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NFPA® 55

Compressed Gases and Cryogenic Fluids Code

2013 Edition



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NFPA® 55

Compressed Gases and Cryogenic Fluids Code

2013 Edition

This edition of NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, was prepared by the Technical Committee on Industrial and Medical Gases. It was issued by the Standards Council on May 29, 2012, with an effective date of June 18, 2012, and supersedes all previous editions.

This edition of NFPA 55 was approved as an American National Standard on June 18, 2012.

Origin and Development of NFPA 55

NFPA 55 was developed by the Industrial and Medical Gases Committee in recognition of the need to provide information on the use of cylinder gases in one standard. The Compressed Gas Association assisted the project by submitting a draft that was used as the framework for the standard.

NFPA 55 supersedes NFPA 43C, *Code for the Storage of Gaseous Oxidizing Materials*, which was developed by the Committee on Hazardous Chemicals and transferred to the Industrial and Medical Gases Committee. The committee believed that one standard covering storage of all gas cylinders was needed and, with the new NFPA 55, the need for NFPA 43C no longer existed.

Since this standard was introduced in 1993, it has been widely used and accepted by users of different types of gases as a single source covering requirements for installation and usage of gases in portable cylinders. The 1998 edition clarified many requirements and provided additional advisory information to assist the users of the standard. Editorial changes were also incorporated for clarity.

The 2003 edition of NFPA 55 was a complete revision of the document that significantly expanded the document scope and introduced requirements for areas
not addressed in
previous editions. For example, the 1998 edition covered only compressed and liquefied gases in portable cylinders and only at consumer (user) locations; the 2003 edition covered the use of compressed and liquefied gases in portable and stationary containers and at manufacturer sites and consumer sites. This expansion to manufacturer sites took a large portion of gas usage that was outside the scope of NFPA 55 and placed it under NFPA 55.

There were many new subjects and requirements in the 2003 edition, including the following:

(1) Requirements for cryogenic fluids
(2) Use of the concept of control areas for defining storage amounts and requirements
(3) An expanded classification scheme to cover a greater range of gaseous materials
(4) Specifications for a hazardous materials management plan
(5) Requirements for treating waste gases
(6) More detailed requirements in many of the areas than the 1998 edition of NFPA 55 covered

The 2003 edition was also restructured to comply with the *Manual of Style for NFPA Technical Committee Documents*.

The 2005 edition of NFPA 55 was a complete revision of the document. The following were some of the significant changes to the document:

(1) Incorporation of the requirements of NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites,* into Chapter 9
(2) Incorporation of the requirements of NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites,* into Chapter 10
(3) Incorporation of NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites,* into Chapter 11
(4) Clarification of threshold storage requirements in Chapters 6 and 7
(5) Clarification of the separation distance tables formerly in NFPA 50, NFPA 50A, and NFPA 50B, and now in Chapters 9–11
(6) Schematic drawings added to annex material to illustrate system siting requirements in Chapters 9 and 11

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The 2010 edition of NFPA 55 included a change in the document's title, from a standard to a code. The following were some of the significant changes to the document in the 2010 edition:

(1) Incorporation of the requirements of NFPA 560, *Standard for the Storage, Handling, and Use of Ethylene Oxide for Sterilization and Fumigation*, into Chapter 14
(2) Updated separation distances to exposure from gaseous hydrogen systems based upon new research
(3) Incorporation of the requirements on medical bulk oxygen systems from NFPA 99, *Standard for Health Care Facilities*, based on joint task group recommendations
(4) Addition of a new chapter, Chapter 12, on gas generation systems
(5) Addition of a new chapter, Chapter 13, on insulated liquid carbon dioxide systems

The 2013 edition of NFPA 55 is a complete revision of the document. Some of the significant changes to the document include the following:

(1) Incorporation of the requirements of NFPA 51A, *Standard for Acetylene Cylinder Charging Plants*, into a new chapter, Chapter 15, on acetylene cylinder charging
(2) Revisions to Chapters 10 and 11 on bulk compressed and liquefied hydrogen systems, including updates to separation distances to exposure from hydrogen systems
(3) Changes to the table in Chapter 6 regarding maximum allowable quantity (MAQ) of hazardous materials per control area to provide clarification and consistency with the approach used to establish the requirement of *NFPA 5000, Building Construction and Safety Code*, and NFPA 1, *Fire Code*

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Committee Scope: This Committee shall have primary responsibility for documents on the storage, transfer, and use of industrial gases. Included are the storage and handling of such gases in their gaseous or liquid phases; the installation of associated storage, piping, and distribution equipment; and operating practices. The Committee also has a technical responsibility for contributions in the same areas for medical gases and clean rooms.

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NFPA 55

Compressed Gases and Cryogenic Fluids Code

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

Chapter 1 Administration

1.1 Scope.

1.1.1 Applicability. This code shall apply to the installation, storage, use, and handling of compressed gases and cryogenic fluids in portable and stationary cylinders, containers, equipment, and tanks in all occupancies.

1.1.2 Specific Applications. This code shall not apply to the following:

(1) *Off-site transportation of materials covered by this code
(2) Storage, use, and handling of radioactive gases in accordance with NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*
(3) *Use and handling of medical compressed gases at health care facilities in accordance with NFPA 99, *Health Care Facilities Code*
(4) Systems consisting of cylinders of oxygen and cylinders of fuel gas used for welding and cutting in accordance with NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes*
• (5) *Flammable gases used as a vehicle fuel when stored on a vehicle.
(6) *Storage, use, and handling of liquefied and nonliquefied compressed gases in laboratory work areas in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*
(7) Storage, use, and handling of liquefied petroleum gases in accordance with NFPA 58, *Liquefied Petroleum Gas Code.*
(8) Storage, use, and handling of compressed gases within closed-cycle refrigeration systems complying with the mechanical code
(9) Liquefied natural gas (LNG) storage at utility plants under NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*
(10) Compressed natural gas (CNG) and liquefied natural gas (LNG) utilized as a vehicle fuel in accordance with NFPA 52, *Vehicular Gaseous Fuel Systems Code*
(11) *Compressed hydrogen gas (GH2), or liquefied hydrogen gas (LH2) generated, installed, stored, piped, used, or handled in accordance with NFPA 2, *Hydrogen Technologies Code*, when there are no specific or applicable requirements in NFPA 55
(12) Nonflammable mixtures of ethylene oxide with other chemicals
(13) Ethylene oxide in chambers 10 scf (0.283 Nm^3) or less in volume or for containers holding 7.05 oz (200 g) of ethylene oxide or less

1.2* Purpose. The purpose of this code shall be to provide fundamental safeguards for the installation, storage, use, and handling of compressed gases and cryogenic fluids in portable and stationary cylinders, containers, and tanks.

1.3 Application. The requirements in this code shall apply to users, producers, distributors, and others who are involved with the storage, use, or handling of compressed gases or cryogenic fluids.

1.4 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.

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

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

1.4.3 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 it is clearly evident that a reasonable degree of safety is provided.

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

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

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

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1.6 Units and Formulas.

1.6.1 The units of measure in the code are presented first in U.S. customary units (inch-pound units), followed by International System (SI) units in parentheses.

1.6.2 Either system of units shall be acceptable for satisfying the requirements in this code.

1.6.3 Users of this code shall apply one system of units consistently and shall not alternate between units.

1.6.4 The values presented for measurements in this code are expressed with a degree of precision appropriate for practical application and enforcement. It is not intended that the application or enforcement of these values be more precise than the precision expressed.

1.6.5 Where extracted text contains values expressed in only one system of units, the values in the extracted text have been retained without conversion to preserve the values established by the responsible technical committee in the source document.

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

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,* 2012 edition.

NFPA 2, *Hydrogen Technologies Code,* 2011 edition.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2010 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2013 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 2011 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2012 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2011 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 2011 edition.

NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes,* 2013 edition.

NFPA 52, *Vehicular Gaseous Fuel Systems Code,* 2010 edition.

NFPA 54, *National Fuel Gas Code,* 2012 edition.

NFPA 58, *Liquefied Petroleum Gas Code,* 2011 edition.

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG),* 2013 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2007 edition.

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

NFPA 70®, National Electrical Code®, 2011 edition.

NFPA 72®, National Fire Alarm and Signaling Code, 2013 edition.

NFPA 79, *Electrical Standard for Industrial Machinery,* 2012 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2013 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2012 edition.

NFPA 99, *Health Care Facilities Code,* 2012 edition.

NFPA *101®, Life Safety Code®,* 2012 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems,* 2013 edition.

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

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

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations,* 2011 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2012 edition.

NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials,* 2008 edition.

NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems,* 2010 edition.

2.3 Other Publications.

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

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

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

ASME A13.1, *Scheme for the Identification of Piping Systems,* 2007.

ANSI/ASME B31.3, *Process Piping,* 2008.

ASME B31.12, *Hydrogen Piping and Pipelines,* 2008.

ASME *Boiler and Pressure Vessel Code,* "Rules for the Construction of Unfired Pressure Vessels," Section VIII, 2010.

2.3.3 ASSE Publications. American Society of Sanitary Engineering, 901 Canterbury Road, Suite A, Westlake, OH 44145-1480.

ASSE/IAMPO/ANSI 6015, *Professional Qualification Standard for Bulk Medical Gas Systems Installers,* 2012.

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

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* 2010

ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* 2009.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* 2011.

ASTM E 681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases),* 2009.

ASTM E 1529, *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies,* 2010.

ASTM E 2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-Shaped Airflow Stabilizer, at 750 Degrees C,* 2009a.

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

CGA C-7, *Guide to Preparation of Precautionary Labeling and Marking of Compressed Gas Containers,* 2004.

CGA G-4.1, *Cleaning Equipment for Oxygen Service,* 2009.

CGA G-5.5, *Hydrogen Vent Systems,* 2007.

ANSI/CGA G-13, *Storage and Handling of Silane and Silane Mixtures,* 2006.

CGA M-1, *Guide for Medical Gas Installations at Consumer Sites,* 2007.

CGA P-1, *Safe Handling of Compressed Gases in Containers,* 2008.

ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites,* 2006.

CGA P-20, *Standard for the Classification of Toxic Gas Mixtures,* 2009.

CGA P-23, *Standard for Categorizing Gas Mixtures Containing Flammable and Nonflammable Components,* 2008.

CGA S-1.1, *Pressure Relief Device Standards – Part 1 – Cylinders for Compressed Gases,* 2007.

CGA S-1.2, *Pressure Relief Device Standards – Part 2 – Cargo and Portable Tanks for Compressed Gases,* 2009.

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

CGA V-6, *Standard Cryogenic Liquid Transfer Connections,* 2008.

2.3.6* CTA Publications. Canadian Transportation Agency, Queen's Printer, Ottawa, Ontario, Canada. (Available from the Canadian Communications Group Publication Centre, Ordering Department, Ottawa, Canada K1A 0S9.)

Transportation of Dangerous Goods Regulations.

2.3.7 IAPMO Publications. International Association of Plumbing and Mechanical Officials, 5001 E. Philadelphia Street, Ontario, CA 91761.

Uniform Mechanical Code, 2009 edition.

2.3.8 ICC Publications. International Code Council, 5203 Leesburg Pike, Suite 600, Falls Church, VA 22041.

International Fuel Gas Code (IFGC), 2009.

2.3.9 ISO Publications. International Organization for Standardization Publications, 1 rue de Varembé, Case Postale 56, CH-1211 Geneve 20, Switzerland.

ISO 10156, *Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets,* 2010.

ISO 10298, *Determination of toxicity of a gas or gas mixture,* 2010.

ISO/DIS 22734, *Hydrogen generators using water electrolysis process,* 2008.

2.3.10 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 263, *Fire Tests of Building Construction and Materials,* 2003.

ANSI/UL 723, *Standard for Test of Surface Burning Characteristics of Building Materials,* 2008, Revised 2010.

2.3.11 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 16, Code of Federal Regulations, Part 1500, "Hazardous Substances and Articles," 1500.41, Method of testing primary irritant substances, and 1500.42, Test for eye irritants.

Title 21, Code of Federal Regulations, Part 210, "Processing, Packing, or Holding Drugs; General."

Title 21, Code of Federal Regulations, Part 211, "Current Good Manufacturing Practice for Finished Pharmaceuticals."

Title 29, Code of Federal Regulations, Part 1910.1000, "Air Contaminants."

Title 29, Code of Federal Regulations, Part 1910.1200, "Hazard Communication."

Title 49, Code of Federal Regulations, Part 173, "Shippers — General Requirements for Shipments and Packages."

2.3.12 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 1, *Fire Code,* 2012 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2012 edition.

NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes,* 2013 edition.

NFPA 52, *Vehicular Gaseous Fuel Systems Code,* 2010 edition.

NFPA 58, *Liquefied Petroleum Gas Code,* 2011 edition.

NFPA 99, *Health Care Facilities Code,* 2012 edition.

NFPA *101®, Life Safety Code®,* 2012 edition.

NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities,* 2012 edition.

NFPA 400, *Hazardous Materials Code,* 2013 edition.

NFPA 5000®, Building Construction and Safety Code®, 2012 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

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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* Absolute Pressure. Pressure based on a zero reference point, the perfect vacuum.

3.3.2* Acetylene.

3.3.2.1 ***High Pressure Acetylene.*** Acetylene at pressures exceeding a gauge pressure of 15 psi (103 kPa), but not exceeding a gauge pressure of 400 psi (2760 kPa).

3.3.2.2 ***Low Pressure Acetylene.*** Acetylene at a pressure not exceeding a gauge pressure of 1 psi (6.9 kPa).

3.3.2.3 ***Medium Pressure Acetylene.*** Acetylene at gauge pressures exceeding 1 psi (6.9 kPa) but not exceeding 15 psi (103 kPa).

3.3.3 Acetylene Operations. Operations that include acetylene generation, storage, purification, compression, cylinder filling, cylinder storage, and calcium carbide storage.

3.3.4 Acetylene Plant. A facility engaged in the generation and compression of acetylene and in the filling of acetylene cylinders either as its sole operation or in conjunction with facilities for filling other compressed gas cylinders.

3.3.5 Aeration Room. A room or area with controlled temperature or airflow where ethylene oxide sterilized products are held initially for outgassing.

3.3.6 Area.

3.3.6.1 ***Control Area.*** A building or portion of a building within which hazardous materials are allowed to be stored, dispensed, used, or handled in quantities not exceeding the maximum allowable quantities (MAQ). [**5000,** 2012]

3.3.6.2 ***Indoor Area.*** An area that is within a building or structure having overhead cover, other than a structure qualifying as "weather protection" in accordance with Section 6.6.

3.3.6.3 ***Outdoor Area.*** An area that is not an indoor area.

3.3.6.4* *Use Area.* A location inside or outside of a building or structure where the material placed into use is situated.

3.3.7 ASME. American Society of Mechanical Engineers. [**58,** 2011]

3.3.8* Assembly Occupancy. An occupancy (1) used for a gathering of 50 or more persons for deliberation, worship, entertainment, eating, drinking, amusement, awaiting transportation, or similar uses; or (2) used as a special amusement building, regardless of occupant load. [***101***, 2012]

3.3.9 ASTM. American Society for Testing and Materials, now known as "ASTM International."

3.3.10 Atmospheric Vents. All points where pipes, stacks, or ducts are open to the atmosphere, including discharge points from emissions control devices, vent pipes from safety valves, vent pipes from filters or pumps, and other vents.

3.3.11 Authorized Cylinder Requalifier. A facility approved by U.S. Department of Transportation (DOT) or Transport Canada (TC) to perform cylinder requalification, inspection, testing, certification, or repair required by transportation regulations.

3.3.12 Back-Vent System. An exhaust vent system designed to transport residual vapors from a sterilization chamber to a designated point of termination outside of the building.

3.3.13 Building. Any structure used or intended for supporting or sheltering any use or occupancy. [***101,*** 2012]

3.3.14 Building Code. The building or construction code adopted by the jurisdiction.

3.3.15* Bulk Oxygen System. An assembly of equipment, such as oxygen storage containers, pressure regulators, pressure relief devices, vaporizers, manifolds, and interconnecting piping, that has a storage capacity of more than 20,000 scf (566 Nm^3) of oxygen and that terminates at the source valve.

3.3.16* Cathodic Protection. A technique to resist the corrosion of a metal surface by making the surface the cathode of an electrochemical cell.

3.3.17 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 and 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.

3.3.18 CFR. The Code of Federal Regulations of the United States Government. [**1,** 2012]

3.3.19 CGA. Compressed Gas Association. [**1,** 2012]

3.3.20* Chime Ring. The two raised rings circling the outer shell of UN 1A1 ethylene oxide drums.

3.3.21 Combustible Liquid. A liquid having a closed-cup flash point at or above 100°F (37.8°C), subdivided as follows: (a) Class II liquids include those having a flash point at or above 100°F (37.8°C) and below 140°F (60°C); (b) Class IIIA liquids include those having a flash point at or above 140°F (60°C) and below 200°F (93.4°C); (c) Class IIIB liquids include those having a flash point at or above 200°F (93.4°C).

3.3.22 Compressor. A mechanical device used to increase the pressure and the resultant density of a gas through the act of compression.

3.3.23 Container. A vessel, such as a cylinder, portable tank, or stationary tank, that varies in shape, size, and material of construction.

3.3.23.1 ***Compressed Gas Container.*** A pressure vessel designed to hold compressed gas at an absolute pressure greater than 1 atmosphere at 68°F (20°C) that includes cylinders, containers, and tanks.

3.3.24 Corrosion Expert. A person who, by reason of knowledge of the physical sciences and the principles of engineering acquired through professional education and related

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practical experience, is qualified to engage in the practice of corrosion control of container systems.

3.3.25 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.

3.3.26 Court. An open, uncovered, unoccupied space, unobstructed to the sky, bounded on three or more sides by exterior building walls. [***101,*** 2012]

3.3.26.1 ***Enclosed Court.*** A court bounded on all sides by the exterior walls of a building or by the exterior walls and lot lines on which walls are permitted. [**5000,** 2012]

3.3.27 Cryogenic Fluid. A fluid with a boiling point lower than –130°F (–90°C) at an absolute pressure of 14.7 psi (101.3 kPa).

3.3.28 Cryogenic Fluid System. An assembly of equipment designed to contain, distribute, or transport cryogenic fluids.

3.3.29 Cylinder. A pressure vessel designed for absolute pressures higher than 40 psi (276 kPa) and having a circular cross-section. It does not include a portable tank, multiunit tank car tank, cargo tank, or tank car.

3.3.30* Cylinder Pack. An arrangement of cylinders into a cluster where the cylinders are confined into a grouping or arrangement with a strapping or frame system and connections are made to a common manifold. The frame system is allowed to be on skids or wheels to permit movement.

3.3.31 Cylinder Containment Vessel. A gastight recovery vessel designed so that a leaking compressed gas container can be placed within its confines, thereby encapsulating the leaking container.

3.3.32 Detached Building. A separate single-story building, without a basement or crawl space, used exclusively for the storage or use of hazardous materials and located an approved distance from other structures.

3.3.33 Distributor. A business engaged in the sale or resale, or both, of compressed gases or cryogenic fluids, or both.

3.3.34 Ethylene Oxide Drum. For the purposes of this code, containers built to UN specification 1A1.

3.3.35 Exit Access. That portion of a means of egress that leads to an exit. [***101,*** 2012]

3.3.36 DOT. U.S. Department of Transportation. [**52,** 2010]

3.3.37 Emergency Shutoff Valve. A designated valve designed to shut off the flow of gases or liquids.

3.3.37.1 ***Automatic Emergency Shutoff Valve.*** A designated fail-safe automatic closing valve designed to shut off the flow of gases or liquids that is initiated by a control system where the control system is activated by either manual or automatic means.

3.3.37.2 ***Manual Emergency Shutoff Valve.*** A designated valve designed to shut off the flow of gases or liquids that is manually operated.

3.3.38 Excess Flow Control. A fail-safe system or approved means designed to shut off flow due to a rupture in pressurized piping systems.

3.3.39* Exhausted Enclosure. An appliance or piece of equipment that consists of a top, a back, and two sides that provides a means of local exhaust for capturing gases, fumes, vapors, and mists.

3.3.40* Explosion Control. A means of either preventing an explosion through the use of explosion suppression, fuel reduction, or oxidant reduction systems or a means to prevent the structural collapse of a building in the event of an explosion through the use of deflagration venting, barricades, or related construction methods.

3.3.41 Fail-Safe. A design arrangement incorporating one or more features that automatically counteracts the effect of an anticipated source of failure or which includes a design arrangement that eliminates or mitigates a hazardous condition by compensating automatically for a failure or malfunction. [**1,** 2012]

3.3.42* Fire Barrier. A continuous membrane or a membrane with discontinuities created by protected openings with a specified fire protection rating, where such membrane is designed and constructed with a specified fire resistance rating to limit the spread of fire, that also restricts the movement of smoke. [**5000,** 2012]

3.3.43 Fire Code. The fire prevention code adopted by the jurisdiction.

3.3.44 Fixed Natural Ventilation. The movement of air into and out of a space through permanent openings that are arranged in such a way that the required ventilation cannot be reduced by operating windows, doors, louvers, or similar devices.

3.3.45 Flammable Cryogenic Fluid. A cryogenic fluid that forms flammable mixtures in air when in its vapor state.

3.3.46* Flammable Liquid (Class I). Any liquid having a closed-cup flash point not exceeding 100°F (37.8°C).

3.3.47 Full Trycock Valve. A manual valve used to indicate when the container is filled to maximum design capacity.

3.3.48 Gallon. A standard U.S. gallon.

3.3.49 Gas.

3.3.49.1* ***Compressed Gas.*** A material, or mixture of materials, that (1) is a gas at 68°F (20°C) or less at an absolute pressure of 14.7 psi (101.3 kPa) and (2) has a boiling point of 68°F (20°C) or less at an absolute pressure of 14.7 psi (101.3 kPa) and that is liquefied, nonliquefied, or in solution, except those gases that have no other health or physical hazard properties are not considered to be compressed gases until the pressure in the packaging exceeds an absolute pressure of 40.6 psi (280 kPa) at 68°F (20°C).

3.3.49.2 ***Corrosive Gas.*** A gas that causes visible destruction of or irreversible alterations in living tissue by chemical action at the site of contact.

3.3.49.3 ***Flammable Gas.*** A material that is a gas at 68°F (20°C) or less at an absolute pressure of 14.7 psi (101.3 kPa), that is ignitable at an absolute pressure of 14.7 psi (101.3 kPa) when in a mixture of 13 percent or less by volume with air, or that has a flammable range at an absolute pressure of 14.7 psi (101.3 kPa) with air of at least 12 percent, regardless of the lower limit.

3.3.49.4 ***Flammable Liquefied Gas.*** A liquefied compressed gas that, when under a charged pressure, is partially liquid at a temperature of 68°F (20°C) and is flammable.

3.3.49.5 ***Highly Toxic Gas.*** A chemical that has a median lethal concentration (LC_{50}) in air of 200 ppm by volume or less of gas or vapor, or 2 mg/L or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or

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less if death occurs within 1 hour) to albino rats weighing between 0.44 lb and 0.66 lb (200 g and 300 g) each.

3.3.49.6* ***Inert Gas.*** A nonreactive, nonflammable, noncorrosive gas such as argon, helium, krypton, neon, nitrogen, and xenon.

3.3.49.7 ***Irritant Gas.*** A chemical that is not corrosive, but that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 CFR 1500.41, for an exposure of 4 or more hours or by other appropriate techniques, it results in an empirical score of 5 or more. A chemical is classified as an eye irritant if so determined under the procedure listed in 16 CFR 1500.42, or other appropriate techniques.

3.3.49.8 ***Nonflammable Gas.*** A gas that does not meet the definition of a flammable gas.

3.3.49.9* ***Other Gas.*** A gas that is not a corrosive gas, flammable gas, highly toxic gas, oxidizing gas, pyrophoric gas, toxic gas, or unstable reactive gas with a hazard rating of Class 2, Class 3, or Class 4 gas.

3.3.49.10 ***Oxidizing Cryogenic Fluid.*** An oxidizing gas in the cryogenic state.

3.3.49.11 ***Oxidizing Gas.*** A gas that can support and accelerate combustion of other materials more than air does.

3.3.49.12 ***Pyrophoric Gas.*** A gas with an autoignition temperature in air at or below 130°F (54.4°C).

3.3.49.13 ***Toxic Gas.*** A gas with a median lethal concentration (LC_{50}) in air of more than 200 ppm but not more than 2000 ppm by volume of gas or vapor, or more than 2 mg/L but not more than 20 mg/L of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 0.44 lb and 0.66 lb (200 g and 300 g) each.

