wording</u>) and strike-through to denote wording to be deleted (~~deleted wording~~).]

**4. Statement of Problem and Substantiation for Proposal:** (Note: State the problem that would be resolved by your recommendation; give the specific reason for your Proposal, including copies of tests, research papers, fire experience, etc. If more than 200 words, it may be abstracted for publication.)

**5. Copyright Assignment**

**(a)** ☐ **I am the author of the text or other material (such as illustrations, graphs) proposed in the Proposal.**

**(b)** ☐ **Some or all of the text or other material proposed in this Proposal was not authored by me. Its source is as follows:** (please identify which material and provide complete information on its source)

____________________________________________

*I hereby grant and assign to the NFPA all and full rights in copyright in this Proposal and understand that I acquire no rights in any publication of NFPA in which this Proposal in this or another similar or analogous form is used. Except to the extent that I do not have authority to make an assignment in materials that I have identified in (b) above, I hereby warrant that I am the author of this Proposal and that I have full power and authority to enter into this assignment.*

**Signature (Required)** ____________________________________________

**PLEASE USE SEPARATE FORM FOR EACH PROPOSAL**

Mail to: Secretary, Standards Council · National Fire Protection Association
1 Batterymarch Park · Quincy, MA 02169-7471 OR
Fax to: (617) 770-3500 OR Email to: proposals_comments@nfpa.org

6/11/2009