3.3.49.14* ***Unstable Reactive Gas.*** A gas that, in the pure state or as commercially produced, will vigorously polymerize, decompose, or condense; become self-reactive; or otherwise undergo a violent chemical change under conditions of shock, pressure, or temperature.

3.3.49.14.1 ***Class 1 Unstable Reactive Gas.*** Materials that in themselves are normally stable, but that can become unstable at elevated temperatures and pressures.

3.3.49.14.2 ***Class 2 Unstable Reactive Gas.*** Materials that readily undergo violent chemical change at elevated temperatures and pressures.

3.3.49.14.3 ***Class 3 Unstable Reactive Gas.*** Materials that in themselves are capable of detonation or explosive decomposition or explosive reaction, but that require a strong initiating source or that must be heated under confinement before initiation.

3.3.49.14.4 ***Class 4 Unstable Reactive Gas.*** Materials that in themselves are readily capable of detonation or explosive decomposition or explosive reaction at normal temperatures and pressures.

3.3.50* Gas Cabinet. A fully enclosed, noncombustible enclosure used to provide an isolated environment for compressed gas cylinders in storage or use.

3.3.51 Gas Generator System. An assembly of equipment that may consist of, but not be limited to, storage containers, pressure regulators, pressure relief devices, membranes, absorption material, and piping. The gas generating system terminates at the point where the gas supply, at service pressure, first enters the supply line.

3.3.52 Gas Manufacturer/Producer. A business that produces compressed gases or cryogenic fluids, or both, or fills portable or stationary gas cylinders, containers, or tanks.

3.3.53 Gas Room. A separately ventilated, fully enclosed room in which only compressed gases, cryogenic fluids, associated equipment, and supplies are stored or used.

3.3.54 Gasifier. An assembly of equipment that converts carbonaceous materials, such as coal or petroleum, into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen.

3.3.55 Handling. The deliberate movement of material in containers by any means to a point of storage or use.

3.3.56* Hazard Rating. The numerical rating of the health, flammability, self-reactivity, and other hazards of the material, including its reaction with water.

3.3.57* Health Care Facilities. Buildings, portions of buildings, or mobile enclosures in which medical, dental, psychiatric, nursing, obstetrical, or surgical care is provided. [**99,** 2012]

3.3.58* Immediately Dangerous to Life and Health (IDLH). A concentration of airborne contaminants, normally expressed in parts per million (ppm) or milligrams per cubic meter, that represents the maximum level from which one could escape within 30 minutes without any escape-impairing symptoms or irreversible health effects.

3.3.59 Inert Cryogenic Fluid. A cryogenic fluid that vaporizes to produce an inert gas when in its vapor state.

3.3.60* ISO Module. An assembly of tanks or tubular cylinders permanently mounted in a frame conforming to International Organization for Standardization (ISO) requirements.

3.3.61 Large Insulated Liquid Carbon Dioxide System. An assembly of equipment consisting of one or more insulated carbon dioxide containers, interconnecting piping, pressure regulators, and pressure relief devices, where the capacity of one or more of the individual containers is greater than 1000 pounds of carbon dioxide.

3.3.62 Limit.

3.3.62.1* ***Ceiling Limit.*** The maximum concentration of an airborne contaminant to which one can be exposed. [**5000,** 2012]

3.3.62.2* ***Permissible Exposure Limit (PEL).*** The maximum permitted 8-hour, time-weighted average concentration of an airborne contaminant.

3.3.62.3* ***Short-Term Exposure Limit (STEL).*** The concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of a degree sufficient to increase the likelihood of accidental injury, impairment of self-rescue, or the material reduction of work efficiency, without exceeding the daily permissible exposure limit (PEL).

3.3.63 Limited Combustible. See 4.12.2.

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3.3.64 Material.

3.3.64.1 ***Limited Combustible Material.*** See 4.12.2.

3.3.64.2 ***Noncombustible Material.*** See 4.12.1.

3.3.65 Material Safety Data Sheet (MSDS). Written or printed material concerning a hazardous material that is prepared in accordance with the provisions of 29 CFR 1910.1200.

3.3.66 Maximum Allowable Quantity per Control Area (MAQ). A threshold quantity of hazardous material in a specific hazard class that once exceeded requires the application of additional administrative procedures, construction features, or engineering controls.

3.3.67 Mechanical Code. The mechanical or mechanical construction code adopted by the jurisdiction.

3.3.68 Metal Hydride. A generic name for compounds composed of metallic element(s) and hydrogen.

3.3.69 Metal Hydride Storage System. A closed system consisting of a group of components assembled as a package to contain metal–hydrogen compounds for which there exists an equilibrium condition where the hydrogen-absorbing metal alloy(s), hydrogen gas, and the metal–hydrogen
compound(s) coexist and
where only hydrogen gas is released from the system in normal use.

3.3.70* Mobile Acetylene Trailer System (MATS). A manifolded group of cylinders held together as a unit on a transport vehicle for the purpose of containing and transporting large quantities of acetylene.

3.3.70.1 ***MATS Fill Valve.*** A shutoff valve on the charging system for MATS where the acetylene supply first enters the charging connection.

3.3.70.2 ***MATS Fire Area.*** The area or footprint occupied by the individual mobile acetylene trailer(s) to include the control system up to the point of the MATS source valve for MATS being discharged or to the point of the fill valve for MATS being charged.

3.3.70.3 ***MATS Source Valve.*** A shutoff valve on the piping system serving MATS where the acetylene supply first enters the user's supply line.

3.3.71 MATS Building. A single-story detached building, without an attic, basement, crawl space, or false ceiling, used for acetylene trailer(s) or mobile acetylene trailer system (MATS) operations located indoors and with the balance of the building used exclusively for acetylene operations including storage and use of hazardous materials.

3.3.72* Mobile Supply Unit. Any supply source that is equipped with wheels so it is able to be moved around.

3.3.73 Nesting. A method of securing cylinders upright in a tight mass using a contiguous three-point contact system whereby all cylinders in a group have a minimum of three contact points with other cylinders or a solid support structure (e.g., a wall or railing).

3.3.74 Noncombustible Material. See 4.12.1.

3.3.75 Normal Cubic Meta (Nm^3) of Gas. A cubic meter of gas at an absolute pressure of 14.7 psi (101.3 kPa) and a temperature of 70°F (21°C).

3.3.76* Normal Temperature and Pressure (NTP). A temperature of 70°F (21°C) at an absolute pressure of 14.7 psi (101.3 kPa).

3.3.77 OSHA. The Occupational Safety and Health Administration of the U.S. Department of Labor.

3.3.78 Outgassing. Release of adsorbed or absorbed ethylene oxide after sterilization.

3.3.79* 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.

3.3.80 Pressure Relief Device. A device designed to open to prevent a rise of internal pressure in excess of a specified value.

3.3.81* Protection Level. A tier of building safety that exceeds the construction requirements for control areas to accommodate quantities of hazardous materials in excess of those permitted using the control area concept.

3.3.82 Qualified Individual. An individual knowledgeable in the hazards of compressed gases and cryogenic fluids through training and work experience.

3.3.83 Reformer. An assembly of equipment that can be used to produce hydrogen gas from hydrocarbons or other hydrogen-containing fuel, usually at high temperature and usually in the presence of a catalyst. The gaseous stream consists principally of a mixture of hydrogen and carbon monoxide.

3.3.84 Remotely Located, Manually Activated Shutdown Control. A control system that is designed to initiate shutdown of the flow of gas or liquid that is manually activated from a point located some distance from the delivery system.

3.3.85* Secondary Containment. That level of containment that is external to and separate from primary containment. [**400,** 2013]

3.3.86 Separation of Hazards. Physically separated by a specified distance, construction, or appliance.

3.3.87 Small Insulated Liquid Carbon Dioxide System. An assembly of equipment consisting of one or more insulated carbon dioxide containers, interconnecting piping, pressure regulators,
and pressure relief devices. The capacity of individual containers is 1000 pounds of carbon dioxide or less.

3.3.88* Source Valve. A shutoff valve on the piping system serving a bulk gas supply system where the gas supply, at service pressure, first enters the supply line.

3.3.89 Special Provisions. Controls required when the maximum allowable quantity in the control area is exceeded.

3.3.90 Standard Cubic Foot (scf) of Gas. An amount of gas that occupies one cubic foot at an absolute pressure of 14.7 psi (101 kPa) and a temperature of 70°F (21°C).

3.3.91* Sterilization Building. A detached building that contains all ancillary systems and rooms supporting the sterilization process.

3.3.92 Storage. An inventory of compressed gases or cryogenic fluids in containers that are not in the process of being examined, serviced, refilled, loaded, or unloaded.

3.3.93 System.

3.3.93.1 ***Bulk Gas System.*** A system in which compressed gas is delivered, stored, and discharged in the gaseous form

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to a piping system. The threshold quantity used to define a bulk gas system is determined based on material-specific requirements. The compressed gas system terminates at the point where compressed gas at service pressure first enters the distribution piping system.

3.3.93.2* ***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 5000 scf (141.6 Nm^3) of compressed hydrogen gas and that terminates at the source valve.

3.3.93.3* ***Bulk Inert Gas System.*** An assembly of equipment that consists of, but is not limited to, storage containers, pressure regulators, pressure relief devices, vaporizers, manifolds, and piping, with a storage capacity of more than 20,000 scf (566 Nm^3) of inert gas, including unconnected reserves on hand at the site, and that terminates at the source valve.

3.3.93.4* ***Bulk Liquefied Hydrogen 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 that terminates at the source valve.

3.3.93.5* ***Compressed Gas System.*** An assembly of equipment designed to contain, distribute, or transport compressed gases. [**318,** 2012]

3.3.93.6 ***Continuous Gas Detection System.*** A gas detection system in which the instrument is maintained in continuous operation and the interval between sampling of any point does not exceed 30 minutes.

3.3.93.7 ***Cryogenic Fluid System.*** An assembly of equipment designed to contain, distribute, or transport cryogenic fluids.

3.3.93.8 ***Cylinder Containment System.*** A gastight recovery system comprising equipment or devices that can be placed over a leak in a compressed gas container, thereby stopping or controlling the escape of gas from the leaking container.

3.3.93.9* ***Fast-Acting Fire Detection System.*** A detection system designed to detect a fire more rapidly than standard smoke or heat detectors.

3.3.93.10* ***Gaseous Hydrogen System.*** A system in which hydrogen is delivered, stored, and discharged in the gaseous form to a piping system. The gaseous hydrogen system terminates at the point where hydrogen at service pressure first enters the distribution piping.

3.3.93.10.1 ***Hydrogen Generation System.*** A packaged, factory matched, or site constructed hydrogen gas generation appliance or system such as (a) an electrolyzer that uses electrochemical reactions to electrolyze water to produce hydrogen and oxygen gas; (b) a reformer that converts hydrocarbon fuel to a hydrogen-rich stream of composition and conditions suitable for the type of device using the hydrogen; or (c) a gasifier that converts coal to a hydrogen-rich stream of composition and conditions suitable for a type of device using the hydrogen. It does not include hydrogen generated as a by-product of a waste treatment process.

3.3.93.11 ***Treatment System.*** An assembly of equipment capable of processing a hazardous gas and reducing the gas concentration to a predetermined level at the point of discharge from the system to the atmosphere.

3.3.94 Tank.

3.3.94.1* ***Portable Tank.*** Any packaging over 60 U.S. gal (227.1 L) capacity designed primarily to be loaded into or on, or temporarily attached to, a transport vehicle or ship and equipped with skids, mountings, or accessories to facilitate handling of the tank by mechanical means.

3.3.94.2* ***Stationary Tank.*** A packaging designed primarily for stationary installations not intended for loading, unloading, or attachment to a transport vehicle as part of its normal operation in the process of use.

3.3.95 TC. Transport Canada.

3.3.96* Tube Trailer. A truck or semitrailer on which a number of very long compressed gas tubular cylinders have been mounted and manifolded into a common piping system.

3.3.97 Unpierced Wall. A wall that is allowed to have pipes or conduits passing through it, or unopenable windows, glazed with safety glass or wired glass, set in it, but such openings are sealed to prevent the flow of air between adjacent rooms.

3.3.98 Use. To place a material into action, including solids, liquids, and gases.

3.3.99 Valve Outlet Cap or Plug. A removable device that forms a gastight seal on the outlet to the control valve that is provided on a source containing a compressed gas or cryogenic fluid.

3.3.100 Valve Protection Cap. A rigid, removable cover provided for container valve protection during handling, transportation, and storage.

Chapter 4 General Requirements

4.1 Permits. Permits shall be obtained in accordance with the requirements of the jurisdiction in which the facility operates.

4.2 Emergency Plan.

4.2.1 Emergency Plan Requirements.

4.2.1.1 An emergency plan shall be prepared and updated wherever compressed gases or cryogenic fluids are produced, handled, stored, or used in amounts exceeding the maximum allowable quantity (MAQ) per control area or where required by the authority having jurisdiction (AHJ).

4.2.1.2 The plan shall be available for inspection by the AHJ upon reasonable notice and shall include the following information:

(1) The type of emergency equipment available and its location
(2) A brief description of any testing or maintenance programs for the available emergency equipment
(3) An indication that hazard identification labeling is provided for each storage area
(4) The location of posted emergency procedures
(5) A material safety data sheet (MSDS) or equivalent for each compressed gas or cryogenic fluid stored or used on the site
(6) A list of personnel who are designated and trained to be liaison personnel for the fire department and who are responsible for the following:
    (a) Aiding the emergency responders in pre-emergency planning

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(b) Identifying the location of the compressed gases and cryogenic fluids stored or used
(c) Accessing MSDSs
(d) Knowing the site emergency procedures

(7) A list of the types and quantities of compressed gases and cryogenic fluids found within the facility

4.3 Facility Closure.

4.3.1 Facilities Temporarily Out of Service. Facilities that are temporarily out of service shall continue to maintain a permit and be monitored and inspected. [**400:**1.9.3.1]

4.3.2 Facilities Permanently Out of Service. Facilities for which a permit is not kept current or that are not monitored and inspected on a regular basis shall be deemed to be permanently out of service and shall be closed in accordance with 4.3.3. [**400:**1.9.3.2]

4.3.3 Closure Plan.

4.3.3.1 Where required by the AHJ, the permit holder or applicant shall submit a closure plan to the fire department to terminate storage, dispensing, handling, or use of hazardous materials at least 30 days prior to facility closure. [**400:**1.9.4.1]

4.3.3.2 The plan shall demonstrate that hazardous materials that were stored, dispensed, handled, or used in the facility have been transported, disposed of, or reused in a manner that eliminates the need for further maintenance and any threat to public health and safety. [**400:**1.9.4.2]

4.3.3.3 The plan shall be submitted with a permit application for facility closure in accordance with Section 4.1.

4.4* 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 serviceable condition.
(4) Security shall be maintained in accordance with 7.1.9.

4.5 Management Plan and Hazardous Materials Documentation.

4.5.1 Hazardous Materials Management Plan. Where required by the AHJ, a hazardous materials management plan (HMMP) shall be submitted to the AHJ.

4.5.1.1 The HMMP shall comply with the requirements of the fire code.

4.5.2 Hazardous Materials Inventory Statement. Where required by the AHJ, permit applications shall include a hazardous materials inventory statement (HMIS) in accordance with the fire code.

4.5.3 Material Safety Data Sheets (MSDS). Material safety data sheets (MSDS) shall be available on the premises for hazardous materials regulated by this code. When approved, MSDSs shall be permitted to be retrievable by electronic access. [**400:**6.1.2]

4.6 Release of Hazardous Materials.

4.6.1 Prohibited Releases. Hazardous materials shall not be released into a sewer, storm drain, ditch, drainage canal, lake, river, or tidal waterway; upon the ground, a sidewalk, a street, or a highway; or into the atmosphere, unless such release is permitted by the following:

(1) Federal, state, or local governing regulations
(2) Permits of the jurisdictional air quality management board
(3) National Pollutant Discharge Elimination System permit
(4) Waste discharge requirements established by the jurisdictional water quality control board
(5) Local sewer pretreatment requirements for publicly owned treatment works

[**400:**6.1.3.1]

4.6.2 Control and Mitigation of Unauthorized Releases. Provisions shall be made for controlling and mitigating unauthorized releases. [**400:**6.1.3.2]

4.6.3 Records of Unauthorized Releases. Accurate records of the unauthorized release of hazardous materials shall be kept by the permittee. [**400:**6.1.3.3]

4.6.4* Notification of Unauthorized Releases. The fire department shall be notified immediately or in accordance with approved emergency procedures when an unauthorized release becomes reportable under state, federal, or local regulations. [**400:**6.1.3.4]

4.6.5 Container Failure. When an unauthorized release due to primary container failure is discovered, the involved primary container shall be repaired or removed from service. [**400:**6.1.3.5]

4.6.5.1 Overpack Containers. Overpack containers shall be permitted to be used as a means to provide protection for primary containers to be transported for repair or removal from service. [**400:**6.1.3.6]

4.6.6 Responsibility for Cleanup of Unauthorized Discharges.

4.6.6.1 The person, firm, or corporation responsible for an unauthorized release shall institute and complete all actions necessary to remedy the effects of such unauthorized release, whether sudden or gradual, at no cost to the AHJ. [**400:**6.1.3.7.1]

4.6.6.2 When deemed necessary by the AHJ, cleanup of an unauthorized release shall be permitted to be initiated by the fire department or by an authorized individual or firm, and costs associated with such cleanup shall be borne by the owner, operator, or other person responsible for the unauthorized release. [**400:**6.1.3.7.2]

4.7* Personnel Training. Persons in areas where hazardous materials are stored, dispensed, handled, or used shall be trained in the hazards of the materials employed and actions required by the emergency plan. The level of training to be conducted shall be consistent with the responsibilities of the persons to be trained in accordance with 4.7.1 through 4.7.4.4. [**400:**6.1.4]

4.7.1 Awareness. The training provided for persons designated in Section 4.7 shall include awareness training in accordance with 4.7.1.1 through 4.7.1.3. [**400:**6.1.4.1]

4.7.1.1 Completion. Initial training shall be completed prior to beginning work in the work area. [**400:**6.1.4.1.1]

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4.7.1.2 Hazard Communications. Training shall be provided prior to beginning work in the work area to enable personnel to recognize and identify hazardous materials stored, dispensed, handled, or used on site and where to find safety information pertaining to the materials employed. [**400:**6.1.4.1.2]

4.7.1.3 Emergency Plan. Training shall be provided prior to beginning work in the work area to enable personnel to implement the emergency plan. [**400:**6.1.4.1.3]

4.7.2 Operations Personnel. Persons engaged in storing, using, or handling hazardous materials shall be designated as operations personnel and shall be trained in accordance with 4.7.1 and 4.7.2.1 through 4.7.2.6. [**400:**6.1.4.2]

4.7.2.1 Physical and Health Hazard Properties. Operations personnel shall be trained in the chemical nature of the materials, including their physical hazards and the symptoms of acute or chronic exposure as provided by the material safety data sheet (MSDS) furnished by the manufacturer or other authoritative sources. **[400:**6.1.4.2.1]

4.7.2.2 Dispensing, Using, and Processing. Operations personnel shall be trained in the use of specific safeguards applicable to the dispensing, processing, or use of the materials and equipment employed. **[400:**6.1.4.2.2]

4.7.2.3 Storage. Operations personnel shall be trained in the application of storage arrangements and site-specific limitations on storage for the materials employed. [**400:**6.1.4.2.3]

4.7.2.4 Transport (Handling). Operations personnel involved in materials handling shall be trained in the requirements for on-site transport of the materials employed. [**400:**6.1.4.2.4]

4.7.2.5 Actions in an Emergency. Operations personnel shall be trained in the necessary actions to take in the event of an emergency, including the operation and activation of emergency controls prior to evacuation. [**400:**6.1.4.2.5]

4.7.2.6 Changes. Training shall be provided whenever a new hazardous material is introduced into the work area that presents a new physical or health hazard, or when new information is obtained pertaining to physical or health hazards of an existing hazardous material that has not been included in previous training, and when there are changes in one of the following:

(1) Equipment
(2) Operations
(3) Hazardous materials

[**400:**6.1.4.2.6]

4.7.3 Emergency Response Liaison. [400:6.1.4.3]

4.7.3.1 Responsible persons shall be designated and trained to be emergency response (ER) liaison personnel. [**400:**6.1.4.3.1]

4.7.3.2 Emergency response liaison personnel shall do the following:

(1) Aid emergency responders in pre-planning responses to emergencies
(2) Identify locations where hazardous materials are located
(3) Have access to material safety data sheets
(4) Be knowledgeable in the site emergency response procedures

[**400:**6.1.4.3.2]

4.7.4* Emergency Responders. Emergency responders shall be trained to be competent in the actions to be taken in an emergency event. [**400:**6.1.4.4]

4.7.4.1* Emergency Response Team Leader. Persons acting as ER team leaders shall be trained under the Incident Command System concept or equivalent. [**400:**6.1.4.4.1]

4.7.4.2* Response to Incipient Events. Responses to incidental releases of hazardous materials where the material can be absorbed, neutralized, or otherwise controlled at the time of release by employees in the immediate release area, or by maintenance personnel, shall not be considered emergency responses as defined within the scope of this code. [**400:**6.1.4.4.2]

4.7.4.3* On-Site Emergency Response Team. When an on-site emergency response team is provided, emergency responders shall be trained in accordance with the requirements of the specific site emergency plan or as required by federal, state, or local governmental agencies. [**400:**6.1.4.4.3]

4.7.4.4 Training Mandated by Other Agencies. Training required by federal, state, or local regulations that is required based on the quantity or type of hazardous materials stored, dispensed, handled, or used shall be conducted in accordance with the requirements of and under the jurisdiction of the governing agency. [**400:**6.1.4.5]

4.7.4.5 Documentation. Training shall be documented and made available to the AHJ upon written request. [**400:**6.1.4.6]

4.8 Fire Department Liaison.

4.8.1 Responsible persons shall be designated and trained to be emergency response (ER) liaison personnel. [**400:**6.1.4.3.1]

4.8.2 Emergency response liaison personnel shall do the following: [**400:**6.1.4.3.2]

(1) Aid emergency responders in pre-planning responses to emergencies
(2) Identify locations where hazardous materials are located
(3) Have access to material safety data sheets
(4) Be knowledgeable in the site emergency response procedures

4.9 Ignition Source Controls.

4.9.1 Smoking. Smoking shall be prohibited in the following locations:

(1) Within 25 ft (7.6 m) of outdoor storage areas, dispensing areas, or open use areas
(2) In rooms or areas where hazardous materials are stored or dispensed or used in open systems in amounts requiring a permit in accordance with Section 4.1

[**400:**6.1.5.1]

4.9.2 Open Flames and High-Temperature Devices. Open flames and high-temperature devices shall not be used in a manner that creates a hazardous condition. [**400:**6.1.5.2]

4.9.3 Energy-Consuming Equipment. Energy-consuming equipment with the potential to serve as a source of ignition shall be listed or approved for use with the hazardous materials stored or used. [**400:**6.1.5.3]

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4.9.3.1* Powered Industrial Trucks. Powered industrial trucks shall be operated and maintained in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations.* [**400:**6.1.5.3.1]

4.10 Signs.

4.10.1 General.

4.10.1.1 Design and Construction. Signs shall be durable, and the size, color, and lettering of signs shall be in accordance with nationally recognized standards. [**400:**6.1.8.1.1]

4.10.1.2 Language. Signs shall be in English as the primary language or in symbols permitted by this code. [**400:**6.1.8.1.2]

4.10.1.3 Maintenance. Signs shall meet the following criteria:

(1) They shall not be obscured.
(2) They shall be maintained in a legible condition.
(3) They shall not be removed, unless for replacement.

[**400:**6.1.8.1.3]

4.10.2 Hazard Identification Signs.

4.10.2.1 General. Visible hazard identification signs in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, shall be placed at the following, locations except where the AHJ has received a hazardous materials management plan and a hazardous materials inventory statement in accordance with 4.5.1 through 4.5.2 and has determined that omission of such signs is consistent with safety:

(1) On stationary aboveground tanks
(2) On stationary aboveground containers
(3) At entrances to locations where hazardous materials are stored, dispensed, used, or handled in quantities requiring a permit
(4) At other entrances and locations designated by the AHJ

[**400:**6.1.8.2.1]

4.10.2.2 Identification of Containers, Cartons, and Packages. Individual containers, cartons, or packages shall be conspicuously marked or labeled in accordance with nationally recognized standards. [**400:**6.1.8.2.2]

4.10.2.3 Identification of Gas Rooms and Cabinets. Rooms or cabinets containing compressed gases shall be conspicuously labeled as follows:

COMPRESSED GAS

[**1:**63.2.11.1.2]

4.10.3 No Smoking Signs. Signs prohibiting smoking shall be provided where smoking is prohibited by 4.9.1 or where required by 6.12.2.2 for an entire site or building.

4.11 Protection from Vehicular Damage.

4.11.1 Where required, guard posts or other approved means shall be provided to protect against physical damage in accordance with 4.11.1.1 and 4.11.1.2.

4.11.1.1 Guard posts or other approved means shall be provided to protect the following areas where subject to vehicular damage:

(1) Storage tanks and connected piping, valves, and fittings
(2) Storage areas containing tanks or portable containers except where the exposing vehicles are powered industrial trucks used for transporting the hazardous materials
(3) Use areas

[**400:**6.1.9.1]

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

(1) They shall be constructed of steel not less than 4 in. (102 mm) 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. (381 mm) 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.

[**400:**6.1.9.2]

4.12* Building Construction Materials.

4.12.1* Noncombustible Material. A material that complies with any of the following shall be considered a noncombustible material. [***101:***4.6.13.1]

(1)*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. [***101:***4.6.13.1(1)]
(2) A material that is reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C*, shall be considered a noncombustible material. [***101:***4.6.13.1(2)]
(3) A material that is reported as complying with the pass/fail criteria of ASTM E 136 when tested in accordance with the test method and procedure in ASTM E 2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750 Degrees C*, shall be considered a noncombustible material. [***101:***4.6.13.1(3)]

4.12.2* Limited-Combustible Material. A material shall be considered a limited-combustible material where all the conditions of 4.12.2.1 and 4.12.2.2, and the conditions of either 4.12.2.3 or 4.12.2.4 are met. [***101:***4.6.14]

4.12.2.1 The material shall not comply with the requirements for a noncombustible material, in accordance with 4.12.1. [***101:***4.6.14.1]

4.12.2.2 The material, in the form in which it is used, shall exhibit a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg), where tested in accordance with NFPA 259, *Standard Test Method for Potential Heat of Building Materials.* [***101:***4.6.14.2]

4.12.2.3 The material shall have a structural base of a noncombustible material with a surfacing not exceeding a thickness of ⅛ in. (3.2 mm) where the surfacing exhibits a flame spread index not greater than 50 when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials.* [***101:***4.6.14.3]

4.12.2.4 The material shall have composed of materials that, in the form and thickness used, neither exhibit a flame spread index greater than 25 nor evidence of continued progressive combustion when tested in accordance with ASTM E 84 or ANSI/UL 723, and are of such composition that all surfaces that would be exposed by cutting through the material on any

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plane would neither exhibit a flame spread index greater than 25 nor exhibit evidence of continued progressive combustion when tested in accordance with ASTM E 84 or ANSI/UL 723. [***101:***4.6.14.4]

4.12.2.5 Where the term *limited-combustible* is used in this Code, it shall also include the term *noncombustible*. [***101:***4.6.14.5]

Chapter 5 Classification of Hazards

5.1 Hazardous Materials Classification.

5.1.1* Pure Gases. Hazardous materials shall be classified according to hazard categories as follows:

(1) Physical hazards, which shall include the following:
   (a) Flammable gas
   (b) Flammable cryogenic fluid
   (c) Oxidizing gas
   (d) Oxidizing cryogenic fluid
   (e) Pyrophoric gas
   (f) Unstable reactive (detonable) gas, Class 3 or Class 4
   (g) Unstable reactive (nondetonable) gas, Class 3
   (h) Unstable reactive gas, Class 1 or Class 2

(2) Health hazards, which shall include the following:
   (a) Corrosive gas
   (b) Cryogenic fluids
   (c) Highly toxic gas
   (d) Toxic gas

5.1.2 Other Hazards. Although it is possible that there are other known hazards, the classification of such gases is not within the scope of this code and they shall be handled, stored, or used as an *other gas*.

5.1.3 Mixtures. Mixtures shall be classified in accordance with the hazards of the mixture as a whole.

5.1.4 Responsibility for Classification. Classification shall be performed by an approved organization, individual, or testing laboratory.

5.1.4.1 Toxicity. The toxicity of gas mixtures shall be classified in accordance with CGA P-20, *Standard for the Classification of Toxic Gas Mixtures,* or by testing in accordance with the requirements of 29 CFR 1910.1000, DOT 49 CFR 173, or ISO 10298, *Determination of toxicity of a gas or gas mixture.*

5.1.4.2 Flammability of Gas Mixtures. For gas mixtures other than those containing ammonia and nonflammable gases, flammability of gas mixtures shall be classified in accordance with CGA P-23, *Standard for Categorizing Gas Mixtures Containing Flammable and Nonflammable Components*; or by physical testing in accordance with the requirements of ASTM E 681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases),* or ISO 10156, *Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets.*

Chapter 6 Building-Related Controls

6.1 General.

6.1.1 Occupancy.

6.1.1.1 Occupancy Requirements. Occupancies containing compressed gases and cryogenic fluids shall comply with this chapter in addition to other applicable requirements of this code.

6.1.1.2 Occupancy Classification. The occupancy of a building or structure, or portion of a building or structure, shall be classified in accordance with the building code.

6.2 Control Areas.

6.2.1 Construction Requirements. Control areas shall be separated from each other by fire barriers in accordance with Table 6.2.1. [**5000:**34.2.5.1.1]

Table 6.2.1 Design and Number of Control Areas

Floor Level	Maximum Allowable Quantity per Control Area (%)†	Number of Control Areas per Floor	Fire Resistance Rating for Fire Barriers‡ (hr)
Above grade plane			
>9	5	1	2
7–9	5	2	2
4–6	12.5	2	2
3	50	2	1
2	75	3	1
1	100	4	1
Below grade plane			
1	75	3	1
2	50	2	1
lower than 2	NP	NP	N/A

NP: Not Permitted.
N/A: Not Applicable.
†Percentages represent the maximum allowable quantities per control area shown in Table 6.3.1.1, with all of the increases permitted in the footnotes of that table.
‡Fire barriers are required to include floors and walls, as necessary, to provide a complete separation from other control areas.
[**5000:** Table 34.2.5.1.1]

6.2.2 Number of Control Areas. The maximum number of control areas within a building shall be in accordance with Table 6.2.1. [**5000:**34.2.5.2]

6.2.3 Where only one control area is present in a building, no special construction provisions shall be required. [**5000:**34.2.5.1.2]

6.2.4 Quantities Less Than or Equal to the MAQ. Indoor control areas with compressed gases or cryogenic fluids stored or used in quantities less than or equal to those shown in Table 6.3.1.1 shall be in accordance with 6.3.1.6 and 6.3.1.7 and Sections 6.1, 6.7, 6.8, 6.12, 6.15, and 6.16, and the applicable provisions of Chapters 1 through 5 and Chapters 7 through 15.

6.3 Occupancy Protection Levels.

6.3.1 Quantity Thresholds for Compressed Gases and Cryogenic Fluids Requiring Special Provisions.

6.3.1.1 Threshold Exceedences. Where the quantities of compressed gases or cryogenic fluids stored or used within an indoor control area exceed those shown in Table 6.3.1.1, the area shall meet the requirements for Protection Levels 1 through 5 in accordance with the building code, based on the requirements of 6.3.2.

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Table 6.3.1.1 Maximum Allowable Quantity (MAQ) of Hazardous Materials per Control Area

			Storage			Use — Closed Systems			Use — Open Systems	
Material	Class	High Hazard Protection Level	Solid Pounds	Liquid Gallons	Gas[a] scf (lb)	Solid Pounds	Liquid Gallons	Gas[a] scf (lb)	Solid Pounds	Liquid Gallons
Cryogenic fluid	Flammable	2	NA	45[b, c]	NA	NA	45[b,c]	NA	NA	45[b,c]
	Oxidizing	3	NA	45[d, e]	NA	NA	45[d,e]	NA	NA	45[d,e]
	Inert	NA	NA	NL	NA	NA	NL	NA	NA	NL
Flammable, gas[f]	Gaseous	2	NA	NA	1000[d,e]	NA	NA	1000[d,e]	NA	NA
	Liquefied	2	NA	NA	(150)[d,e]	NA	NA	(150)[d,e]	NA	NA
	LP	2	NA	NA	(300)[g,h,i]	NA	NA	(300)[g]	NA	NA
Inert gas	Gaseous	NA	NA	NA	NL	NA	NA	NL	NA	NA
	Liquefied	NA	NA	NA	NL	NA	NA	NL	NA	NA
Oxidizing gas	Gaseous	3	NA	NA	1500[d,e]	NA	NA	1500[d,e]	NA	NA
	Liquefied	3	NA	NA	(150)[d,e]	NA	NA	(150)[d,e]	NA	NA
Pyrophoric gas	Gaseous	2	NA	NA	50[d,j]	NA	NA	50[d,j]	NA	NA
	Liquefied	2	NA	NA	(4)[d,j]	NA	NA	(4)[d,j]	NA	NA
Unstable (reactive) gas	Gaseous									
	4 or 3 detonable	1	NA	NA	10[d,j]	NA	NA	10[d,j]	NA	NA
	3 nondetonable	2	NA	NA	50[d,e]	NA	NA	50[d,e]	NA	NA
	2	3	NA	NA	750[d,e]	NA	NA	750[d,e]	NA	NA
	1	NA	NA	NA	NL	NA	NA	NL	NA	NA
Unstable (reactive) gas	Liquefied									
	4 or 3 detonable	1	NA	NA	(1)[d,j]	NA	NA	(1)[d,j]	NA	NA
	3 nondetonable	2	NA	NA	(2)[d,e]	NA	NA	(2)[d,e]	NA	NA
	2	3	NA	NA	(150)[d,e]	NA	NA	(150)[d,e]	NA	NA
	1	NA	NA	NA	NL	NA	NA	NL	NA	NA
Corrosive gas	Gaseous	4	NA	NA	810[d,e]	NA	NA	810[d,e]	NA	NA
	Liquefied		NA	NA	(150)[d,e]	NA	NA	(150)[d,e]	NA	NA
Highly toxic gas	Gaseous	4	NA	NA	20[e,k]	NA	NA	20[e,k]	NA	NA
	Liquefied		NA	NA	(4)[e,k]	NA	NA	(4)[e,k]	NA	NA
Toxic gas	Gaseous	4	NA	NA	810[d,e]	NA	NA	810[d,e]	NA	NA
	Liquefied		NA	NA	(150)[d,e]	NA	NA	(150)[d,e]	NA	NA

NA: Not applicable within the context of NFPA 55 (refer to the applicable building or fire code for additional information on these materials).
NL: Not limited in quantity.
Notes:
(1) For use of control areas, see Section 6.2.
(2) Table values in parentheses or brackets correspond to the unit name in parentheses or brackets at the top of the column.
(3) The aggregate quantity in use and storage is not permitted to exceed the quantity listed for storage. In addition, quantities in specific occupancies are not permitted to exceed the limits in the building code.
[a]Measured at NTP [70°F (20°C) and 14.7 psi (101.3 kPa)].
[b]None allowed in unsprinklered buildings unless stored or used in gas rooms or in approved gas cabinets or exhausted enclosures, as specified in this code.
[c]With pressure-relief devices for stationary or portable containers vented directly outdoors or to an exhaust hood.
[d]Quantities are permitted to be increased 100 percent where stored or used in approved cabinets, gas cabinets, exhausted enclosures, gas rooms, as appropriate for the material stored. Where Footnote e also applies, the increase for the quantities in both footnotes is permitted to be applied accumulatively.
[e]Maximum quantities are permitted to be increased 100 percent in buildings equipped throughout with an automatic sprinkler system in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*. Where Footnote d also applies, the increase for the quantities in both footnotes is permitted to be applied accumulatively.
[f]Flammable gases in the fuel tanks of mobile equipment or vehicles are permitted to exceed the MAQ where the equipment is stored and operated in accordance with the applicable fire code.
[g]See NFPA 58, *Liquefied Petroleum Gas Code*, for requirements for liquefied petroleum gas (LP-Gas). LP-Gas is not within the scope of NFPA 55.
[h]Additional storage locations are required to be separated by a minimum of 300 ft (92 m).
[i]In mercantile occupancies, storage of LP-Gas is limited to a maximum of 200 lb (91 kg) in nominal 1 lb (0.45 kg) LP-Gas containers.
[j]Permitted only in buildings equipped throughout with an automatic sprinkler system in accordance with NFPA 13.
[k]Allowed only where stored or used in gas rooms or in approved gas cabinets or exhausted enclosures, as specified in this code.

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6.3.1.2 Quantities Greater Than the MAQ. Building-related controls in areas with compressed gases or cryogenic fluids stored or used within an indoor area in quantities greater than those shown in Table 6.3.1.1 shall be in accordance with the requirements of Chapter 6.

6.3.1.3 Aggregate Allowable Quantities. The aggregate quantity in use and storage shall not exceed the quantity listed for storage.

6.3.1.4 Incompatible Materials. When the classification of materials in individual containers requires the area to be placed in more than one protection level, the separation of protection levels shall not be required, provided the area is constructed to meet the requirements of the most restrictive protection level and that the incompatible materials are separated as required by 7.1.11.2.

6.3.1.5 Multiple Hazards. Where a compressed gas or cryogenic fluid has multiple hazards, all hazards shall be addressed and controlled in accordance with the provisions for the protection level for which the threshold quantity is exceeded.

6.3.1.6 Flammable and Oxidizing Gases.

6.3.1.6.1 Flammable and oxidizing gases shall not be stored or used in other than industrial and storage occupancies.

6.3.1.6.2 Cylinders, containers, or tanks not exceeding 250 scf (7.1 Nm^3) content at normal temperature and pressure (NTP) and used for maintenance purposes, patient care, or operation of equipment shall be permitted.

6.3.1.7 Toxic and Highly Toxic Compressed Gases. Except for containers or cylinders not exceeding 20 scf (0.6 Nm^3) content at NTP stored or used within gas cabinets or exhausted enclosures of educational occupancies, toxic or highly toxic compressed gases shall not be stored or used in other than industrial and storage occupancies.

6.3.2 Classification of Protection Levels. The protection level required shall be based on the hazard class of the material involved as indicated in 6.3.2.1 through 6.3.2.5.

6.3.2.1 Protection Level 1. Occupancies used for the storage or use of unstable reactive Class 4 and unstable reactive Class 3 detonable compressed gases in quantities that exceed the quantity thresholds for gases requiring special provisions shall be classified Protection Level 1.

6.3.2.2 Protection Level 2. Occupancies used for the storage or use of flammable, pyrophoric, and nondetonable, unstable reactive Class 3 compressed gases or cryogenic fluids in quantities that exceed the quantity thresholds for gases requiring special provisions shall be classified as Protection Level 2.

6.3.2.3 Protection Level 3. Occupancies used for the storage or use of oxidizing and unstable reactive Class 2 compressed gases or cryogenic fluids in quantities that exceed the quantity thresholds for gases requiring special provisions shall be classified as Protection Level 3.

6.3.2.4 Protection Level 4. Occupancies used for the storage or use of toxic, highly toxic, and corrosive compressed gases in quantities that exceed the quantity thresholds for gases requiring special provisions shall be classified as Protection Level 4.

6.3.2.5 Protection Level 5. Buildings and portions thereof used for fabrication of semiconductors or semiconductor research and development and containing quantities of hazardous materials exceeding the maximum allowable quantities of high hazard level 5 contents permitted in control areas shall be classified as Protection Level 5.

6.4 Gas Rooms. Where a gas room is used to increase the threshold quantity for a gas requiring special provisions or where otherwise required by the material or application specific requirements of Chapters 7 through 15, the room shall meet the requirements of 6.4.1 through 6.4.5.

6.4.1 Pressure Control. Gas rooms shall operate at a negative pressure in relationship to the surrounding area.

6.4.2 Exhaust Ventilation. Gas rooms shall be provided with an exhaust ventilation system.

6.4.3 Construction. Gas rooms shall be constructed in accordance with the building code.

6.4.4 Separation. Gas rooms shall be separated from other occupancies by a minimum of 1-hour fire resistance.

6.4.5 Limitation on Contents. The function of compressed gas rooms shall be limited to storage and use of compressed gases and associated equipment and supplies.

6.5* Detached Buildings. Occupancies used for the storage or use of compressed gases, including individual bulk hydrogen compressed gas systems in quantities exceeding those specified in Table 6.5, shall be in detached buildings constructed in accordance with the provisions of the building code.

6.6 Weather Protection.

6.6.1 For other than explosive materials and hazardous materials presenting a detonation hazard, a weather protection structure shall be permitted to be used for sheltering outdoor storage or use areas, without requiring such areas to be classified as indoor storage or use.

6.6.2 Weather protected areas constructed in accordance with 6.6.3 shall be regulated as outdoor storage or use.

6.6.2.1 Weather protected areas that are not constructed in accordance with 6.6.3 shall be regulated as indoor storage or use.

Table 6.5 Detached Buildings Required Where Quantity of Material Exceeds Amount Shown

Gas Hazard	Class	Quantity of Material	
		scf	Nm^3
Individual bulk hydrogen compressed gas systems	NA	15,000	425
Unstable reactive (detonable)	4 or 3	Quantity thresholds for gases requiring special provisions*	
Unstable reactive (nondetonable)	3	2,000	57
Unstable reactive (nondetonable)	2	10,000	283
Pyrophoric gas	NA	2,000	57

NA: Not applicable.
*See Table 6.3.1.1.

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6.6.3 Buildings or structures used for weather protection shall be in accordance with the following:

(1) The building or structure shall be constructed of noncombustible materials.
(2) Walls shall not obstruct more than one side of the structure.
(3) Walls shall be permitted to obstruct portions of multiple sides of the structure, provided that the obstructed area does not exceed 25 percent of the structure's perimeter area.
(4) The building or structure shall be limited to a maximum area of 1500 ft^2 (140 m^2), with increases in area allowed by the building code based on occupancy and type of construction.
(5) The distance from the structure constructed as weather protection to buildings, lot lines, public ways, or means of egress to a public way shall not be less than the distance required for an outside hazardous material storage or use area without weather protection based on the hazard classification of the materials contained.
(6) Reductions in separation distance shall be permitted based on the use of fire barrier walls where permitted for specific materials in accordance with the requirements of Chapters 7 through 11.

6.7* Electrical Equipment. Electrical wiring and equipment shall be in accordance with Section 6.7 and *NFPA 70, National Electrical Code*.

6.7.1 Standby Power.

6.7.1.1 Where the following systems are required by this code for the storage or use of compressed gases or cryogenic fluids that exceed the quantity thresholds for gases requiring special provisions, such systems shall be connected to a standby power system in accordance with *NFPA 70, National Electrical Code*:

(1) Mechanical ventilation
(2) Treatment systems
(3) Temperature controls
(4) Alarms
(5) Detection systems
(6) Other electrically operated systems

6.7.1.2 The requirements of 6.7.1.1 shall not apply where emergency power is provided in accordance with 6.7.2 and *NFPA 70, National Electrical Code*.

6.7.2 Emergency Power. When emergency power is required, the system shall meet the requirements for a Level 2 system in accordance with NFPA 110, *Standard for Emergency and Standby Power Systems*.

6.8* Employee Alarm System. Where required by government regulations, an employee alarm system shall be provided to allow warning for necessary emergency action as called for in the emergency action plan required by 4.2.1.1, or for reaction time for safe egress of employees from the workplace or the immediate work area, or both.

6.9 Explosion Control. Explosion control shall be provided as required by Table 6.9 in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, or NFPA 69, *Standard on Explosion Prevention Systems*, where amounts of compressed gases in storage or use exceed the quantity thresholds requiring special provisions.

6.10* Fire Protection Systems. Except as provided in 6.10.1, buildings or portions thereof required to comply with Protection Levels 1 through 5 shall be protected by an approved automatic fire sprinkler system complying with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

6.10.1 Rooms or areas that are of noncombustible construction with wholly noncombustible contents shall not be required to be protected by an automatic fire sprinkler system.

6.10.2 Sprinkler System Design.

6.10.2.1 When sprinkler protection is required, the area in which compressed gases or cryogenic fluids are stored or used shall be protected with a sprinkler system designed to be not less than that required by NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Ordinary Hazard Group 2.

6.10.2.2 When sprinkler protection is required, the area in which the flammable or pyrophoric compressed gases or cryogenic fluids are stored or used shall be protected with a sprinkler system designed to be not less than that required by NFPA 13, *Standard for the Installation of Sprinkler Systems*, for Extra Hazard Group 1.

6.11 Lighting. Approved lighting by natural or artificial means shall be provided for areas of storage or use.

6.12 Hazard Identification Signs.

6.12.1 Location. Hazard identification signs shall be placed at all entrances to locations where compressed gases are produced, stored, used, or handled in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*.

Table 6.9 Explosion Control Requirements

		Explosion Control Methods	
Material	**Class**	**Barricade Construction**	**Explosion Venting or Prevention Systems**
Flammable cryogenic fluid	—	Not required	Required
Flammable gas	Nonliquefied	Not required	Required
	Liquefied	Not required	Required
Pyrophoric gas	—	Not required	Required
Unstable reactive gas	4	Required	Not required
	3 (detonable)	Required	Not required
	3 (nondetonable)	Not required	Required

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6.12.1.1 Ratings shall be assigned in accordance with NFPA 704.

6.12.1.2 The authority having jurisdiction shall be permitted to waive 6.12.1 where consistent with safety.

6.12.2 Application. Signage shall be provided as specified in 6.12.2.1 and 6.12.2.2.

6.12.2.1 Signs. Signs shall not be obscured or removed.

6.12.2.2 No Smoking. Signs prohibiting smoking or open flames within 25 ft (7.6 m) of area perimeters shall be provided in areas where toxic, highly toxic, corrosive, unstable reactive, flammable, oxidizing, or pyrophoric gases are produced, stored, or used.

6.13 Spill Control, Drainage, and Secondary Containment. Spill control, drainage, and secondary containment shall not be required for compressed gases.

6.14 Shelving.

6.14.1 Shelves used for the storage of cylinders, containers, and tanks shall be of noncombustible construction and designed to support the weight of the materials stored.

6.14.2 In seismically active areas, shelves and containers shall be secured from overturning.

6.15 Vent Pipe Termination. 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.

6.16 Ventilation. Indoor storage and use areas and storage buildings for compressed gases and cryogenic fluids shall be provided with mechanical exhaust ventilation or fixed natural ventilation, where natural ventilation is shown to be acceptable for the material as stored.

6.16.1 Compressed Air. The requirements of Section 6.16 shall not apply to cylinders, containers, and tanks containing compressed air.

6.16.2 Ventilation Systems. In addition to the requirements of Section 6.16, ventilation systems shall be designed and installed in accordance with the requirements of the mechanical code.

6.16.3 Mechanical Exhaust Ventilation. Where mechanical exhaust ventilation is provided, the system shall be operational during the time the building or space is occupied.

6.16.3.1 Continuous Operation. When operation of ventilation systems is required, systems shall operate continuously unless an alternative design is approved by the AHJ.

6.16.3.2 Ventilation Rate. Mechanical exhaust or fixed natural ventilation shall be provided at a rate of not less than 1 scf/min/ft^2 (0.3048 Nm^3/min/m^2) of floor area over the area of storage or use.

6.16.3.3 Shutoff Controls. Where powered ventilation is provided, a manual shutoff switch shall be provided outside the room in a position adjacent to the principal access door to the room or in an approved location.

6.16.3.3.1 Manual Shutoff Switch. The switch shall be the breakglass or equivalent type and shall be labeled as follows:

WARNING:

VENTILATION SYSTEM EMERGENCY SHUTOFF

6.16.4 Inlets to the Exhaust System.

6.16.4.1 The exhaust ventilation system design shall take into account the density of the potential gases released.

6.16.4.2 For gases that are heavier than air, exhaust shall be taken from a point within 12 in. (305 mm) of the floor. The use of supplemental inlets shall be allowed to be installed at points above the 12 in. (305 mm) threshold level.

6.16.4.3 For gases that are lighter than air, exhaust shall be taken from a point within 12 in. (305 mm) of the ceiling. The use of supplemental inlets shall be allowed to be installed at points below the 12 in. (305 mm) threshold level.

6.16.4.4 The location of both the exhaust and inlet air openings shall be designed to provide air movement across all portions of the floor or ceiling of the room or area to prevent the accumulation of vapors within the ventilated space.

6.16.5 Recirculation of Exhaust. Exhaust ventilation shall not be recirculated within the room or building if the cylinders, containers, or tanks stored are capable of releasing hazardous gases.

6.16.6 Ventilation Discharge. Ventilation discharge systems shall terminate at a point not less than 50 ft (15 m) from intakes of air-handling systems, air-conditioning equipment, and air compressors.

6.16.7 Air Intakes. Storage and use of compressed gases shall be located not less than 50 ft (15 m) from air intakes. For material-specific requirements, see Sections 7.4 through 7.10.

6.17 Gas Cabinets. Where a gas cabinet is required, is used to provide separation of gas hazards, or is used to increase the threshold quantity for a gas requiring special provisions, the gas cabinet shall be in accordance with the requirements of 6.17.1 through 6.17.5.

6.17.1 Construction.

6.17.1.1 Materials of Construction. The gas cabinet shall be constructed of not less than 0.097 in. (2.46 mm) (12 gauge) steel.

6.17.1.2 Access to Controls. The gas cabinet shall be provided with self-closing limited access ports or noncombustible windows to give access to equipment controls.

6.17.1.3 Self-Closing Doors. The gas cabinet shall be provided with self-closing doors.

6.17.2 Ventilation Requirements.

6.17.2.1 The gas cabinet shall be provided with an exhaust ventilation system designed to operate at a negative pressure relative to the surrounding area.

6.17.2.2 Where toxic, highly toxic, pyrophoric, unstable reactive Class 3 or Class 4, or corrosive gases are contained, the velocity at the face of access ports or windows, with the access port or window open, shall not be less than 200 ft/min (61 m/min) average, with not less than 150 ft/min (46 m/min) at any single point.

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6.17.3 Fire Protection. Gas cabinets used to contain toxic, highly toxic, or pyrophoric gases shall be internally sprinklered.

6.17.4 Quantity Limits. Gas cabinets shall contain not more than three cylinders, containers, or tanks.

6.17.5 Separation of Incompatibles. Incompatible gases, as defined by Table 7.1.11.2, shall be stored or used within separate gas cabinets.

6.18 Exhausted Enclosures.

6.18.1 Ventilation Requirements. Where an exhausted enclosure is required or used to increase the threshold quantity for a gas requiring special provisions, the exhausted enclosure shall be provided with an exhaust ventilation system designed to operate at a negative pressure in relationship to the surrounding area.

6.18.1.1 Control Velocity at Access Openings. Where toxic, highly toxic, pyrophoric, unstable reactive Class 3 or Class 4, or corrosive gases are contained, the velocity at the face openings providing access shall be not less than 200 ft/min (61 m/min) average, with not less than 150 ft/min (46 m/min) at any single point.

6.18.1.2 Separation of Incompatible Gases Within Enclosures. Cylinders, containers, and tanks within enclosures shall be separated in accordance with Table 7.1.11.2.

6.18.1.3 Fire Protection. Exhausted enclosures shall be internally sprinklered.

6.18.2 Separation. Incompatible gases, as defined by Table 7.1.11.2, shall be stored or used within separate exhausted enclosures.

6.19* Source Valve. Bulk gas systems shall be provided with a source valve.

6.19.1 The source valve shall be marked.

6.19.2 The source valve shall be designated on the design drawings for the installation.

Chapter 7 Compressed Gases

7.1 General. The storage, use, and handling of compressed gases in cylinders, containers, and tanks shall be in accordance with the provisions of Chapters 1 through 7.

7.1.1 Compressed Gas Systems.

7.1.1.1 Design. Compressed gas systems shall be designed for the intended use and shall be designed by persons competent in such design.

7.1.1.2 Installation. Installation of bulk compressed gas systems shall be supervised by personnel knowledgeable in the application of the standards for their construction and use.

7.1.2 Insulated Liquid Carbon Dioxide Systems. Insulated liquid carbon dioxide systems shall be in accordance with Chapter 13.

7.1.3* Insulated Liquid Nitrous Oxide Systems. (Reserved)

7.1.4* Listed and Approved Hydrogen Equipment.

7.1.4.1 Listed and approved hydrogen generating and consuming equipment shall be in accordance with the listing requirements and manufacturers' instructions.

7.1.4.2 Such equipment shall not be required to meet the requirements of Chapter 7.

7.1.5* Metal Hydride Storage Systems.

7.1.5.1 General Requirements.

7.1.5.1.1 Metal Hydride Storage System Requirements. The storage and use of metal hydride storage systems shall be in accordance with 7.1.5.

7.1.5.1.2 Metal Hydride Systems Storing or Supplying Hydrogen. Those portions of the system that are used as a means to store or supply hydrogen shall also comply with Chapter 7 and Chapter 10 as applicable.

7.1.5.1.3 Classification. The hazard classification of the metal hydride storage system, as required by 5.1.1 and 5.1.3, shall be based on the hydrogen stored without regard to the metal hydride content.

7.1.5.1.4 Listed or Approved Systems. Metal hydride storage systems shall be listed or approved for the application and designed in a manner that prevents the addition or removal of the metal hydride by other than the original equipment manufacturer.

7.1.5.1.5 Containers, Design, and Construction. Compressed gas cylinders, containers, and tanks used for metal hydride storage systems shall be designed and constructed in accordance with 7.1.6.1.

7.1.5.1.6 Service Life and Inspection of Containers. Metal hydride storage system cylinders, containers, and tanks shall be inspected, tested, and requalified for service at not less than 5-year intervals.

7.1.5.1.7 Marking and Labeling. Marking and labeling of cylinders, containers, tanks, and systems shall be in accordance with 7.1.6 and the requirements in 7.1.5.1.7.1 through 7.1.5.1.7.4.

7.1.5.1.7.1 System Marking. Metal hydride storage systems shall be marked with the following:

(1) Manufacturer's name
(2) Service life indicating the last date the system can be used
(3) A unique code or serial number specific to the unit
(4) System name or product code that identifies the system by the type of chemistry used in the system
(5) Emergency contact name, telephone number, or other contact information
(6) Limitations on refilling of containers to include rated charging pressure and capacity

7.1.5.1.7.2 Valve Marking. Metal hydride storage system valves shall be marked with the following:

(1) Manufacturer's name
(2) Service life indicating the last date the valve can be used
(3) Metal hydride service in which the valve can be used or a product code that is traceable to this information

7.1.5.1.7.3 Pressure Relief Device Marking. Metal hydride storage system pressure relief devices shall be marked with the following:

(1) Manufacturer's name
(2) Metal hydride service in which the device can be used or a product code that is traceable to this information
(3) Activation parameters to include temperature, pressure, or both

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(A) Pressure Relief Devices Integral to Container Valves. The required markings for pressure relief devices that are integral components of valves used on cylinders, containers, and tanks shall be allowed to be placed on the valve.

7.1.5.1.7.4 Pressure Vessel Markings. Cylinders, containers, and tanks used in metal hydride storage systems shall be marked with the following:

(1) Manufacturer's name
(2) Design specification to which the vessel was manufactured
(3) Authorized body approving the design and initial inspection and test of the vessel
(4) Manufacturer's original test date
(5) Unique serial number for the vessel
(6) Service life identifying the last date the vessel can be used
(7) System name or product code that identifies the system by the type of chemistry used in the system

7.1.5.1.8 Temperature Extremes. Metal hydride storage systems, whether full or partially full, shall not be exposed to artificially created high temperatures exceeding 125°F (52°C) or subambient (low) temperatures unless designed for use under the exposed conditions.

7.1.5.1.9 Falling Objects. Metal hydride storage systems shall not be placed in areas where they are capable of being damaged by falling objects.

7.1.5.1.10 Piping Systems. Piping, including tubing, valves, fittings, and pressure regulators, serving metal hydride storage systems shall be maintained gastight to prevent leakage.

7.1.5.1.10.1 Leaking Systems. Leaking systems shall be removed from service.

7.1.5.1.11 Refilling of Containers. The refilling of listed or approved metal hydride storage systems shall be in accordance with the listing requirements and manufacturers' instructions.

7.1.5.1.11.1 Industrial Trucks. The refilling of metal hydride storage systems serving powered industrial trucks shall be in accordance with NFPA 2, *Hydrogen Technologies Code*.

7.1.5.1.11.2 Hydrogen Purity. The purity of hydrogen used for the purpose of refilling containers shall be in accordance with the listing and the manufacturers' instructions.

7.1.5.1.12 Electrical. Electrical components for metal hydride storage systems shall be designed, constructed, and installed in accordance with *NFPA 70, National Electrical Code*.

7.1.5.2 Portable Containers or Systems.

7.1.5.2.1 Securing Containers. Cylinders, containers, and tanks shall be secured in accordance with 7.1.9.4.

7.1.5.2.1.1 Use on Mobile Equipment. Where a metal hydride storage system is used on mobile equipment, the equipment shall be designed to restrain cylinders, containers, or tanks from dislodgement, slipping, or rotating when the equipment is in motion.

7.1.5.2.1.2 Motorized Equipment. Metal hydride storage systems used on motorized equipment shall be installed in a manner that protects valves, pressure regulators, fittings, and controls against accidental impact.

(A) Protection from Damage. Metal hydride storage systems, including cylinders, containers, tanks, and fittings, shall not extend beyond the platform of the mobile equipment.

7.1.5.2.2 Valves. Valves on cylinders, containers, and tanks shall remain closed except when containers are connected to closed systems and ready for use.

7.1.6 Cylinders, Containers, and Tanks.

7.1.6.1 Design and Construction. Cylinders, containers, 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.

7.1.6.2 Defective Cylinders, Containers, and Tanks.

7.1.6.2.1 Defective cylinders, containers, and tanks shall be returned to the supplier.

7.1.6.2.2 Suppliers shall repair the cylinders, containers, and tanks, remove them from service, or dispose of them in an approved manner.

7.1.6.2.3 Suppliers shall ensure that defective cylinders, containers, and tanks that have been repaired are evaluated by qualified individuals to verify that the needed repairs and any required testing has been performed and that those repaired or tested are in a serviceable condition before returning them to service.

7.1.6.3 Supports. Stationary cylinders, containers, and tanks shall be provided with engineered supports of noncombustible material on noncombustible foundations.

7.1.6.4 Cylinders, Containers, and Tanks Containing Residual Gas. Compressed gas cylinders, containers, and tanks containing residual product shall be treated as full except when being examined, serviced, or refilled by a gas manufacturer, authorized cylinder requalifier, or distributor.

7.1.6.5 Pressure Relief Devices.

7.1.6.5.1 When required by 7.1.6.5.2, pressure relief devices shall be provided to protect containers and systems containing compressed gases from rupture in the event of overpressure from thermal exposure.

7.1.6.5.2 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*, for stationary tanks or in accordance with applicable equivalent requirements in the country of use.

7.1.6.5.3 Pressure relief devices shall be sized in accordance with the specifications to which the container was fabricated.

7.1.6.5.4 The pressure relief device shall have the capacity to prevent the maximum design pressure of the container or system from being exceeded.

7.1.6.5.5 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 scf (0.057 Nm^3) or less.

7.1.6.5.6 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.

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7.1.7 Cathodic Protection. Where required, cathodic protection shall be in accordance with 7.1.7.

7.1.7.1 Operation. Where installed, cathodic protection systems shall be operated and maintained to continuously provide corrosion protection.

7.1.7.2 Inspection. Container systems equipped with cathodic protection shall be inspected for the intended operation by a cathodic protection tester. The frequency of inspection shall be determined by the designer of the cathodic protection system.

7.1.7.2.1 The cathodic protection tester shall be certified as being qualified by the National Association of Corrosion Engineers, International (NACE).

7.1.7.3 Impressed Current Systems. Systems equipped with impressed current cathodic protection systems shall be inspected in accordance with the requirements of the design and 7.1.7.2.

7.1.7.3.1 The design limits of the cathodic protection system shall be available to the AHJ upon request.

7.1.7.3.2 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

7.1.7.4 Repairs, maintenance, or replacement of a cathodic protection system shall be under the supervision of a corrosion expert certified by NACE.

7.1.7.4.1 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.

7.1.8 Labeling Requirements.

7.1.8.1 Containers. Individual compressed gas cylinders, containers, and tanks shall be marked or labeled in accordance with DOT requirements or those of the applicable regulatory agency.

7.1.8.2 Label Maintenance. The labels applied by the gas manufacturer to identify the liquefied or nonliquefied compressed gas cylinder contents shall not be altered or removed by the user.

7.1.8.3 Stationary Compressed Gas Cylinders, Containers, and Tanks.

7.1.8.3.1 Stationary compressed gas cylinders, containers, and tanks shall be marked in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response.*

7.1.8.3.2 Markings shall be visible from any direction of approach.

7.1.8.4 Piping Systems.

7.1.8.4.1 Except as provided in 7.1.8.4.2, piping systems shall be marked in accordance with ASME A13.1, *Scheme for the Identification of Piping Systems,* or other applicable approved standards as follows:

(1) Marking shall include the name of the gas and a direction-of-flow arrow.
(2) Piping that is used to convey more than one gas at various times shall be marked to provide clear identification and warning of the hazard.
(3) Markings for piping systems shall be provided at the following locations:
   (a) At each critical process control valve
   (b) At wall, floor, or ceiling penetrations
   (c) At each change of direction
   (d) At a minimum of every 20 ft (6.1 m) or fraction thereof throughout the piping run

7.1.8.4.2 Piping within gas manufacturing plants, gas processing plants, refineries, and similar occupancies shall be marked in an approved manner.

7.1.9 Security.

7.1.9.1 General. Compressed gas cylinders, containers, tanks, and systems shall be secured against accidental dislodgement and against access by unauthorized personnel.

7.1.9.2* Security of Areas. Storage, use, and handling areas shall be secured against unauthorized entry.

7.1.9.2.1 Administrative controls shall be allowed to be used to control access to individual storage, use, and handling areas located in secure facilities not accessible by the general public.

7.1.9.3 Physical Protection.

7.1.9.3.1 Compressed gas cylinders, containers, tanks, and systems that could be exposed to physical damage shall be protected.

7.1.9.3.2 Guard posts or other means shall be provided to protect compressed gas cylinders, containers, tanks, and systems indoors and outdoors from vehicular damage in accordance with Section 4.11.

7.1.9.4 Securing Compressed Gas Cylinders, Containers, and Tanks. Compressed gas cylinders, containers, and tanks in use or in storage shall be secured to prevent them from falling or being knocked over by corralling them and securing them to a cart, framework, or fixed object by use of a restraint, unless otherwise permitted by 7.1.9.4.1 and 7.1.9.4.2.

7.1.9.4.1 Compressed gas cylinders, containers, and tanks in the process of examination, servicing, and refilling shall not be required to be secured.

7.1.9.4.2 At cylinder-filling plants, authorized cylinder requalifier's facilities, and distributors' warehouses, the nesting of cylinders shall be permitted as a means to secure cylinders.

7.1.10 Valve Protection.

7.1.10.1 General. Compressed gas cylinder, container, and tank valves shall be protected from physical damage by means of protective caps, collars, or similar devices.

7.1.10.1.1 Valve protection of individual valves shall not be required to be installed on individual cylinders, containers, or tanks installed on tube trailers or similar transportable bulk gas systems equipped with manifolds that are provided with a means of physical protection that will protect the valves from physical damage when the equipment is in use. Protective systems required by DOT for over the road transport shall provide an acceptable means of protection.

7.1.10.1.1.1 Valve protection of individual valves shall not be required on cylinders, containers, or tanks that comprise bulk or non-bulk gas systems where the containers are stationary, or

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portable equipped with manifolds, that are provided with physical protection in accordance with Section 4.11 and 7.1.9.3 or other approved means. Protective systems required by DOT for over the road transport shall provide an acceptable means of protection.

7.1.10.2 Valve-Protective Caps. Where compressed gas cylinders, containers, and tanks are designed to accept valve-protective caps, the user shall keep such caps on the compressed gas cylinders, containers, and tanks at all times, except when empty, being processed, or connected for use.

7.1.10.3 Valve Outlet Caps or Plugs.

7.1.10.3.1 Gastight valve outlet caps or plugs shall be provided and in place for all full or partially full cylinders, containers, and tanks containing toxic, highly toxic, pyrophoric, or unstable reactive Class 3 or Class 4 gases that are in storage.

7.1.10.3.2 Valve outlet caps and plugs shall be designed and rated for the container service pressure.

7.1.11 Separation from Hazardous Conditions.

7.1.11.1 General. Compressed gas cylinders, containers, tanks, and systems in storage or use shall be separated from materials and conditions that present exposure hazards to or from each other.

7.1.11.2* Incompatible Materials. Gas cylinders, containers, and tanks shall be separated in accordance with Table 7.1.11.2.

7.1.11.2.1 Subparagraph 7.1.11.2 shall not apply to gases contained within closed piping systems.

7.1.11.2.2 The distances shown in Table 7.1.11.2 shall be permitted to be reduced without limit where compressed gas cylinders, containers, and tanks are separated by a barrier of noncombustible construction that has a fire resistance rating of at least 0.5 hour and interrupts the line of sight between the containers.

7.1.11.2.3 The 20 ft (6.1 m) distance shall be permitted to be reduced to 5 ft (1.5 m) where one of the gases is enclosed in a gas cabinet or without limit where both gases are enclosed in gas cabinets.

7.1.11.2.4 Cylinders without pressure relief devices shall not be stored without separation from flammable and pyrophoric gases with pressure relief devices.

7.1.11.2.5* Spatial separation shall not be required between cylinders deemed to be incompatible in gas production facilities where cylinders are connected to manifolds for the purposes of filling, analysis of compressed gases or, manufacturing procedures, assuming the prescribed controls for the manufacture of gas mixtures are in place.

7.1.11.3* Clearance from Combustibles and Vegetation. Combustible waste, vegetation, and similar materials shall be kept a minimum of 10 ft (3.1 m) from compressed gas cylinders, containers, tanks, and systems.

7.1.11.3.1 A noncombustible partition without openings or penetrations and extending not less than 18 in. (457 mm) above and to the sides of the storage area shall be permitted in lieu of the minimum distance.

7.1.11.3.2 The noncombustible partition shall be either an independent structure or the exterior wall of the building adjacent to the storage area.

7.1.11.4 Ledges, Platforms, and Elevators. Compressed gas cylinders, containers, and tanks shall not be placed near elevators, unprotected platform ledges, or other areas where compressed gas cylinders, containers, or tanks could fall distances exceeding one-half the height of the container, cylinder, or tank.

7.1.11.5 Temperature Extremes. Compressed gas cylinders, containers, and tanks, whether full or partially full, shall not be exposed to temperatures exceeding 125°F (52°C) or subambient (low) temperatures unless designed for use under such exposure.

7.1.11.5.1 Compressed gas cylinders, containers, and tanks that have not been designed for use under elevated temperature conditions shall not be exposed to direct sunlight outdoors where ambient temperatures exceed 125°F (52°C). The use of a weather protected structure or shaded environment for storage or use shall be permitted as a means to protect against direct exposure to sunlight.

Table 7.1.11.2 Separation of Gas Cylinders, Containers, and Tanks by Hazard Class

Gas Category	Other Gas	Unstable Reactive Class 2, Class 3, or Class 4		Corrosive		Oxidizing		Flammable		Pyrophoric		Toxic or Highly Toxic	
		ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
Toxic or highly toxic	NR	20	6.1	20	6.1	20	6.1	20	6.1	20	6.1	—	—
Pyrophoric	NR	20	6.1	20	6.1	20	6.1	20	6.1	—	—	20	6.1
Flammable	NR	20	6.1	20	6.1	20	6.1	—	—	20	6.1	20	6.1
Oxidizing	NR	20	6.1	20	6.1	—	—	20	6.1	20	6.1	20	6.1
Corrosive	NR	20	6.1	—	—	20	6.1	20	6.1	20	6.1	20	6.1
Unstable reactive Class 2, Class 3, or Class 4	NR	—	—	20	6.1	20	6.1	20	6.1	20	6.1	20	6.1
Other gas	—	NR		NR		NR		NR		NR		NR	

NR: No separation required.

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7.1.11.6 Falling Objects. Compressed gas cylinders, containers, and tanks shall not be placed in areas where they are capable of being damaged by falling objects.

7.1.11.7 Heating. Compressed gas cylinders, containers, and tanks, whether full or partially full, shall not be heated by devices that could raise the surface temperature of the container, cylinder, or tank to above 125°F (52°C).

7.1.11.7.1 Electrically Powered Heating Devices. Electrical heating devices shall be in accordance with *NFPA 70, National Electrical Code.*

7.1.11.7.2 Fail-Safe Design. Devices designed to maintain individual compressed gas cylinders, containers, and tanks at constant temperature shall be designed to be fail-safe.

7.1.11.8 Sources of Ignition. Open flames and high-temperature devices shall not be used in a manner that creates a hazardous condition.

7.1.11.9 Exposure to Chemicals. Compressed gas cylinders, containers, and tanks shall not be exposed to corrosive chemicals or fumes that could damage cylinders, containers, tanks, or valve-protective caps.

7.1.11.10 Exposure to Electrical Circuits. Compressed gas cylinders, containers, and tanks shall not be placed where they could become a part of an electrical circuit.

7.1.11.10.1* Electrical devices mounted on compressed gas piping, cylinders, containers, or tanks shall be installed, grounded, and bonded in accordance with the methods specified in *NFPA 70, National Electrical Code* (NEC).

7.1.12 Service and Repair. Service, repair, modification, or removal of valves, pressure relief devices, or other compressed gas cylinder, container, and tank appurtenances shall be performed by trained personnel and with the permission of the container owner.

7.1.13 Unauthorized Use. Compressed gas cylinders, containers, and tanks shall not be used for any purpose other than to serve as a vessel for containing the product for which it was designed.

7.1.14 Cylinders, Containers, and Tanks Exposed to Fire. Compressed gas cylinders, containers, and tanks exposed to fire shall not be used or shipped while full or partially full until they are requalified in accordance with the pressure vessel code under which they were manufactured.

7.1.15 Leaks, Damage, or Corrosion.

7.1.15.1 Removal from Service. Leaking, damaged, or corroded compressed gas cylinders, containers, and tanks shall be removed from service.

7.1.15.2 Replacement and Repair. Leaking, damaged, or corroded compressed gas systems shall be replaced or repaired.

7.1.15.3* Handling of Cylinders, Containers, and Tanks Removed from Service. Compressed gas cylinders, containers, and tanks that have been removed from service shall be handled in an approved manner.

7.1.15.4 Leaking Systems. Compressed gas systems that are determined to be leaking, damaged, or corroded shall be repaired to a serviceable condition or shall be removed from service.

7.1.16 Surfaces.

7.1.16.1 To prevent bottom corrosion, cylinders, containers, and tanks shall be protected from direct contact with soil or surfaces where water might accumulate.

7.1.16.2 Surfaces shall be graded to prevent accumulation of water.

7.1.17 Storage Area Temperature.

7.1.17.1 Compressed Gas Containers. Storage area temperatures shall not exceed 125°F (52°C).

7.1.18 Underground Piping.

7.1.18.1 Underground piping shall be of welded construction without valves, unwelded mechanical joints, or connections installed underground.

7.1.18.1.1 Valves or connections located in boxes or enclosures shall be permitted to be installed underground where such boxes or enclosures are accessible from above ground and where the valves or connections contained are isolated from direct contact with earth or fill.

7.1.18.1.1.1 Valve boxes or enclosures installed in areas subject to vehicular traffic shall be constructed to resist uniformly distributed and concentrated live loads in accordance with the building code for areas designated as vehicular driveways and yards, subject to trucking.

7.1.18.1.2* Piping installed in trench systems located below grade where the trench is open to above shall not be considered to be underground.

7.1.18.2 Gas piping in contact with earth or other material that could corrode the piping shall be protected against corrosion in an approved manner.

7.1.18.2.1 When cathodic protection is provided, it shall be in accordance with 7.1.7.

7.1.18.3 Underground piping shall be installed on at least 6 in. (150 mm) of well-compacted bedding material. [**30:**27.6.5.1]

7.1.18.4 In areas subject to vehicle traffic, the pipe trench shall be deep enough to permit a cover of at least 18 in. (450 mm) of well-compacted backfill material and pavement. [**30:**27.6.5.2]

7.1.18.5 In paved areas where a minimum 2 in. (50 mm) of asphalt is used, backfill between the pipe and the asphalt shall be permitted to be reduced to 8 in. (200 mm) minimum. [**30:**27.6.5.3]

7.1.18.6 In paved areas where a minimum 4 in. (100 mm) of reinforced concrete is used, backfill between the pipe and the concrete shall be permitted to be reduced to 4 in. (100 mm) minimum. **[30:**27.6.5.4]

7.1.18.7 In areas not subject to vehicle traffic, the pipe trench shall be deep enough to permit a cover of at least 12 in. (300 mm) of well-compacted backfill material.

7.1.18.8 A greater burial depth shall be provided when required by the manufacturer's instructions or where frost conditions are present. [**30:**27.6.5.6]

7.1.18.9 Piping within the same trench shall be separated horizontally by at least two pipe diameters. Separation shall not need to exceed 9 in. (230 mm). [**30:**27.6.5.7]

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7.1.18.10 Two or more levels of pipes within the same trench shall be separated vertically by a minimum 6 in. (150 mm) of well-compacted bedding material. [**30:**27.6.5.8]

7.2 Storage.

7.2.1 General.

7.2.1.1 Applicability. The storage of compressed gas cylinders, containers, and tanks shall be in accordance with Section 7.2.

7.2.1.2 Upright Storage Flammable Gas in Solution and Liquefied Flammable Gas. Cylinders, containers, and tanks containing liquefied flammable gases and flammable gases in solution shall be positioned in the upright position.

7.2.1.2.1 Cylinders and Containers of 1.3 Gal (5 L) or Less. Containers with a capacity of 1.3 gal (5 L) or less shall be permitted to be stored in a horizontal position.

7.2.1.2.2 Cylinders, Containers, and Tanks Designed for Horizontal Use. Cylinders, containers, and tanks designed for use in a horizontal position shall be permitted to be stored in a horizontal position.

7.2.1.2.3 Palletized Cylinders, Containers, and Tanks. Cylinders, containers, and tanks, with the exception of those containing flammable liquefied compressed gases, that are palletized for transportation purposes shall be permitted to be stored in a horizontal position.

7.2.1.3 Classification of Weather Protection as an Indoor Versus an Outdoor Area. For other than explosive materials and hazardous materials presenting a detonation hazard, a weather protection structure shall be permitted to be used for sheltering outdoor storage or use areas without requiring such areas to be classified as indoor storage.

7.2.2 Material-Specific Regulations.

7.2.2.1 Indoor Storage. Indoor storage of compressed gases shall be in accordance with the material-specific provisions of Sections 7.4 through 7.10.

7.2.2.2 Exterior Storage.

7.2.2.2.1 General. Exterior storage of compressed gases shall be in accordance with the material-specific provisions of Sections 7.4 through 7.10.

7.2.2.2.2 Separation. Distances from property lines, buildings, and exposures shall be in accordance with the material-specific provisions of Sections 7.4 through 7.10.

7.3 Use and Handling.

7.3.1 General.

7.3.1.1 Applicability. The use and handling of compressed gas cylinders, containers, tanks, and systems shall be in accordance with 7.3.1.

7.3.1.2 Controls.

7.3.1.2.1 Compressed gas system controls shall be designed to prevent materials from entering or leaving the process at an unintended time, rate, or path.

7.3.1.2.2 Automatic controls shall be designed to be fail-safe.

7.3.1.3 Piping Systems. Piping, tubing, fittings, and related components shall be designed, fabricated, and tested in accordance with the requirements of ANSI/ASME B31.3, *Process Piping*, or other approved standards.

7.3.1.3.1 Integrity. Piping, tubing, pressure regulators, valves, and other apparatus shall be kept gastight to prevent leakage.

7.3.1.3.2 Backflow Prevention. 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.

7.3.1.4 Valves.

7.3.1.4.1 Valves utilized on compressed gas systems shall be designed for the gas or gases and pressure intended and shall be accessible.

7.3.1.4.2 Valve handles or operators for required shutoff valves shall not be removed or otherwise altered to prevent access.

7.3.1.5 Vent Pipe Termination.

7.3.1.5.1 Venting of gases shall be directed to an approved location.

7.3.1.5.2 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 in accordance with Section 6.15.

7.3.1.6 Upright Use.

7.3.1.6.1 Compressed gas cylinders, containers, and tanks containing flammable liquefied gas, except those designed for use in a horizontal position and those compressed gas cylinders, containers, and tanks containing nonliquefied gases, shall be used in a "valve end up" upright position.

7.3.1.6.2 An upright position shall include a position in which the cylinder, container, or tank axis is inclined as much as 45 degrees from the vertical and in which the relief device is always in direct communication with the gas phase.

7.3.1.7 Inverted Use. Cylinders, containers, and tanks containing nonflammable liquefied gases shall be permitted to be used in the inverted position when the liquid phase is used.

7.3.1.7.1 Flammable liquefied gases at processing plants shall be permitted to use this inverted position method while transfilling.

7.3.1.7.2 The cylinder, container, or tank shall be secured, and the dispensing apparatus shall be designed for use with liquefied gas.

7.3.1.8 Cylinders and Containers of 1.3 Gal (5 L) or Less. Cylinders or containers with a water volume of 1.3 gal (5 L) or less shall be permitted to be used in a horizontal position.

7.3.1.9 Transfer. Transfer of gases between cylinders, containers, and tanks shall be performed by qualified personnel using equipment and operating procedures in accordance with CGA P-1, *Safe Handling of Compressed Gases in Containers*.

7.3.1.10 Use of Compressed Gases for Inflation. Inflatable equipment, devices, or balloons shall only be pressurized or filled with compressed air or inert gases.

7.3.1.11 Emergency Shutoff Valves.

7.3.1.11.1 Accessible manual or automatic emergency shutoff valves shall be provided to shut off the flow of gas in case of emergency.

7.3.1.11.1.1* Manual emergency shutoff valves or the device that activates an automatic emergency shutoff valve on a bulk

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source or piping system serving the bulk supply shall be identified by means of a sign.

7.3.1.11.2 Emergency shutoffs shall be located at the point of use and at the tank, cylinder, or bulk source, and at the point where the system piping enters the building.

7.3.1.12 Excess Flow Control.

7.3.1.12.1* Where compressed gases having a hazard ranking in one or more of the following hazard classes in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, are carried in pressurized piping above a gauge pressure of 15 psi (103 kPa), an approved means of either leak detection with emergency shutoff or excess flow control shall be provided:

(1) Health hazard Class 3 or Class 4
(2) Flammability Class 4
(3) Instability Class 3 or Class 4

7.3.1.12.1.1 Excess Flow Control Location with Hazardous Material Storage. Where the piping originates from within a hazardous material storage room or area, the excess flow control shall be located within the storage room or area.

7.3.1.12.1.2* Excess Flow Control Location with Bulk Storage. Where the piping originates from a bulk source, the excess flow control shall be located at the bulk source at a point immediately downstream of the source valve.

7.3.1.12.2 The controls required by 7.3.1.12 shall not be required for the following:

(1) Piping for inlet connections designed to prevent backflow at the source
(2) Piping for pressure relief devices
(3) Where the source of the gas is not in excess of the quantity threshold indicated in Table 6.3.1.1

7.3.1.12.3 Location. The location of excess flow control shall be as specified in 7.3.1.12.1.1 and 7.3.1.12.1.2.

7.3.1.12.3.1 Where piping originates from a source located in a room or area, the excess flow control shall be located within the room or area.

7.3.1.12.3.2 Where piping originates from a bulk source, the excess flow control shall be as close to the bulk source as possible.

7.3.1.12.4 Location Exemptions. The requirements of 7.3.1.12 shall not apply to the following:

(1) Piping for inlet connections designed to prevent backflow
(2) Piping for pressure relief devices
(3) Systems containing 430 scf (12.7 Nm^3) or less of flammable gas

7.3.2 Material-Specific Regulations.

7.3.2.1 Indoor Use. Indoor use of compressed gases shall be in accordance with the requirements of Sections 7.4 through 7.10.

7.3.2.2 Exterior Use.

7.3.2.2.1 General. Exterior use of compressed gases shall be in accordance with the requirements of Sections 7.4 through 7.10.

7.3.2.2.2 Separation. Distances from property lines, buildings, and exposure hazards shall be in accordance with the material-specific provisions of Sections 7.4 through 7.10.

7.3.3 Handling.

7.3.3.1 Applicability. The handling of compressed gas cylinders, containers, and tanks shall be in accordance with 7.3.3.

7.3.3.2 Carts and Trucks.

7.3.3.2.1 Cylinders, containers, and tanks shall be moved using an approved method.

7.3.3.2.2 Where cylinders, containers, and tanks are moved by hand cart, hand truck, or other mobile device, such carts, trucks, or devices shall be designed for the secure movement of cylinders, containers, and tanks.

7.3.3.3 Lifting Devices. Ropes, chains, or slings shall not be used to suspend compressed gas cylinders, containers, and tanks unless provisions at time of manufacture have been made on the cylinder, container, or tank for appropriate lifting attachments, such as lugs.

7.4 Medical Gas Systems. Medical gas systems for health care shall be in accordance with NFPA 99, *Health Care Facilities Code*.

7.5 Corrosive Gases.

7.5.1 General. The storage or use of corrosive compressed gases exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.3.1.1 shall be in accordance with Chapters 1 through 6 and Sections 7.1 through 7.3 and 7.5.

7.5.2 Distance to Exposures. The outdoor storage or use of corrosive compressed gas shall not be within 20 ft (6.1 m) of buildings not associated with the manufacture or distribution of corrosive gases, lot lines, streets, alleys, public ways, or means of egress.

7.5.2.1 A 2-hour fire barrier wall without openings or penetrations and that extends not less than 30 in. (762 mm) above and to the sides of the storage or use area shall be permitted in lieu of the 20 ft (6.1 m) distance.

7.5.2.1.1* Where a fire barrier is used to protect compressed gas systems, the system shall terminate downstream of the source valve.

7.5.2.1.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

7.5.2.1.3 The 2-hour fire barrier shall be located at least 5 ft (1.5 m) from any exposure.

7.5.2.1.4 The 2-hour fire barrier wall shall not have more than two sides at approximately 90 degree (1.57 rad) directions or not more than three sides with connecting angles of approximately 135 degrees (2.36 rad).

7.5.3 Indoor Use. The indoor use of corrosive gases shall be provided with a gas cabinet, exhausted enclosure, or gas room.

7.5.3.1 Gas Cabinets. Gas cabinets shall be in accordance with Section 6.17.

7.5.3.2 Exhausted Enclosures. Exhausted enclosures shall be in accordance with Section 6.18.

7.5.3.3 Gas Rooms. Gas rooms shall be in accordance with Section 6.4.

7.5.3.4 Treatment Systems. Treatment systems, except as provided for in 7.5.3.4.1, gas cabinets, exhausted enclosures, and gas rooms containing corrosive gases in use shall be provided with exhaust ventilation, with all exhaust directed to a treatment system designed to process the accidental release of gas.

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7.5.3.4.1 Treatment systems shall not be required for corrosive gases in use where provided with the following:

(1) Gas detection in accordance with 7.9.3.2.1.1
(2) Fail-safe automatic closing valves in accordance with 7.9.3.2.2

7.5.3.4.2 Treatment systems shall be capable of diluting, adsorbing, absorbing, containing, neutralizing, burning, or otherwise processing the release of corrosive gas in accordance with 7.9.3.4.1.

7.5.3.4.3 Treatment system sizing shall be in accordance with 7.9.3.4.

7.6 Flammable Gases.

7.6.1 Storage, Use, and Handling.

7.6.1.1 The storage or use of flammable gases exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.3.1.1 shall be in accordance with Chapters 1 through 6 and Sections 7.1 through 7.3 and 7.6.

7.6.1.2 Storage, use, and handling of gaseous hydrogen shall be in accordance with 7.6.1 and Chapter 10.

7.6.2 Distance to Exposures. The outdoor storage or use of non-bulk flammable compressed gas shall be located from lot lines, public streets, public alleys, public ways, or buildings not associated with the manufacture or distribution of such gases in accordance with Table 7.6.2.

7.6.2.1 Bulk hydrogen gas installations shall be in accordance with Chapter 10.

7.6.2.1.1* Where a protective structure is used to protect compressed gas systems, the system shall terminate downstream of the source valve.

7.6.2.1.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

7.6.2.2 Bulk gas systems for flammable gases other than hydrogen shall be in accordance with Table 10.3.2.1(a), Table 10.3.2.1(b), or Table 10.3.2.1(c) where the quantity of flammable compressed gas exceeds 5000 scf (141.6 Nm^3).

7.6.2.2.1 Where fire barriers are used as a means of distance reduction, fire barriers shall be in accordance with 10.3.2.4.

7.6.2.2.2 Mobile acetylene trailer systems (MATS) shall be located in accordance with 15.2.2.

7.6.2.3 The configuration of the protective structure shall be designed to allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

7.6.2.4 Storage and use of flammable compressed gases shall not be located within 50 ft (15.2 m) of air intakes.

7.6.2.5 Storage and use of flammable gases outside of buildings shall also be separated from building openings by 25 ft (7.6 m). Fire barriers shall be permitted to be used as a means to separate storage areas from openings or a means of egress used to access the public way.

7.6.3 Indoor Non-Bulk Hydrogen Compressed Gas System Location.

7.6.3.1 Hydrogen systems of less than 3500 scf (99 Nm^3) and greater than the MAQ, where located inside buildings, shall be in accordance with the following:

(1) In a ventilated area in accordance with the provisions of Section 6.16
(2) Separated from incompatible materials in accordance with the provisions of 7.1.11.2
(3) A distance of 25 ft (7.6 m) from open flames and other sources of ignition
(4) A distance of 50 ft (15 m) from intakes of ventilation, air-conditioning equipment, and air compressors located in the same room or area as the hydrogen system
    (a) The distance shall be permitted to be reduced to 10 ft (3.1 m) where the room or area in which the hydrogen system is installed is protected by a listed detection system per Article 500.7(K) of *NFPA 70, National Electrical Code*, and the detection system shuts down the fuel supply in the event of a leak that results in a concentration that exceeds 25 percent of the LFL.
    (b) Emergency shutoff valves shall be provided in accordance with 7.3.1.11.
(5) A distance of 50 ft (15 m) from other flammable gas storage
(6) Protected against damage in accordance with the provisions of 7.1.9.3

Table 7.6.2 Distance to Exposures for Non-Bulk Flammable Gases

Maximum Amount per Storage Area (scf)	Minimum Distance Between Storage Areas (ft)	Minimum Distance to Lot Lines of Property That Can Be Built Upon (ft)	Minimum Distance to Public Streets, Public Alleys or Public Ways (ft)	Minimum Distance to Buildings on the Same Property		
				Less Than 2-Hour Construction	2-Hour Construction	4-Hour Construction
0–4225	5	5	5	5	0	0
4226–21,125	10	10	10	10	5	0
21,126–50,700	10	15	15	20	5	0
50,701–84,500	10	20	20	20	5	0
84,501–200,000	20	25	25	20	5	0

For SI units, 1 ft = 304.8 mm; 1 scf = 0.02832 Nm^3.

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

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7.6.3.2 Systems Installed in One Room.

7.6.3.2.1 More than one system of 3500 scf (99 Nm^3) or less shall be permitted to be installed in the same room or area, provided the systems are separated by at least 50 ft (15 m) or a full-height fire-resistive partition having a minimum fire resistance rating of 2 hours is located between the systems.

7.6.3.2.2 The separation distance between multiple systems of 3500 scf (99 Nm^3) or less shall be permitted to be reduced to 25 ft (7.6 m) in buildings where the space between storage areas is free of combustible materials and protected with a sprinkler system designed for Extra Hazard, Group 1 in accordance with the requirements of Section 6.10.

7.6.3.2.3 The required separation distance between individual portable systems in the process of being filled or serviced in facilities associated with the manufacture or distribution of hydrogen and its mixtures shall not be limited by 7.6.3.2.1 or 7.6.3.2.2 when such facilities are provided with Protection Level 2 controls and the applicable requirements of Chapters 1 through 7.

7.6.4 Ignition Source Control. Ignition sources in areas containing flammable gases shall be in accordance with 7.6.4.

7.6.4.1 Static Producing Equipment. Static producing equipment located in flammable gas areas shall be grounded.

7.6.4.2 No Smoking or Open Flame. Signs shall be posted in areas containing flammable gases stating that smoking or the use of open flame, or both, is prohibited within 25 ft (7.6 m) of the storage or use area perimeter.

7.6.4.3 Heating. Heating, where provided, shall be by indirect means. Equipment used for heating applications in rooms or areas where flammable gases are stored or used shall be listed and labeled for use in hazardous environments established by the gases present and shall be installed in accordance with the conditions of the listing and the manufacturer's installation instructions.

7.6.5 Electrical. Areas in which the storage or use of compressed gases exceeds the quantity thresholds for gases requiring special provisions shall be in accordance with *NFPA 70, National Electrical Code*.

7.6.6 Maintenance of Piping Systems.

7.6.6.1 Maintenance of flammable gas system piping and components shall be performed annually by a qualified representative of the equipment owner.

7.6.6.2 This maintenance shall include inspection for physical damage, leak tightness, ground system integrity, vent system operation, equipment identification, warning signs, operator information and training records, scheduled maintenance and retest records, alarm operation, and other safety-related features.

7.6.6.3 Scheduled maintenance and retest activities shall be formally documented, and records shall be maintained a minimum of 3 years.

7.7 Oxidizing Gases.

7.7.1 General. The storage or use of oxidizing compressed gases exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.3.1.1 shall be in accordance with Chapters 1 through 6 and Sections 7.1 through 7.3 and 7.7.

7.7.2 Distance to Exposures. The outdoor storage or use of oxidizing compressed gas shall be in accordance with Table 7.7.2.

7.7.2.1 The distances shall not apply where fire barriers having a minimum fire resistance of 2 hours interrupt the line of sight between the container and the exposure.

7.7.2.1.1* Where a fire barrier is used to protect compressed gas systems, the system shall terminate downstream of the source valve.

7.7.2.1.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

7.7.2.2 The fire barrier shall be at least 5 ft (1.5 m) from the storage or use area perimeter.

7.7.2.3 The configuration of the fire barrier shall allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

7.8 Pyrophoric Gases.

7.8.1 General. Pyrophoric compressed gases exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.3.1.1 shall be stored and used in accordance with Chapters 1 through 6 and Sections 7.1 through 7.3 and Section 7.8.

7.8.2 Silane and Silane Mixtures. Silane and silane mixtures shall be stored, used, and handled in accordance with the provisions of ANSI/CGA G-13, *Storage and Handling of Silane and Silane Mixtures*.

7.8.3 Distance to Exposures. The outdoor storage or use of pyrophoric compressed gas shall be in accordance with Table 7.8.3.

7.8.3.1 The distances shall be allowed to be reduced to 5 ft (1.5 m) where fire barriers having a minimum fire resistance of 2 hours interrupt the line of sight between the container and the exposure.

7.8.3.1.1* Where a fire barrier is used to protect compressed gas systems, the system shall terminate downstream of the source valve.

7.8.3.1.2 The fire barrier shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

7.8.3.1.3 The fire barrier shall be at least 5 ft (1.5 m) from the storage or use area perimeter.

7.8.3.1.4 The configuration of the fire barrier shall allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

7.8.3.2 Storage and use of pyrophoric gases outside buildings shall be separated from building openings by 25 ft (7.6 m).

7.8.3.2.1 Fire barriers shall be permitted to be used as a means to separate storage areas from building openings that are used to access the public way.

7.9 Toxic and Highly Toxic Gases.

7.9.1 General. The storage or use of toxic or highly toxic gases exceeding the quantity thresholds for gases that require special provisions as specified in Table 6.3.1.1 shall be in accordance with Chapters 1 through 6 and Sections 7.1 through 7.3 and Section 7.9.

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Table 7.7.2 Distance to Exposures for Oxidizing Gases

Quantity of Gas Stored (at NTP)		Distance to a Building Not Associated with the Manufacture or Distribution of Oxidizing Gases or to a Public Way or Property Line		Minimum Distance Between Storage Areas	
scf	Nm^3	ft	m	ft	m
0–50,000	0–1416	5	1.5	5	1.5
50,001–100,000	1417– 2832	10	3.0	10	3.0
≥100,001	≥2833	15	4.6	15	4.6

Table 7.8.3 Distance to Exposures for Pyrophoric Gases

Maximum Amount per Storage Area		Minimum Distance Between Storage Areas		Minimum Distance to Property Lines		Minimum Distance to Public Ways		Minimum Distance to Buildings on the Same Property					
								Less Than 2-Hour Construction		2-Hour Construction		4-Hour Construction	
scf	Nm^3	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
250	7.1	5	1.5	25	7.6	5	1.5	5	1.5	0	0	0	0
>250 to 2500	>7.1 to 71.0	10	3.0	50	15.2	10	3.0	10	3.0	5	1.5	0	0
>2500 to 7500	>71.0 to 212.4	20	6.0	100	30.5	20	6.0	20	6.0	10	3.0	0	0

7.9.2 Ventilation and Arrangement.

7.9.2.1 Indoors. The indoor storage or use of highly toxic gases or toxic gases shall be provided with a gas cabinet, exhausted enclosure, or gas room.

7.9.2.1.1 Gas cabinets shall be in accordance with Section 6.17.

7.9.2.1.2 Exhausted enclosures shall be in accordance with Section 6.18.

7.9.2.1.3 Gas rooms shall be in accordance with Section 6.4.

7.9.2.2 Distance to Exposures. The outdoor storage or use of toxic or highly toxic compressed gases shall not be within 75 ft (23 m) of lot lines, streets, alleys, public ways or means of egress, or buildings not associated with such storage or use.

7.9.2.2.1 A 2-hour fire barrier wall without openings or penetrations that extends not less than 30 in. (762 mm) above and to the sides of the storage or use area and that interrupts the line of sight between the storage or use area and the exposure shall be permitted in lieu of the 75 ft (23 m) distance.

7.9.2.2.1.1* Where a fire barrier is used to protect compressed gas systems, the system shall terminate downstream of the source valve.

7.9.2.2.1.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

7.9.2.2.1.3 The 2-hour fire barrier wall shall be located at least 5 ft (1.5 m) from any exposure.

7.9.2.2.1.4 The 2-hour fire barrier wall shall not have more than two sides at approximately 90 degree (1.5 rad) directions or more than three sides with connecting angles of approximately 135 degrees (2.36 rad).

7.9.2.2.2 Where the storage or use area is located closer than 75 ft (23 m) to a building not associated with the manufacture or distribution of toxic or highly toxic compressed gases, openings in the building other than for piping shall not be permitted above the height of the top of the 2-hour fire barrier wall or within 50 ft (15 m) horizontally from the storage area, regardless of whether the openings are shielded by a fire barrier.

7.9.2.3 Air Intakes. Storage and use of toxic or highly toxic compressed gases shall not be located within 75 ft (23 m) of air intakes.

7.9.3 Treatment Systems. Except as provided in 7.9.3.1 and 7.9.3.2, gas cabinets, exhausted enclosures, and gas rooms containing toxic or highly toxic gases shall be provided with exhaust ventilation, with all exhaust directed to a treatment system designed to process accidental release of gas.

7.9.3.1 Storage of Toxic or Highly Toxic Gases. Treatment systems shall not be required for toxic or highly toxic gases in storage where cylinders, containers, and tanks are provided with the controls specified in 7.9.3.1.1 through 7.9.3.1.3.

7.9.3.1.1 Valve Outlets Protected. Valve outlets shall be equipped with outlet plugs or caps, or both, rated for the container service pressure.

7.9.3.1.2 Handwheels Secured. Where provided, handwheel-operated valves shall be secured to prevent movement.

7.9.3.1.3 Containment Devices Provided. Approved cylinder containment vessels or cylinder containment systems shall be provided at an approved location.

7.9.3.2 Use of Toxic Gases. Treatment systems shall not be required for toxic gases in use where cylinders, containers,

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and tanks are provided with the controls specified in 7.9.3.2.1 and 7.9.3.2.2.

7.9.3.2.1 Gas Detection.

7.9.3.2.1.1 A gas detection system with a sensing interval not exceeding 5 minutes shall be provided.

7.9.3.2.1.2 The gas detection system shall monitor the exhaust system at the point of discharge from the gas cabinet, exhausted enclosure, or gas room.

7.9.3.2.2 Fail-Safe Automatic Closing Valve. An approved automatic-closing fail-safe valve shall be located on or immediately adjacent to and downstream of active cylinder, container, or tank valves.

7.9.3.2.2.1 The fail-safe valve shall close when gas is detected at the permissible exposure limit, short-term exposure limit (STEL), or ceiling limit by the gas detection system.

7.9.3.2.2.2 For attended operations, a manual closing valve shall be permitted when in accordance with 7.9.3.4.3.

7.9.3.2.2.3 For gases used at unattended operations for the protection of public health, such as chlorine at water or wastewater treatment sites, the automatic valve shall close if the concentration of gas detected by a gas detection system reaches one-half of the IDLH.

7.9.3.2.2.4 The gas detection system shall also alert persons on-site and a responsible person off-site when the gas concentration in the storage/use area reaches the OSHA PEL, OSHA ceiling limit, or OSHA STEL for the gas employed.

7.9.3.3 Treatment System Design and Performance. Treatment systems shall be capable of diluting, adsorbing, absorbing, containing, neutralizing, burning, or otherwise processing stored or used toxic or highly toxic gas, or both.

7.9.3.3.1 Where a total containment system is used, the system shall be designed to handle the maximum anticipated pressure of release to the system when it reaches equilibrium.

7.9.3.3.2 Treatment systems shall be capable of reducing the allowable discharge concentrations to one-half the IDLH threshold at the point of discharge.

7.9.3.4 Treatment System Sizing.

7.9.3.4.1 Worst-Case Release of Gas. Treatment systems shall be sized to process the maximum worst-case release of gas based on the maximum flow rate of release from the largest vessel utilized in accordance with 7.9.3.4.2.

7.9.3.4.2 Largest Compressed Gas Vessel. The entire contents of the single largest compressed gas vessel shall be considered.

7.9.3.4.3 Attended Operations — Alternative Method of System Sizing.

7.9.3.4.3.1 Where source cylinders, containers, and tanks are used in attended process operations, with an operator present at the enclosure where the activity occurs, the volume of the release shall be limited to the estimated amount released from the process piping system within a period not to exceed 5 minutes.

7.9.3.4.3.2 Such process piping systems shall comply with the requirements of 7.9.3.4.3.2(A) through 7.9.3.4.3.2(E).

(A) Local Exhaust. All gas transfer operations shall be conducted within a zone of local exhaust that is connected to a treatment system.

(B) Gas Detection. Gas detection shall be used to provide a warning to alert the operators to emission of gas into the zone of local exhaust, and the following requirements also shall apply:

(1) The system shall be capable of detecting gas at the PEL or the ceiling limit for the gas being processed.
(2) Activation of the gas detection system shall provide a local alarm.

(C) Process Shutdown. Operations involving the gas detected shall be shut down and leaks repaired.

(D) Piping System Construction. Piping systems used to convey gases shall be of all-welded construction throughout, with the exception of fittings used to connect cylinders, containers, or tanks, or any combination thereof, to the process system.

(E) Piping System Accessibility. Piping systems shall be designed to provide for readily accessible manual shutdown controls.

7.9.3.5 Rate of Release. The time release shall be in accordance with Table 7.9.3.5 for the type of container indicated.

7.9.3.6* Maximum Flow Rate of Release.

7.9.3.6.1 For portable cylinders, containers, and tanks, the maximum flow rate of release shall be calculated based on assuming the total release from the cylinder or tank within the time specified.

7.9.3.6.2* When portable cylinders, containers, or tanks are equipped with reduced flow orifices, the worst-case rate of release shall be determined by the maximum achievable flow from the valve based on the following formula:

$$CFM = (767 \times A \times P)\frac{(28.96/MW)^{1/2}}{60}$$

where:

CFM = standard cubic feet per minute of gas of concern under flow conditions
A = area of orifice in square inches *(See Table A.7.9.3.6 for areas of typical restricted flow orifices.)*
P = supply pressure of gas at NTP in pounds per square inch absolute
MW = molecular weight

Table 7.9.3.5 Rate of Release

Container Type	Time Release	
	Nonliquefied Gases	Liquefied Gases
Cylinders without restrictive flow orifices	5 minutes	30 minutes
Portable tanks without restrictive flow orifices	40 minutes	240 minutes
All others	Based on peak flow from maximum valve orifice	Based on peak flow from maximum valve orifice

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7.9.3.6.3 For mixtures, the average of the molecular weights shall be used.

7.9.4 Leaking Cylinders, Containers, and Tanks. When cylinders, containers, or tanks are used outdoors in excess of the quantities specified in Table 6.3.1.1 in the column for unsprinklered areas (unprotected by gas cabinets or exhausted enclosures), a gas cabinet, exhausted enclosure, or containment vessel or system shall be provided to control leaks from leaking cylinders, containers, and tanks in accordance with 7.9.4.1 through 7.9.4.2.3.

7.9.4.1 Gas Cabinets or Exhausted Enclosures. Where gas cabinets or exhausted enclosures are provided to handle leaks from cylinders, containers, or tanks, exhaust ventilation shall be provided that is directed to a treatment system in accordance with the provisions of 7.9.3.

7.9.4.2 Containment Vessels or Systems. Where containment vessels or containment systems are provided, they shall comply with the requirements of 7.9.4.2.1 through 7.9.4.2.3.

7.9.4.2.1 Performance. Containment vessels or containment systems shall be capable of fully containing or terminating a release.

7.9.4.2.2 Personnel. Trained personnel capable of operating the containment vessel or containment system shall be available at an approved location.

7.9.4.2.3 Location. Containment vessels or systems shall be capable of being transported to the leaking cylinder, container, or tank.

7.9.5 Emergency Power.

7.9.5.1 General. Emergency power shall comply with the requirements of 7.9.5 in accordance with *NFPA 70, National Electrical Code*.

7.9.5.2 Alternative to Emergency Power. Emergency power shall not be required where fail-safe engineering is provided for mechanical exhaust ventilation, treatment systems, and temperature control, and standby power is provided to alternative systems that utilize electrical energy.

7.9.5.3 Where Required. Emergency power shall be provided for the following systems:

(1) Exhaust ventilation
(2) Treatment system
(3) Gas detection system
(4) Temperature control system
(5) Required alarm systems

7.9.5.4 Level. Emergency power systems shall comply with the requirements for a Level 2 system in accordance with NFPA 110, *Standard for Emergency and Standby Power Systems*.

7.9.6 Gas Detection. Except as provided in 7.9.6.1, a continuous gas detection system in accordance with the requirements of 7.9.6.2 through 7.9.6.6 shall be provided for the indoor storage or use of toxic or highly toxic compressed gases.

7.9.6.1 Where Gas Detection Is Not Required. A gas detection system shall not be required for toxic gases where the physiological warning properties for the gas are at a level below the accepted PEL or the ceiling limit for the gas.

7.9.6.2 Local Alarm. The gas detection system shall initiate a local alarm that is both audible and visible.

7.9.6.3 Alarm Monitored. The gas detection system shall transmit a signal to a constantly attended control station for quantities exceeding one toxic or highly toxic compressed gas cylinder.

7.9.6.4 Automatic Shutdown.

7.9.6.4.1 Activation of the gas detection system shall automatically shut off the flow of gas related to the system being monitored.

7.9.6.4.2 An automatic shutdown shall not be required for reactors utilized for the production of toxic or highly toxic gases when such reactors are operated at gauge pressures less than 15 psi (103.4 kPa), constantly attended, and provided with readily accessible emergency shutoff valves.

7.9.6.5 Detection Points. Detection shall be provided at the locations specified in 7.9.6.5.1 through 7.9.6.5.4.

7.9.6.5.1 Treatment System Discharge. Detection shall be provided at the discharge from the treatment system.

7.9.6.5.2 Point of Use. Detection shall be provided in the room or area in which the gas is used.

7.9.6.5.3 Source. Detection shall be provided at the source cylinder, container, or tank used for delivery of the gas to the point of use.

7.9.6.5.4 Storage. Detection shall be provided in the room or area in which the gas is stored.

7.9.6.6 Level of Detection. The gas detection system shall detect the presence of gas at or below the PEL or the ceiling limit of the gas for those points identified in 7.9.6.5.2 and 7.9.6.5.3 and at not less than one-half the IDLH level for points identified in 7.9.6.5.1.

7.9.7 Automatic Smoke Detection System. An automatic smoke detection system shall be provided for the indoor storage or use of highly toxic compressed gases in accordance with *NFPA 72, National Fire Alarm and Signaling Code*.

7.10 Unstable Reactive Gases (Nondetonable). The storage or use of unstable reactive (nondetonable) gases exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.3.1.1 shall be in accordance with Chapters 1 through 6 and Sections 7.1 through 7.3 and Section 7.10.

7.10.1 Distances to Exposures for Class 2.

7.10.1.1 The outdoor storage or use of unstable reactive Class 2 compressed gas shall not be within 20 ft (6 m) of buildings, lot lines, streets, alleys, or public ways or means of egress.

7.10.1.2 A 2-hour fire barrier wall without openings or penetrations shall be permitted in lieu of the 20 ft (6 m) distance required by 7.10.1.1.

7.10.1.2.1* Where a fire barrier wall is used to protect compressed gas systems, the system shall terminate downstream of the source valve.

7.10.1.2.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building.

7.10.1.2.3 The 2-hour fire barrier wall shall be located at least 5 ft (1.5 m) from any exposure.

7.10.1.2.4 The 2-hour fire barrier wall shall not have more than two sides at approximately 90 degree (1.57 rad) directions or not more than three sides with connecting angles of approximately 135 degrees (2.36 rad).

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7.10.2 Distances to Exposures for Class 3.

7.10.2.1 The outdoor storage or use of unstable reactive Class 3 (nondetonable) compressed gas shall not be within 75 ft (23 m) of buildings, lot lines, streets, alleys, or public ways or means of egress.

7.10.2.2 A 2-hour fire barrier wall without openings or penetrations, extending not less than 30 in. (762 mm) above and to the sides of the storage or use area, that interrupts the line of sight between the storage or use and the exposure shall be permitted in lieu of the 75 ft (23 m) distance specified in 7.10.2.1.

7.10.2.2.1* Where a fire barrier wall is used to protect compressed gas systems, the system shall terminate downstream of the source valve.

7.10.2.2.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

7.10.2.2.3 The 2-hour fire barrier wall shall be located at least 5 ft (1.5 m) from any exposure.

7.10.2.2.4 The 2-hour fire barrier wall shall not have more than two sides at approximately 90 degree (1.57 rad) directions or more than three sides with connecting angles of approximately 135 degrees (2.36 rad).

7.10.3 Storage Configuration.

7.10.3.1 Unstable reactive Class 3 compressed gases stored in cylinders, containers, or tanks shall be arranged to limit individual groups of cylinders, containers, or tanks to areas not exceeding 100 ft^2 (9.3 m^2).

7.10.3.2 Multiple areas shall be separated by aisles.

7.10.3.3 Aisle widths shall not be less than the height of the cylinders, containers, or tanks or 4 ft (1.2 m), whichever is greater.

7.10.4 Basements. Unstable reactive compressed gases shall not be stored in basements.

7.10.5 Unstable Reactive Gases (Detonable).

7.10.5.1 Storage or Use. The storage or use of unstable reactive (detonable) gases exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.3.1.1 shall be in accordance with Chapters 1 through 6, Sections 7.1 through 7.3, and 7.10.5.

7.10.5.2 Location. The location of storage areas shall be determined based on the requirements of the building code for explosive materials.

Chapter 8 Cryogenic Fluids

8.1 General. This chapter shall apply to all cryogenic fluids, including those fluids regulated elsewhere in this code, except that where specific requirements are provided in other chapters, those specific requirements shall apply in accordance with the applicable chapter.

8.1.1 Storage, use, and handling of cryogenic fluids shall be in accordance with Chapters 1 through 6 and Chapter 8 as applicable.

8.1.2 Storage, use, and handling of inert cryogenic fluids shall be in accordance with CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites*.

8.2* Containers — Design, Construction, and Maintenance. Containers employed for the storage or use of cryogenic fluids shall be designed, fabricated, tested, marked (stamped), and maintained in accordance with DOT regulations; Transport Canada (TC), *Transportation of Dangerous Goods Regulations*; the ASME *Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels"; or regulations of other administering agencies.

8.2.1 Aboveground Tanks. Aboveground tanks for the storage of cryogenic fluids shall be in accordance with 8.2.1.

8.2.1.1 Construction of the Inner Vessel. The inner vessel of storage tanks in cryogenic fluid service shall be designed and constructed in accordance with Section VIII, Division 1 of the ASME *Boiler and Pressure Vessel Code* and shall be vacuum jacketed in accordance with 8.2.1.2.

8.2.1.2 Construction of the Vacuum Jacket (Outer Vessel).

8.2.1.2.1 The vacuum jacket used as an outer vessel for storage tanks in cryogenic fluid service shall be of welded steel construction designed to withstand the maximum internal and external pressure to which it will be subjected under operating conditions to include conditions of emergency pressure relief of the annular space between the inner vessel and the outer vessel.

8.2.1.2.2 The jacket shall be designed to withstand a minimum collapsing pressure differential of 30 psi (207 kPa).

8.2.1.2.3 Vacuum Level Monitoring.

8.2.1.2.3.1 A connection shall be provided on the exterior of the vacuum jacket to allow measurement of the pressure within the annular space between the inner vessel and the outer vessel.

8.2.1.2.3.2 The connection shall be fitted with a bellows-sealed or diaphragm-type valve equipped with a vacuum gauge tube that is shielded to protect against damage from impact.

8.2.2 Nonstandard Containers.

8.2.2.1 Containers, equipment, and devices that are not in compliance with recognized standards for design and construction shall be permitted if approved by the authority having jurisdiction upon presentation of evidence that they are designed and constructed for safe operation.

8.2.2.2 The following data shall be submitted to the authority having jurisdiction with reference to the deviation from the standard with the application for approval:

(1) Type and use of container, equipment, or device
(2) Material to be stored, used, or transported
(3) Description showing dimensions and materials used in construction
(4) Design pressure, maximum operating pressure, and test pressure
(5) Type, size, and setting of pressure relief devices

8.2.3 Foundations and Supports. Stationary tanks shall be provided with concrete or masonry foundations or structural steel supports on firm concrete or masonry foundations, and the requirements of 8.2.3.1 through 8.2.3.5 also shall apply.

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8.2.3.1 Excessive Loads. Stationary tanks shall be supported to prevent the concentration of excessive loads on the supporting portion of the shell.

8.2.3.2 Expansion and Contraction. Foundations for horizontal containers shall be constructed to accommodate expansion and contraction of the container.

8.2.3.3* Support of Ancillary Equipment.

8.2.3.3.1 Foundations shall be provided to support the weight of vaporizers or heat exchangers.

8.2.3.3.2 Foundations shall be designed to withstand soil and frost conditions as well as the anticipated seismic, snow, wind, and hydrostatic loading under operating conditions.

8.2.3.4 Temperature Effects. Where drainage systems, terrain, or surfaces beneath stationary tanks are arranged in a manner that can subject stationary tank foundations or supports to temperatures below –130°F (–90°C), the foundations or supports shall be constructed of materials that are capable of withstanding the low-temperature effects of cryogenic fluid spillage.

8.2.3.5 Corrosion Protection. Portions of stationary tanks in contact with foundations or saddles shall be painted to protect against corrosion.

8.2.4 Pressure Relief Devices.

8.2.4.1 General.

8.2.4.1.1 Pressure relief devices shall be provided to protect containers and systems containing cryogenic fluids from rupture in the event of overpressure.

8.2.4.1.2 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.

8.2.4.2 Containers Open to the Atmosphere. Portable containers that are open to the atmosphere and are designed to contain cryogenic fluids at atmospheric pressure shall not be required to be equipped with pressure relief devices.

8.2.4.3 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.

8.2.4.4 Sizing.

8.2.4.4.1 Pressure relief devices shall be sized in accordance with the specifications to which the container was fabricated.

8.2.4.4.2 The pressure relief device shall have the capacity to prevent the maximum design pressure of the container or system from being exceeded.

8.2.4.5 Accessibility. Pressure relief devices shall be located such that they are accessible for inspection and repair.

8.2.4.5.1* ASME pressure relief valves shall be made to be tamper resistant in order to prevent adjusting of the set pressure by other than authorized personnel.

8.2.4.5.2 Non-ASME pressure relief valves shall not be field adjusted.

8.2.4.6 Arrangement.

8.2.4.6.1 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.

8.2.4.6.2 Portable Containers with Volume Less Than 2.0 scf (0.057 Nm^3).

8.2.4.6.2.1 The arrangement of the discharge from pressure relief devices from DOT-specified containers with an internal water volume of 2.0 scf (0.057 Nm^3) or less shall be incorporated in the design of the container.

8.2.4.6.2.2 Additional safeguards regarding placement or arrangement shall not be required.

8.2.4.7 Shutoffs Between Pressure Relief Devices and Containers.

8.2.4.7.1 General. Shutoff valves installed between pressure relief devices and containers shall be in accordance with 8.2.4.7.

8.2.4.7.2 Location. Shutoff valves shall not be installed between pressure relief devices and containers unless the valves or their use meet the requirements of 8.2.4.7.2.1 or 8.2.4.7.2.2.

8.2.4.7.2.1 Security. Shutoff valves shall be locked in the open position, 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.*

8.2.4.7.2.2 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.

8.2.4.8 Temperature Limits. Pressure relief devices shall not be subjected to cryogenic fluid temperatures except when operating.

8.3 Pressure Relief Vent Piping.

8.3.1 General. Pressure relief vent piping systems shall be constructed and arranged to direct the flow of gas to a safe location and in accordance with Section 8.3.

8.3.2 Sizing. Pressure relief device vent piping shall have a cross-sectional area not less than that of the pressure relief device vent opening and shall be arranged so as not to restrict the flow of escaping gas.

8.3.3 Arrangement. Pressure relief device vent piping and drains in vent lines shall be arranged so that escaping gas discharges unobstructed to the open air and does not impinge on personnel, containers, equipment, and adjacent structures or enter enclosed spaces.

8.3.4 Installation. Pressure relief device vent lines shall be installed in a manner that excludes or removes moisture and condensation to prevent malfunction of the pressure relief device due to freezing or ice accumulation.

8.3.5 Overfilling. Controls shall be provided to prevent overfilling of stationary containers.

8.4 Marking.

8.4.1 General. Cryogenic containers and systems shall be marked in accordance with nationally recognized standards and in accordance with Section 8.4.

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8.4.1.1 Portable Containers.

8.4.1.1.1 Portable cryogenic containers shall be marked in accordance with CGA C-7, *Guide to the Preparation of Precautionary Labeling and Marking of Compressed Gas Containers*.

8.4.1.1.2* All DOT-4L/TC-4LM liquid cylinders shall have product identification visible from all directions with minimum 2 in. (51 mm) high letters.

8.4.1.2 Stationary Tanks. Stationary tanks shall be marked in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*.

8.4.1.3 Identification Signs. Visible hazard identification signs shall be provided in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, at entrances to buildings or areas in which cryogenic fluids are stored, handled, or used.

8.4.2 Identification of Contents. Stationary containers shall be placarded with the identity of their contents to indicate the name of the material contained.

8.4.3 Container Specification. Stationary containers shall be marked with the manufacturing specification and maximum allowable working pressure on a permanent nameplate.

8.4.3.1 The nameplate shall be installed on the container in an accessible location.

8.4.3.2 The nameplate shall be marked in accordance with nationally recognized standards.

8.4.4 Identification of Container Connections.

8.4.4.1 Container inlet and outlet connections, liquid-level limit controls, valves, and pressure gauges shall be identified using one of the methods prescribed by 8.4.4.1.1 through 8.4.4.1.2.

8.4.4.1.1 They shall be marked with a permanent tag or label identifying their function.

8.4.4.1.2 They shall be identified by a schematic drawing that indicates their function and designates whether they are connected to the vapor or liquid space of the container.

8.4.4.1.2.1 When a schematic drawing is provided, it shall be attached to the container and maintained in a legible condition.

8.4.5 Identification of Piping Systems. Piping systems shall be identified in accordance with ASME A13.1, *Scheme for the Identification of Piping Systems*.

8.4.6 Identification of Emergency Shutoff Valves. Emergency shutoff valves on stationary containers shall be identified, visible, and indicated by means of a sign.

8.5 Medical Cryogenic Systems.

8.5.1 Bulk cryogenic fluid systems in medical gas applications at health care facilities shall be in accordance with Chapter 8, 1.1.2(3), and the material-specific requirements of Chapter 9 as applicable.

8.5.1.1 Bulk cryogenic fluid systems shall be in accordance with the following provisions as applicable:

(1) Where located in a court, systems shall be in accordance with 8.13.2.7.2.
(2) Where located indoors, systems shall be in accordance with 8.14.11.1.
(3) Systems shall be installed by personnel qualified in accordance with CGA M-1, *Guide for Medical Gas Installations at Consumer Sites*, or ASSE 6015, *Professional Qualification Standard for Bulk Medical Gas Systems Installers*.
(4) Systems shall be installed in compliance with Food and Drug Administration Current Good Manufacturing Practices as found in 21 CFR 210 and 21 CFR 211.

8.5.1.2 The following components of the bulk system shall be accessible and visible to delivery personnel during filling operations:

(1) Fill connection
(2) Top and bottom fill valves
(3) Hose purge valve
(4) Vent valve
(5) Full trycock valve
(6) Liquid level gauge
(7) Tank pressure gauge

8.5.1.3 Bulk cryogenic fluid systems shall be anchored with foundations in accordance with the provisions of CGA M-1, *Guide for Medical Gas Installations at Consumer Sites*.

8.5.1.4 Bulk cryogenic fluid systems shall consist of the following:

(1) One or more main supply vessel(s), whose capacity shall be determined after consideration of the customer usage requirements, delivery schedules, proximity of the facility to alternative supplies, and the emergency plan
(2) A contents gauge on each of the main vessel(s)
(3) A reserve supply sized for greater than an average day's supply, with the size of vessel or number of cylinders being determined after consideration of delivery schedules, proximity of the facility to alternative supplies, and the facility's emergency plan
(4) At least two main vessel relief valves and rupture discs installed downstream of a three-way (three-port) valve
(5) A check valve located in the primary supply piping upstream of the intersection with a secondary supply or reserve supply

8.5.1.5 Bulk cryogenic fluid reserve supply systems consisting of either a second cryogenic fluid source or a compressed gas source shall include the following:

(1) When the reserve source is a compressed gas source, the reserve shall be equipped with the following:
   (a) A cylinder manifold having not less than three gas cylinder connections or as otherwise required for an average of one day's gas supply
   (b) A pressure switch to monitor the pressure in the cylinder manifold
(2) When the reserve source is a second cryogenic fluid vessel, the reserve tank shall be equipped with the following:
   (a) An actuating switch or sensor to monitor the internal tank pressure
   (b) A contents gauge to monitor the liquid level
(3) When the reserve source is either a cryogenic fluid or compressed gas source, a check valve shall be provided to prevent backflow into the reserve system

8.5.1.6 Bulk cryogenic fluid systems shall include a fill mechanism consisting of the following components:

(1) A nonremovable product-specific fill connection in compliance with CGA V-6, *Standard Cryogenic Liquid Transfer Connection*

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(2) A means to cap and secure the fill connection inlet
(3) A check valve to prevent product backflow from the fill inlet
(4) A fill hose purge valve
(5) Supports that hold the fill piping off the ground
(6) A secure connection between the bulk tank and the fill piping
(7) Supports as necessary to hold the fill line in position during all operations associated with the filling procedure

8.5.1.7 Where vaporizers are required to convert cryogenic liquid to the gaseous state, the vaporizer units shall conform to the following:

(1) Be permitted to operate by either ambient heat transfer or external thermal source (e.g., electric heater, hot water, steam)
(2) Be designed to provide capacity for the customer's peak and average flow rates under local conditions, seasonal conditions for weather and humidity, and structures that obstruct air circulation flow and sunlight
(3) If switching is required as part of the system design, have piping and manual/automatic valving configured in such a manner that operating vaporizer(s) or sections of the vaporizer can be switched to nonoperating vaporizer or section of the vaporizer to de-ice through a valving configuration that ensures continuous flow to the facility through either or both vaporizers and/or sections of the vaporizer if valving switchover fails

8.5.1.8 Where a vaporizer requires an external thermal source, the flow from the source of supply shall be unaffected by the loss of the external thermal source through either of the following:

(1) Reserve ambient heat transfer vaporizers capable of providing capacity for at least one day's average supply and piped so as to be unaffected by flow stoppage through the main vaporizer
(2) A reserve noncryogenic source capable of providing at least one day's average supply

8.6 Security.

8.6.1 General. Cryogenic containers and systems shall be secured against accidental dislodgement and against access by unauthorized personnel in accordance with Section 8.6.

8.6.2* Security of Areas. Areas used for the storage of containers and systems shall be secured against unauthorized entry.

8.6.2.1 Administrative controls shall be allowed to be used to control access to individual storage areas located in secure facilities not accessible by the general public.

8.6.3 Securing of Containers. Stationary containers shall be secured to foundations in accordance with the building code.

8.6.3.1 Portable containers subject to shifting or upset shall be secured.

8.6.3.2 Nesting shall be permitted as a means of securing portable containers.

8.6.4 Securing of Vaporizers. Vaporizers, heat exchangers, and similar equipment shall be secured to foundations, and their connecting piping shall be designed and constructed to provide for the effects of expansion and contraction due to temperature changes.

8.6.5 Physical Protection. Containers, piping, valves, pressure relief devices, regulating equipment, and other appurtenances shall be protected against physical damage and tampering.

8.7 Separation from Hazardous Conditions.

8.7.1 General. Cryogenic containers and systems in storage or use shall be separated from materials and conditions that present exposure hazards to or from each other in accordance with Section 8.7.

8.7.2* Stationary Cryogenic Containers. Stationary containers located outdoors shall be separated from exposure hazards in accordance with the minimum separation distances indicated in Table 8.7.2.

Table 8.7.2 Minimum Separation Distance Between Stationary Cryogenic Containers and Exposures

Exposure	Minimum Distance ft	Minimum Distance m
(1) Buildings, regardless of construction type	1	0.3
(2) Wall openings	1	0.3
(3) Air intakes	10	3.1
(4) Property lines	5	1.5
(5) Places of public assembly (assembly occupancies)	50	15
(6) Nonambulatory patient areas	50	15
(7) Combustible materials, (e.g., paper, leaves, weeds, dry grass, debris)	15	4.5
(8) Incompatible hazardous materials	20	6.1
(9) Building exits	10	3.1

8.7.2.1 Fire Barriers. A 2-hour fire barrier wall shall be permitted in lieu of the distances specified in Table 8.7.2 for items 1, 4, 7, 8, and 9, where in accordance with the provisions of 8.7.2.1.1 through 8.7.2.1.4.

8.7.2.1.1 The fire barrier wall shall be without openings or penetrations.

8.7.2.1.1.1 Penetrations of the fire barrier wall by conduit or piping shall be permitted provided that the penetration is protected with a firestop system in accordance with the building code.

8.7.2.1.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage system.

8.7.2.1.3 The fire barrier wall shall be located not less than 5 ft (1.5 m) from any exposure.

8.7.2.1.4 The fire barrier wall shall not have more than two sides at 90 degree (1.57 rad) directions or not more than three sides with connecting angles of 135 degrees (2.36 rad).

8.7.2.1.4.1* The connecting angles between fire barrier walls shall be permitted to be reduced to less than 135 degrees (2.36 rad) for installations consisting of three walls when in accordance with 8.13.2.7.2.

8.7.2.1.5 Where the requirement of 8.7.2.1.4 is met, the bulk system shall be a minimum distance of 1 ft (0.3 m) from the fire barrier wall.

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8.7.2.2 Point-of-Fill Connections. Point-of-fill connections serving stationary containers filled by mobile transport equipment shall not be positioned closer to exposures than the minimum distances in Table 8.7.2.

8.7.2.3 Surfaces Beneath Containers. The surface of the area on which stationary containers are placed, including the surface of the area located below the point at which connections are made for the purpose of filling such containers, shall be compatible with the fluid in the container.

8.7.3 Portable Cryogenic Containers. Portable containers used for cryogenic fluids located outdoors shall be separated from exposure hazards in accordance with Table 8.7.3.

8.7.3.1 Non-bulk portable containers of liquefied hydrogen shall be separated from exposure hazards in accordance with Table 8.7.3.1.

8.7.3.2 Fire Barriers. A 2-hour fire barrier wall shall be permitted in lieu of the distances specified by Table 8.7.3 or Table 8.7.3.1 when in accordance with the provisions of 8.7.3.2.1 through 8.7.3.2.4.

8.7.3.2.1 The fire barrier wall shall be without openings or penetrations.

8.7.3.2.1.1 Penetrations of the fire barrier wall by conduit or piping shall be permitted provided that the penetration is protected with a firestop system in accordance with the building code.

8.7.3.2.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage system.

8.7.3.2.3 The fire barrier wall shall be located not less than 5 ft (1.5 m) from any exposure.

8.7.3.2.4 The fire barrier wall shall not have more than two sides at approximately 90 degree (1.57 rad) directions, or not more than three sides with connecting angles of approximately 135 degrees (2.36 rad).

Table 8.7.3 Minimum Separation Distance Between Portable Cryogenic Containers and Exposures

	Minimum Distance	
Exposure	**ft**	**m**
Building exits	10	3.1
Wall openings	1	0.3
Air intakes	10	3.1
Property lines	5	1.5
Room or area exits	3	0.9
Combustible materials, (e.g., paper, leaves, weeds, dry grass, debris)	15	4.5
Incompatible hazardous materials	20	6.1

8.8 Electrical Wiring and Equipment.

8.8.1 General. Electrical wiring and equipment shall be in accordance with *NFPA 70, National Electrical Code*, and Section 8.8.

8.8.2 Location. Containers and systems shall not be located where they could become part of an electrical circuit.

8.8.3 Electrical Grounding and Bonding. Containers and systems shall not be used for electrical grounding.

8.8.3.1 When electrical grounding and bonding are required, the system shall be in accordance with *NFPA 70, National Electrical Code*.

8.8.3.2 The grounding system shall be protected against corrosion, including corrosion caused by stray electrical currents.

8.9 Service and Repair. Service, repair, modification, or removal of valves, pressure relief devices, or other container

Table 8.7.3.1 Distance to Exposures for Non-Bulk Liquefied Hydrogen (LH_2)

				Minimum Distance to Buildings on the Same Property		
Maximum Amount per Storage Area (gal)	**Minimum Distance Between Storage Areas (ft)**	**Minimum Distance to Lot Lines of Property That Can Be Built Upon (ft)**	**Minimum Distance to Public Streets, Public Alleys or Public Ways (ft)**	**Less than 2-Hour Construction**	**2-Hour Construction**	**4-Hour Construction**
0–39.7	5	5	5	5	0	0
39.8–186.9	10	10	10	10	5	0
187–448.7	10	15	15	20	5	0
448.8–747.8	10	20	20	20	5	0
>747.8	20	25	25	20	5	0

For SI units: 1 ft = 305 mm.

Notes:

(1) For requirements on minimum distance to air intakes, see 7.6.2.4.

(2) For requirements on minimum distance to building openings including exits, see 7.6.2.5.

(3) When 8.7.3.2 is used as a means of distance reduction, the configuration of the fire barriers should be designed to allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

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appurtenances shall be in accordance with nationally recognized codes and standards.

8.9.1 Containers. Containers that have been removed from service shall be handled in an approved manner.

8.9.1.1 Testing. Containers out of service in excess of 1 year shall be inspected and tested as required in 8.9.1.2.

8.9.1.2 Pressure Relief Device Testing. The pressure relief devices shall be tested for operability and to determine if they are set at the relief pressure required by the tank design.

8.9.1.3 Containers that have previously been used for flammable cryogenic fluids and have been removed from service shall be purged with an inert gas to remove residual flammable gas and stored with all valves closed and the valve outlets plugged.

8.9.2 Systems. Service and repair of containers or systems shall be performed by trained personnel in accordance with nationally recognized standards and with the permission of the container owner.

8.10 Unauthorized Use. Containers shall not be used for any purpose other than to serve as a vessel for containing the product for which it is designated.

8.11 Leaks, Damage, and Corrosion.

8.11.1 Leaking, damaged, or corroded containers shall be removed from service.

8.11.2 Leaking, damaged, or corroded systems shall be replaced, repaired, or removed from service.

8.12 Lighting. 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.

8.13 Storage.

8.13.1 Indoor Storage.

8.13.1.1 Installation. Stationary containers indoors shall be installed in accordance with Chapters 9 and 11 or with ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites.*

8.13.1.2 Stationary Containers. Stationary containers shall be in accordance with Section 8.2.

8.13.1.3 Cryogenic Fluids. Cryogenic fluids in stationary or portable containers stored indoors shall be stored in buildings, rooms, or areas constructed in accordance with the building code.

8.13.1.4 Ventilation. Ventilation shall be in accordance with Section 6.16.

8.13.2 Outdoor Storage.

8.13.2.1 General. Cryogenic fluids in stationary or portable containers stored outdoors shall be in accordance with 8.13.2.

8.13.2.2 Access. Stationary containers shall be located to provide access by mobile supply equipment and authorized personnel.

8.13.2.2.1 Where exit access is provided to serve areas in which equipment is installed, the minimum width shall be not less than 28 in. (710 mm).

8.13.2.3 Physical Protection. Cryogenic fluid containers, cylinders, tanks, and systems that could be exposed to physical damage shall be protected.

8.13.2.3.1 Guard posts or other means shall be provided to protect cryogenic fluid containers, cylinders, tanks, and systems indoors and outdoors from vehicular damage. *(See Section 4.11.)*

8.13.2.4 Diked Areas Containing Other Hazardous Materials. Containers of cryogenic fluids shall not be located within diked areas with other hazardous materials.

8.13.2.5* Areas Subject to Flooding. Stationary containers located in flood hazard areas shall be anchored to prevent flotation during conditions of the design flood as designated by the building code.

8.13.2.5.1 Elevated Tanks. Structures supporting elevated tanks and tanks that are supported at a level above that designated in the design flood shall be anchored to resist lateral shifting due to flood and other hydrostatic effects.

8.13.2.5.2 Underground Tanks. Underground tanks in flood hazard areas shall be anchored to prevent flotation, collapse, or lateral movement resulting from hydrostatic loads, including the effects of buoyancy, during conditions of the design flood.

8.13.2.6 Drainage.

8.13.2.6.1 The area surrounding stationary and portable containers shall be provided with a means to prevent accidental discharge of fluids from endangering personnel, containers, equipment, and adjacent structures and from entering enclosed spaces in accordance with NFPA 1, *Fire Code*.

8.13.2.6.2 The stationary container shall not be placed where spilled or discharged fluids will be retained around the container.

8.13.2.6.3 The provisions of 8.13.2.5.2 shall be permitted to be altered or waived where the authority having jurisdiction determines that the container does not constitute a hazard after consideration of special features such as the following:

(1) Crushed rock utilized as a heat sink
(2) Topographical conditions
(3) Nature of occupancy
(4) Proximity to structures on the same or adjacent property
(5) Capacity and construction of containers and character of fluids to be stored

8.13.2.6.4 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.

8.13.2.6.4.1* Drainage Control.

(A) 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 8.13.2.6.4, 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.

(B) 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.

8.13.2.7 Outdoor Installations.

8.13.2.7.1 Enclosed Courts. Stationary containers shall not be installed within enclosed courts.

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8.13.2.7.2* Courts. Stationary containers shall be sited so that they are open to the surrounding environment except that encroachment by building walls of unlimited height shall be permitted when in accordance with the distances specified by Table 8.7.2 or the material-specific tables in Chapters 9 through 11.

8.13.2.7.2.1* Where exterior building walls encroach on the system to form a court, the system shall be located at a distance not less than the height of the wall from at least two court walls.

8.13.2.7.2.2 The required distance between the exterior walls of the building forming the court and the container shall be determined independently without regard to fire barrier walls used to allow encroachment by fire exposure hazards.

8.13.2.7.3 Fire Department Access. Fire department access roadways or other approved means shall be in accordance with NFPA 1, *Fire Code*.

8.14 Use and Handling.

8.14.1 General. Use and handling of containers and systems shall be in accordance with Section 8.14.

8.14.1.1 Operating Instructions. Operating instructions shall be provided for installations that require the operation of equipment.

8.14.1.2 Attended Delivery. A qualified person shall be in attendance at all times cryogenic fluid is transferred from mobile supply units to a storage system.

8.14.1.3 Inspection.

8.14.1.3.1 Cryogenic fluid storage systems shall be inspected and maintained by a qualified representative of the equipment owner as required by the material-specific requirements of Chapters 9 and 11.

8.14.1.3.1.1* The interval between inspections other than those specified by material-specific requirements shall be based on nationally recognized good practices or standards.

8.14.1.3.2 A record of the inspection shall be prepared and provided to the user or the authority having jurisdiction upon request.

8.14.1.4 Design.

8.14.1.4.1 Nationally Recognized Good Practices. Where nationally recognized good practices or standards have been established for the process employed, such practices and standards shall be followed.

8.14.1.4.2 Piping Systems. Piping, tubing, fittings, and related components shall be designed, fabricated, and tested in accordance with the requirements of ANSI/ASME B31.3, *Process Piping*, or other approved standards and shall be in accordance with 8.14.2.

8.14.2 Piping and Appurtenances.

8.14.2.1 Piping systems shall be designed for the use intended through the full range of pressure and temperature to which they will be subjected.

8.14.2.2 Piping systems shall be designed and constructed to allow for expansion, contraction, vibration, settlement, and fire exposure.

8.14.3 Joints. Joints in piping and tubing shall be in accordance with the requirements of ANSI/ASME B31.3, *Process Piping*, or other approved standards.

8.14.4 Valves and Accessory Equipment. Valves and accessory equipment shall be acceptable for the intended use at the temperatures of the application and shall be designed and constructed to withstand the maximum pressure at the minimum temperature to which they will be subjected.

8.14.5 Shutoff Valves on Containers. Shutoff valves shall be provided on all container connections, except for pressure relief devices.

8.14.5.1 Shutoff valves for containers with multiple pressure relief devices shall be permitted in accordance with 8.2.4.7.

8.14.5.2 Shutoff valves shall be accessible and located as close as practical to the container.

8.14.6 Shutoff Valves on Piping.

8.14.6.1 Shutoff valves shall be installed in piping containing cryogenic fluids where needed to limit the volume of liquid discharged in the event of piping or equipment failure.

8.14.6.2 Pressure relief valves shall be installed where liquid or cold gas can be trapped between shutoff valves in the piping system. *(See 8.2.4.)*

8.14.7 Physical Protection and Support.

8.14.7.1 Aboveground piping systems shall be supported and protected from physical damage.

8.14.7.2 Piping passing through walls shall be protected from mechanical damage.

8.14.8 Corrosion Protection.

8.14.8.1 Aboveground piping that is subject to corrosion shall be protected against corrosion.

8.14.8.2 Belowground piping shall be protected against corrosion.

8.14.9 Cathodic Protection. Where required, cathodic protection shall be in accordance with 8.14.9.

8.14.9.1 Operation. Where installed, cathodic protection systems shall be operated and maintained to continuously provide corrosion protection.

8.14.9.2 Inspection.

8.14.9.2.1 Container systems equipped with cathodic protection shall be inspected for the intended operation by a cathodic protection tester.

8.14.9.2.2 The cathodic protection tester shall be certified as being qualified by the National Association of Corrosion Engineers, International (NACE).

8.14.9.3 Impressed Current Systems.

8.14.9.3.1 Systems equipped with impressed current cathodic protection systems shall be inspected in accordance with the requirements of the design and 8.14.9.2.

8.14.9.3.2 The design limits shall be available to the AHJ upon request.

8.14.9.3.3 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

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8.14.9.4 Repairs, maintenance, or replacement of a cathodic protection system shall be under the supervision of a corrosion expert certified by NACE.

8.14.9.4.1 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.

8.14.10 Testing.

8.14.10.1 Piping systems shall be tested and proved free of leaks after installation as required by the codes and standards to which they are designed and constructed.

8.14.10.2 Test pressures shall not be less than 150 percent of the maximum allowable working pressure when hydraulic testing is conducted or 110 percent when testing is conducted pneumatically.

8.14.11 Material-Specific Requirements.

8.14.11.1 Indoor Use. Indoor use of cryogenic fluids shall be in accordance with the material-specific provisions of Chapters 9 and 11 or with ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites,* and 8.14.2.

8.14.11.2 Outdoor Use.

8.14.11.2.1 General. Outdoor use of cryogenic fluids shall be in accordance with the material-specific provisions of Chapters 9 and 11 or with ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites,* and 8.14.2.

8.14.11.2.2 Separation. Distances from property lines, buildings, and exposure hazards shall be in accordance with Table 8.7.2 and Table 8.7.3 and the material-specific provisions of Chapters 9 and 11 or with ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites.*

8.14.11.2.3 Emergency Shutoff Valves.

8.14.11.2.3.1* Accessible manual or automatic emergency shutoff valves shall be provided to shut off the cryogenic fluid supply in case of emergency.

(A) Manual emergency shutoff valves or the device that activates an automatic emergency shutoff valve on a bulk source or piping systems serving the bulk supply shall be identified by means of a sign.

8.14.11.2.3.2 Emergency shutoff valves shall be located at the point of use, at the source of supply, and at the point where the system piping enters the building.

8.14.11.3 Filling and Dispensing.

8.14.11.3.1 General. Filling and dispensing of cryogenic fluids shall be in accordance with 8.14.1.2.

8.14.11.3.2 Dispensing Areas. Dispensing of cryogenic fluids associated with physical or health hazards shall be conducted in approved locations.

8.14.11.3.2.1 Indoor Dispensing Areas. Dispensing indoors shall be conducted in areas constructed in accordance with the building code.

8.14.11.3.2.2 Ventilation. Indoor areas in which cryogenic fluids are dispensed shall be ventilated in accordance with the requirements of Section 6.16 and the mechanical code.

8.14.11.3.2.3 Piping Systems. Piping systems utilized for filling or dispensing of cryogenic fluids shall be designed and constructed in accordance with 8.14.2.

8.14.11.3.3 Vehicle Loading and Unloading Areas. Loading and unloading areas shall be constructed in accordance with the requirements of Chapter 9 for liquid oxygen, Chapter 11 for liquid hydrogen, or ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites,* for inert cryogenic fluids, as applicable.

8.14.11.3.4* A noncombustible, delivery vehicle spill pad shall be provided when required by the material-specific requirements of Chapter 9 for liquid oxygen, Chapter 11 for liquid hydrogen, or ANSI/CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites.*

8.14.11.3.4.1* A noncombustible spill pad shall be provided for delivery areas where bulk liquid helium is transferred from delivery vehicles.

8.14.11.3.5 Filling Controls. A pressure gauge and full trycock valve shall be provided and shall be visible from the delivery point to allow the delivery operator to monitor the internal pressure and liquid level of stationary containers during filling.

8.14.11.3.5.1 When the containers being filled are remote from the delivery point and pressure gauges or full trycock valves are not visible, redundant gauges and valves shall be installed at the filling connection.

8.14.11.4 Handling.

8.14.11.4.1 Applicability. Handling of cryogenic containers shall be in accordance with 8.14.11.4.

8.14.11.4.2 Carts and Trucks.

8.14.11.4.2.1 Cryogenic containers shall be moved using an approved method.

8.14.11.4.2.2 Where cryogenic containers are moved by hand cart, hand truck, or other mobile device, that device shall be designed for the secure movement of the container.

8.14.11.4.3 Design. Carts and trucks used to transport cryogenic containers shall be designed to provide a stable base for the commodities to be transported and shall have a means of restraining containers to prevent accidental dislodgement.

8.14.11.4.4 Closed Containers.

8.14.11.4.4.1 Pressurized containers shall be closed while being transported.

8.14.11.4.4.2 Containers designed for use at atmospheric conditions shall be transported with appropriate loose-fitting covers in place to prevent spillage.

Chapter 9 Bulk Oxygen Systems

9.1* General. The storage, use, and handling of oxygen in bulk oxygen systems shall be in accordance with the provisions of Chapters 1 through 9, as applicable.

9.1.1 Application.

9.1.1.1* This chapter shall not apply to oxygen storage systems having capacities less than those stated in 3.3.15, Bulk Oxygen System.

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9.1.1.2 A bulk oxygen system used in medical gas applications shall be in be in accordance with Section 8.5 in addition to the provisions stated herein.

9.2 Materials of Construction.

9.2.1* Oxygen system components, including, but not limited to, containers, valves, valve seats, lubricants, fittings, gaskets, and interconnecting equipment including hoses, shall be compatible with oxygen under the conditions of temperature and pressure to which the components are exposed in the containment and use of oxygen.

9.2.2 The use of ignitible materials shall be prohibited unless they are parts of equipment or systems that are approved, listed, or proved suitable by tests or by past experience.

9.3 Location of Bulk Oxygen Systems. Bulk oxygen systems shall be located in accordance with one of the following:

(1) Above ground and out of doors
(2) In a building of fire-resistive or noncombustible/limited-combustible construction, ventilated to prevent the accumulation of oxygen vapors, and equipped with protection level controls in accordance with the requirements of the building code

9.3.1 Rooftop Installation. Bulk oxygen systems shall not be located on rooftops of buildings or other structures.

9.3.2* Separation from Exposure Hazards. Oxygen systems located out of doors shall be separated from exposure hazards in accordance with the requirements of Table 9.3.2 as applicable.

9.3.2.1* The distances shown in items 2, 4, 5, 8, and 10 through 14 of Table 9.3.2 shall not apply where a fire barrier wall having a minimum fire resistance of 2 hours interrupts the line of sight between uninsulated portions of the bulk storage system and the exposure.

9.3.2.1.1 Fire barrier walls shall comply with the requirements of 8.7.2.1.1 through 8.7.2.1.5.

9.3.2.2 The distances shown shall be permitted to be reduced to 15 ft (4.6 m) for Class IIIB combustible liquids.

9.3.2.3 The area of noncombustible surfacing provided under liquid mobile supply equipment shall have a width not less than the full width of the delivery vehicle and a length not less than 8 ft (2.5 m) in the direction of the vehicle axis.

9.4 System Fabrication.

9.4.1 Piping, Tubing, and Fittings.

9.4.1.1 System Design. Piping, tubing, valves, and fittings shall be designed, installed, and tested in accordance with the requirements of ANSI/ASME B31.3, *Process Piping*.

9.4.1.2 Operating Conditions. Piping systems shall be designed for the most severe condition of coincident internal or external pressures and temperatures expected during service.

9.4.1.3* Low-Temperature Service. Piping or tubing operating at temperatures below –20°F (–28.9°C) shall be fabricated from materials meeting the impact test requirements of Chapter III of ANSI/ASME B31.3, *Process Piping*, when tested at the minimum operating temperature to which the piping could be subjected when in service.

9.4.1.4 Requirements for Piping Joints.

9.4.1.4.1 Joints in piping and tubing shall be permitted to be made by welding or brazing or by use of flanged, threaded, socket, slip, or compression fittings.

9.4.1.4.2 Gaskets or thread sealants shall be designed for oxygen service. Brazing materials shall have a melting point above 1000°F (538°C).

9.4.1.5 Accessory Equipment. Valves, gauges, regulators, and other accessories shall be designed for oxygen service.

9.4.1.6 Leak Testing.

9.4.1.6.1 After installation, all field-erected piping shall be tested and proved gastight in accordance with the requirements of ANSI/ASME B31.3, *Process Piping*.

9.4.1.6.2 Any medium used for testing shall be oil-free and nonflammable.

9.4.1.7 Underground Piping System for Gaseous Systems. Underground piping systems for gaseous systems shall be in accordance with 7.1.18.

9.4.1.8 Underground Piping Systems for Liquid Oxygen Systems. (Reserved)

9.4.2 Liquid Oxygen Vaporizers. In addition to the requirements in Chapter 8, vaporizers used in liquid oxygen service shall be in accordance with the requirements of 9.4.2.1 and 9.4.2.1.1.

9.4.2.1 Heating. Heat used in an oxygen vaporizer shall be supplied indirectly through mediums such as steam, air, water, or materials that do not react with oxygen.

9.4.2.1.1 Electric Heating. If electric heaters are used to provide the primary source of heat to vaporizers, the vaporizing system shall be electrically grounded in accordance with the requirements of *NFPA 70, National Electrical Code*.

9.4.3 Equipment Assembly and Installation.

9.4.3.1 Oxygen Cleaning. Equipment used in a bulk oxygen system shall be cleaned in accordance with the requirements of CGA G-4.1, *Cleaning Equipment for Oxygen Service*, before placing the system in service in order to remove oil, grease, solvents, particulates, or other oxidizable materials.

9.4.3.2 Venting of Enclosures. Any enclosure containing oxygen control or operating equipment shall be vented to the atmosphere.

9.4.4 Signage. The bulk oxygen storage location shall be permanently placarded to read as follows:

OXYGEN

NO SMOKING — NO OPEN FLAMES

9.4.5* Electrical Wiring and Equipment. Electrical wiring and equipment shall be installed in accordance with the applicable provisions of *NFPA 70, National Electrical Code*.

9.5 Inspection.

9.5.1 Cryogenic oxygen storage systems shall be inspected annually and maintained by a qualified representative of the equipment owner.

9.5.2 A record of the inspection shall be prepared and provided to the user or the AHJ upon request.

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Table 9.3.2 Minimum Separation Distances Between Bulk Liquid Oxygen Systems and Exposure Hazards

Type of Exposure	Distance *(See 9.3.2.1.)* ft	m
(1) Buildings of Type I and II construction as defined by the building code	1	0.3
(2) Buildings of Type III, IV, or V construction as defined by the building code	50	15
(3) Wall openings as measured from high-pressure gas or liquefied gas regulators, pressure relief devices, vaporizers, manifolds, and interconnected piping	10	3
(4) Property lines	5	1.5
(5) Public sidewalks	10	3
(6) Public assembly	50	15
(7) Areas occupied by nonambulatory patients as measured from the primary pressure relief device discharge vent and from filling and vent connections	50	15
(8) Parked vehicles	10	3
(9) Exterior walls that encroach on the container to form a court with three or more sides	*See 8.13.2.7.*	
(10) All classes of flammable and combustible liquids above ground *(See 9.3.2.2.)*		
(a) 0 gal to 1000 gal (0 to 3785 L)	25	7.5
(b) Over 1000 gal (3785 L)	50	15
(11) All classes of flammable and combustible liquids in belowground tanks or vaults		
(a) Horizontal distance from oxygen storage container to tank or vault	15	4.6
(b) Horizontal distance from oxygen storage container to filling and vent connections or other openings to tank or vault	25	7.5
(12) Flammable gases aboveground		
(a) Liquefied hydrogen (any quantity)	75	22.5
(b) Other liquefied gas, 0 gal to 1000 gal (0 L to 3785 L)	25	7.5
(c) Other liquefied gas, over 1000 gal (3785 L)	50	15
(d) Nonliquefied or dissolved gases, 0 scf to 25,000 scf (0 Nm^3 to 708 Nm^3)	25	7.5
(e) Nonliquefied or dissolved gases, over 25,000 scf (708 Nm^3)	50	15
(13) Rapidly burning solids, including, but not limited to, excelsior, paper, or combustible waste	50	15
(14) Slowly burning solids, including, but not limited to, heavy timber or coal	25	7.5
(15) Inlets to underground sewer or drainage systems from liquid delivery connections, pressure relief device outlets, mobile supply equipment, and liquid withdrawal connections	8	2.5
(16) Areas below connections where liquid can fall during loading or unloading operations and system operation from combustible surfaces, including, but not limited to, asphalt or bitumastic paving and expansion joint fillers *(See 9.3.2.3.)*	3	1
(17) Encroachment by overhead utilities		
(a) Horizontal distance from the vertical plane below the nearest overhead wire of an electric trolley, train, or bus line	50	15
(b) Horizontal distance from the vertical plane below the nearest overhead electrical wire other than those noted in (a)	5	1.5
(c) Piping containing other hazardous materials	15	4.6

Chapter 10 Bulk Hydrogen Compressed Gas Systems

10.1 Applicability. The storage, use, and handling of hydrogen in bulk hydrogen compressed gas systems shall be in accordance with the applicable provisions of Chapters 1 through 7 and Chapter 10.

10.1.1 This chapter shall not apply to individual systems each having a total hydrogen content of less than 5000 scf (141.6 Nm^3) or to systems located in control areas when the aggregate quantity contained is less than the maximum allowable quantity per control area (MAQ).

10.2 General.

10.2.1 Marking.

10.2.1.1 Hazard identification signs shall be provided in accordance with Section 6.12.

10.2.1.2 In addition, the area in which a hydrogen system is located shall be permanently placarded as follows:

WARNING: HYDROGEN — FLAMMABLE GAS
NO SMOKING — NO OPEN FLAMES

10.2.2* Piping Systems. Piping, tubing, valves, and fittings shall be designed and installed in accordance with ASME B31.12, *Hydrogen Piping and Pipelines*, 7.3.1.3, and Sections 704.1.2.3, 704.1.2.4, and 704.1.2.5 of the ICC *International Fuel Gas Code (IFGC)*. Cast-iron pipe, valves, and fittings shall not be used.

10.2.2.1 Prior to acceptance and initial operation, all piping installations shall be inspected and pressure tested in accordance with ASME B31.12, *Hydrogen Piping and Pipelines*, and the ICC *International Fuel Gas Code (IFGC)*, Section 705.

10.2.2.2 In addition to the requirements of 7.3.1.3, brazing materials used for joints in piping and tubing systems shall have a melting point above 1000°F (538°C).

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10.2.2.3 Underground piping systems shall be in accordance with 7.1.18.

10.2.3 Hydrogen-Venting Systems. Hydrogen-venting systems serving pressure relief devices discharging hydrogen to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*.

10.2.3.1 Venting from the relief vents from the hydrogen supply piping serving listed fuel cell systems shall be permitted to be discharged into an enclosure integral to the fuel cell system where the concentration of hydrogen is diluted below 25 percent of the lower flammable limit (LFL) at the outlet of the enclosure.

10.2.3.1.1 The hydrogen supply piping system shall be designed to isolate the source of hydrogen from the relief vent in the event of loss of dilution ventilation or power.

10.2.4 Equipment Assembly.

10.2.4.1 Valves, gauges, regulators, and other accessories used for bulk hydrogen compressed gas systems shall be specified for hydrogen service by the manufacturer or the hydrogen supplier.

10.2.4.1.1 Storage containers, piping, valves, regulating equipment, and other appurtenances serving bulk hydrogen compressed gas systems shall be accessible and shall be protected against physical damage and tampering.

10.2.4.2 Cabinets or enclosures containing hydrogen control or operating equipment shall be ventilated to prevent the accumulation of hydrogen.

10.2.4.3 Mobile hydrogen supply units used as part of a bulk hydrogen compressed gas system shall be secured to prevent movement.

10.2.5 Bonding and Grounding. The bulk hydrogen compressed gas system shall be electrically bonded and grounded.

10.2.5.1 Mobile hydrogen supply units shall be electrically bonded to the storage system before hydrogen is discharged from the supply unit.

10.2.6 Compression and Processing Equipment. Compression and gas processing equipment integral to bulk hydrogen compressed gas storage systems shall be designed for use with gaseous hydrogen (GH2) and for maximum pressures and temperatures to which it can be subjected under normal operating conditions.

10.2.6.1 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.

10.2.6.2 Where GH2 compression equipment is operated unattended, it shall be equipped with a high discharge and a low suction pressure automatic shutdown control.

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

10.2.6.4 Stationary Compressors.

10.2.6.4.1 Valves.

10.2.6.4.1.1 Valves shall be installed such that each compressor is able to be isolated for maintenance.

10.2.6.4.1.2 The discharge line shall be equipped with a check valve to prevent the backflow of gas from high-pressure sources located downstream of the compressor.

10.2.6.5 Foundations.

10.2.6.5.1 Foundations used for supporting equipment shall be designed and constructed to prevent frost heaving.

10.2.6.5.2 The structural aspects of such foundations shall be designed and constructed in accordance with the provisions of the building code.

10.2.6.6 Emergency Shutdown. When an emergency shutdown system is required, activation of the emergency shutdown system shall shut down operation of all compressors serving a single bulk gas installation.

10.2.6.7 Relief Valves.

10.2.6.7.1 Each compressor shall be provided with a vent or relief device that will prevent overpressurizing of the compressor under normal or upset conditions.

10.2.6.7.2 Pressure relief devices used to serve pumps or compression equipment shall be connected to a vent pipe system in accordance with 10.2.3.

10.2.6.8 Pressure Monitoring. The pressure on the compressor discharge shall be monitored by a control system.

10.2.6.8.1 Discharge pressures in excess of the equipment design pressures shall cause the compressor to shut down.

10.2.6.9 Protection. Transfer piping and compressors shall be protected from vehicular damage.

10.2.7 Operation and Maintenance.

10.2.7.1 Operating Instructions.

10.2.7.1.1 For installations that require any operation of equipment by the user, the user shall be instructed in the operation of the equipment and emergency shutdown procedures.

10.2.7.1.2 Instructions shall be maintained at the operating site at a location acceptable to the authority having jurisdiction.

10.2.7.2 Maintenance.

10.2.7.2.1 Maintenance shall be performed annually by a qualified representative of the equipment owner.

10.2.7.2.2 The maintenance shall include inspection for physical damage, leak tightness, ground system integrity, vent system operation, equipment identification, warning signs, operator information and training records, scheduled maintenance and retest records, alarm operation, and other safety-related features.

10.2.7.2.3 Scheduled maintenance and retest activities shall be formally documented, and records shall be maintained a minimum of 3 years.

10.2.8 Cargo Transport Unloading.

10.2.8.1 Vehicular protection shall be provided in accordance with 7.1.9.3.

10.2.8.2 Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 10.3.2.1(a), Table 10.3.2.1(b), or Table 10.3.2.1(c) than the distances given for the bulk hydrogen compressed gas storage system.

10.2.8.3 During transfer of hydrogen from cargo vehicles to the bulk hydrogen compressed gas storage system, the hand

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or emergency brake of the vehicle shall be set, and chock blocks shall be used to prevent the vehicle from moving.

10.2.8.4 Cargo vehicles equipped with air-brake interlock in front of the unloading connection to protect against drive-aways shall be engaged such that the interlock is activated.

10.2.8.5 Mobile hydrogen supply units shall be electrically bonded to the bulk hydrogen compressed gas storage system before hydrogen is discharged from the supply unit.

10.2.8.6 Transfer System Depressurization.

10.2.8.6.1 The transfer systems shall be capable of depressurizing to facilitate disconnection.

10.2.8.6.2 Bleed connections shall be connected to a hydrogen venting system in accordance with 10.2.3.

10.2.8.7 Where required, check valves on delivery systems shall be in accordance with 7.3.1.3.2.

10.2.8.8 Prohibitions on smoking or the use of open flame shall be in accordance with 7.6.4.2.

10.2.8.9 An emergency shutoff valve shall be provided in accordance with 7.3.1.11.

10.3 Outdoor Bulk Hydrogen Compressed Gas Systems.

10.3.1 General Requirements.

10.3.1.1 Bulk Hydrogen Compressed Gas. Systems located above ground either at grade or above grade shall be in accordance with Section 10.3.

10.3.1.2 Electrical wiring and equipment shall be in accordance with Table 10.3.1.2.

Table 10.3.1.2 Electrical Area Classification

Location	Classification	Extent of Classified Area
Storage equipment excluding the piping system downstream of the source valve	Class I, Division 2	Between 0 ft (0 m) and 15 ft (4.6 m)

10.3.2 Location.

10.3.2.1* Minimum Distance. The minimum distance from a bulk hydrogen compressed gas system located outdoors to specified exposures shall be in accordance with Table 10.3.2.1(a), Table 10.3.2.1(b), or Table 10.3.2.1(c). *(See also Annex G.)*

10.3.2.1.1 The separation distance for piping systems with internal diameters other than those specified in Table 10.3.2.1(a) for the pressure range selected shall be permitted with tabular distances determined based on the use of Table 10.3.2.1(b) or Table 10.3.2.1(c).

10.3.2.2 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 be required to be in accordance with the values shown in Table 10.3.2.1(a) when in accordance with Table 10.3.2.1(b) or Table 10.3.2.1(c).

10.3.2.2.1* Determination of Internal Diameter. The internal diameter of the piping system shall be determined by the diameter of the piping serving that portion of a storage array with content greater than 5000 scf (141.6 Nm^3). The piping system size used in the application of Table 10.3.2.1(a), Table 10.3.2.1(b), or Table 10.3.2.1(c) shall be determined based on that portion of the system with the greatest maximum internal diameter.

10.3.2.2.2 Separation distances determined based on the use of Table 10.3.2.1(b) or Table 10.3.2.1(c) shall be subject to review and approval by the AHJ.

10.3.2.3* Determination of System Pressure. The system pressure shall be determined by the maximum operating pressure of the storage array with content greater than 5000 scf (141.6 Nm^3), irrespective of those portions of the system elevated to a higher pressure.

10.3.2.4* Reduction of Distance by Mitigation Means.

10.3.2.4.1* Passive Means. Except for distances to air intakes, the distances to Group 1 and 2 exposures shown in Table 10.3.2.1(a), Table 10.3.2.1(b), and Table 10.3.2.1(c) shall be permitted to be reduced by one-half and shall not apply to Group 3 exposures where fire barrier walls are located between the system and the exposure and constructed in accordance with the following:

(1) Fire barrier walls shall have a minimum fire resistance rating of not less than 2 hours.
(2) The fire barrier wall shall interrupt the line of sight between the bulk hydrogen compressed gas system and the exposure.
(3) The configuration of the fire barrier shall allow natural ventilation to prevent the accumulation of hazardous gas concentrations.
(4) The number of fire barrier walls used to separate individual systems shall be limited to three.
(5) The fire barrier wall shall not have more than two sides at 90 degrees (1.57 rad) directions or not more than three sides with connecting angles of 135 degrees (2.36 rad).
    (a)*The connecting angles between fire barrier walls shall be permitted to be reduced to less than 135 degrees (2.36 rad) for installations consisting of three walls when in accordance with 8.13.2.7.2.
(6) Fire barrier walls shall be designed and constructed as a structure in accordance with the requirements of the building code without exceeding the specified allowable stresses for the materials of construction utilized. Structures shall be designed to resist the overturning effects caused by lateral forces due to wind, soil, flood, and seismic events.
(7) Where clearance is required between the bulk hydrogen compressed gas system and the barrier wall for the performance of service or maintenance-related activities, a minimum horizontal clearance of 5 ft (1.5 m) shall be provided between the structure and the system.
(8) The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area when the exterior building wall meets the requirements for fire barrier walls.
(9) The minimum wall height shall be not less than 8 ft (2.1 m).
(10) The minimum wall length shall project not less than 5 ft (1.5 m) horizontally beyond the most remote point of the system or the exposure.

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Table 10.3.2.1(a) Minimum Distance (D) from Outdoor Bulk Hydrogen Compressed Gas Systems to Exposures — Typical Maximum Pipe Size

Pressure Internal Pipe Diameter (ID) d_{mm}	>15 to ≤250 psig >103.4 to ≤1724 kPa $d = 52.5_{mm}$		>250 to ≤3000 psig >1724 to ≤20,684 kPa $d = 18.97_{mm}$		>3000 to ≤7500 psig >20,684 to ≤51,711 kPa $d = 7.31_{mm}$		>7500 to ≤15000 psig >51,711 to ≤103,421 kPa $d = 7.16_{mm}$	
Exposures Group 1	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**
(a) Lot lines (b) Air intakes (HVAC, compressors, other) (c) Operable openings in buildings and structures (d) Ignition sources such as open flames and welding	12	40	14	46	9	29	10	34
Exposures Group 2	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**
(a) Exposed persons other than those servicing the system (b) parked cars	6	20	7	24	4	13	5	16
Exposures Group 3	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**
(a) Buildings of non-combustible non-fire-rated construction (b) Buildings of combustible construction (c) Flammable gas storage systems above or below ground (d) Hazardous materials storage systems above or below ground (e) Heavy timber, coal, or other slow-burning combustible solids (f) 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 (g) Unopenable openings in building and structures (h) Utilities overhead including electric power, building services or hazardous materials piping systems	5	17	6	19	4	12	4	14

10.3.2.4.2* Active Means. Active control systems that mitigate the risk of system leaks and failures shall be permitted to be used as a means to reduce separation distances where approved by the AHJ under the authority as granted by Section 1.5.

10.3.2.5 Required Separation Distance for All Systems. Separation distances shall be required for bulk hydrogen compressed gas systems independent of system pressure or internal diameter of piping systems in accordance with 10.3.2.5.1 through 10.3.2.5.3.

10.3.2.5.1 Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 10.3.2.1(a), Table 10.3.2.1(b), or Table 10.3.2.1(c) than the distances given for the storage system.

10.3.2.5.2 The minimum separation distance between gaseous and liquid systems integrated into a single system where the liquid source is vaporized, compressed, and stored in the gaseous state shall be 15 ft (4.6 m).

10.3.2.5.3 Systems within 50 ft (15 m) of aboveground storage of all classes of flammable and combustible liquids shall be located on ground higher than such storage, except where dikes, diversion curbs, grading, or separating solid walls are used to prevent accumulation of these liquids under the system.

10.3.2.6 Bulk hydrogen compressed gas systems shall be allowed to integrate or co-locate other nonliquefied flammable gas systems as a component of the hydrogen gas system without separation, 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.

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Table 10.3.2.1(b) Minimum Distance (D) from Outdoor Bulk Hydrogen Compressed Gas Systems to Exposures by Maximum Pipe Size with Pressures >15 to ≤3000 psig

Pressure		>15 to ≤250 psig >103.4 to ≤1724 kPa						>250 to ≤3000 psig >1724 to ≤20,684 kPa					
		Exposures*†						Exposures*†					
Internal Pipe Diameter (ID)		Group 1		Group 2		Group 3		Group 1		Group 2		Group 3	
ID (in.)	d (mm)	D = 0.231d		D = 0.12584d – 0.47126		D = 0.096d		D = 0.738d		D = 0.43616d – 0.91791		D = 0.307d	
		m	ft	m	ft	m	ft	m	ft	m	ft	m	ft
0.2	5.1	1	4	0	1	0	2	4	12	1	4	2	5
0.3	7.6	2	6	0	2	1	2	6	18	2	8	2	8
0.4	10.2	2	8	1	3	1	3	7	25	4	12	3	10
0.5	12.7	3	10	1	4	1	4	9	31	5	15	4	13
0.6	15.2	4	12	1	5	1	5	11	37	6	19	5	15
0.7	17.8	4	13	2	6	2	6	13	43	7	22	5	18
0.8	20.3	5	15	2	7	2	6	15	49	8	26	6	20
0.9	22.9	5	17	2	8	2	7	17	55	9	30	7	23
1.0	25.4	6	19	3	9	2	8	19	62	10	33	8	26
1.1	27.9	6	21	3	10	3	9	21	68	11	37	9	28
1.2	30.5	7	23	3	11	3	10	22	74	12	41	9	31
1.3	33.0	8	25	4	12	3	10	24	80	13	44	10	33
1.4	35.6	8	27	4	13	3	11	26	86	15	48	11	36
1.5	38.1	9	29	4	14	4	12	28	92	16	52	12	38
1.6	40.6	9	31	5	15	4	13	30	98	17	55	12	41
1.7	43.2	10	33	5	16	4	14	32	105	18	59	13	43
1.8	45.7	11	35	5	17	4	14	34	111	19	62	14	46
1.9	48.3	11	37	6	18	5	15	36	117	20	66	15	49
2.0	50.8	12	39	6	19	5	16	37	123	21	70	16	51
2.1	53.3	12	40	6	20	5	17	39	129	22	73	16	54

Note: Linear interpolation of internal pipe diameters and distances between table entries is allowed.

*For a list of exposures in each exposure group see Column 1 of Table 10.3.2.1(a).

†When calculating the minimum separation distance (D) using the formulas indicated, based on the exposure group and pressure indicated, the internal pipe diameter (d) is entered in millimeters (mm). The calculated distance (D) is expressed in units of measure in meters (m). To convert distance (D) to units of measure in feet, multiply the value of (D) in meters by 3.2808 and round to the nearest whole foot.

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Table 10.3.2.1(c) Minimum Distance (D) from Outdoor Bulk Hydrogen Compressed Gas Systems to Exposures by Maximum Pipe Size with Pressures >3000 to ≤15,000 psig

Pressure		>3000 to ≤7500 psig >20,684 to ≤51,711 kPa						>7500 to ≤15,000 psig >51,711 to ≤103,421 kPa					
		Exposures*†						Exposures*†					
Internal Pipe Diameter (ID)		Group 1		Group 2		Group 3		Group 1		Group 2		Group 3	
ID (in.)	d (mm)	D = 1.105d		D = 0.68311d – 1.3123		D = 0.459d		D = 1.448d		D = 0.92909d – 1.6813		D = 0.602d	
		m	ft	m	ft	m	ft	m	ft	m	ft	m	ft
0.2	5.1	6	18	2	7	2	8	7	24	3	10	3	10
0.3	7.6	8	28	4	13	3	11	11	36	5	18	5	15
0.4	10.2	11	37	6	18	5	15	15	48	8	25	6	20
0.5	12.7	14	46	7	24	6	19	18	60	10	33	8	25
0.6	15.2	17	55	9	30	7	23	22	72	12	41	9	30
0.7	17.8	20	64	11	36	8	27	26	84	15	49	11	35
0.8	20.3	22	74	13	41	9	31	29	97	17	56	12	40
0.9	22.9	25	83	14	47	10	34	33	109	20	64	14	45
1.0	25.4	28	92	16	53	12	38	37	121	22	72	15	50
1.1	27.9	31	101	18	58	13	42	40	133	24	80	17	55
1.2	30.5	34	111	20	64	14	46	44	145	27	87	18	60
1.3	33.0	36	120	21	70	15	50	48	157	29	95	20	65
1.4	35.6	39	129	23	75	16	54	51	169	31	103	21	70
1.5	38.1	42	138	25	81	17	57	55	181	34	111	23	75
1.6	40.6	45	147	26	87	19	61	59	193	36	118	24	80
1.7	43.2	48	157	28	92	20	65	63	205	38	126	26	85
1.8	45.7	51	166	30	98	21	69	66	217	41	134	28	90
1.9	48.3	53	175	32	104	22	73	70	229	43	142	29	95
2.0	50.8	56	184	33	110	23	77	74	241	46	149	31	100

Note: Linear interpolation of internal pipe diameters and distances between table entries is allowed.

*For a list of exposures in each exposure group see Column 1 of Table 10.3.2.1(a).

†When calculating the minimum separation distance (D) using the formulas indicated, based on the exposure group and pressure indicated, the internal pipe diameter (d) is entered in millimeters (mm). The calculated distance (D) is expressed in units of measure in meters (m). To convert distance (D) to units of measure in feet, multiply the value of (D) in meters by 3.2808 and round to the nearest whole foot.

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10.4 Underground Bulk Hydrogen Compressed Gas Systems.

10.4.1 Underground Systems. Bulk hydrogen compressed gas systems installed underground where compressed gas containers are to be buried in contact with earth or fill shall be in accordance with 10.4.1.

10.4.1.1 Design. Pressure compressed gas containers installed underground using burial methods shall be of seamless construction in accordance with Part UF or Appendix 22 of the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1.

10.4.1.1.1* Compressed gas containers shall be designed to include cyclic pressure life calculations using fracture mechanics methods.

10.4.1.1.2 Compressed Gas Container Examination.

10.4.1.1.2.1 Compressed gas containers shall be examined for internal and external surface flaws and inclusions before burial or at the time of manufacture.

10.4.1.1.2.2 Compressed gas containers with flaws or inclusions exceeding the lesser of 5 percent of the wall thickness or 0.12 in. (3 mm) shall not be used.

10.4.1.2 Composite Containers. (Reserved)

10.4.1.3 Corrosion Protection. Compressed gas containers and underground piping shall be protected from corrosion in accordance with 7.1.11.9, 7.1.16, or 7.1.18 as applicable.

10.4.1.4* Outlet Connections.

10.4.1.4.1 Threaded compressed gas container outlet connections shall be designed with primary and secondary seals that shall be tested for functionality.

10.4.1.4.2 The seal design shall include a method of detecting a leak in the primary seal.

10.4.1.5 Piping Systems.

10.4.1.5.1 Joints in the piping system shall be installed and inspected in accordance with the requirements of ASME B31.12, *Hydrogen Piping and Pipelines*, or other approved standards.

10.4.1.5.2 Valves, controls, safety devices, and instrumentation shall be above ground and accessible to authorized personnel.

10.4.1.6 Location. Compressed gas containers shall be located in accordance with 10.4.1.6.1 through 10.4.1.6.6.

10.4.1.6.1 Underground compressed gas containers shall not be located beneath buildings.

10.4.1.6.2 Compressed gas containers 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.

10.4.1.6.3 The distance from any part of the compressed gas container to the nearest wall of a basement, pit, cellar, or lot line shall not be less than 10 ft (3.1 m).

10.4.1.6.4 A structure or foundation of a structure on the same property shall not be erected or constructed within 10 ft (3.1 m) of any point on the container surface, unless the footings extend to the bottom of the container or the container's foundation.

10.4.1.6.5 A minimum distance of 1 ft (0.3 m), shell to shell, shall be maintained between adjacent underground containers.

10.4.1.6.6* A minimum distance of 3 ft (0.9 m) shall be maintained between compressed gas containers and buried utilities.

10.4.1.7 Foundations. Underground compressed gas containers 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.

10.4.1.7.1 The concrete shall extend a minimum of 1 ft (0.3 m) horizontally beyond the footprint of the tank in all directions.

10.4.1.8 Depth, Cover, and Fill. Containers shall be buried such that the top of the container 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.

10.4.1.9* Anchorage and Security. Compressed gas containers installed underground in flood hazard areas shall be anchored to prevent flotation, collapse, or lateral movement resulting from hydrostatic loads, including the effects of buoyancy, during conditions of the design flood.

10.4.1.10 Venting of Underground Compressed Gas Containers. Vent pipes for underground compressed gas containers shall be in accordance with 10.2.2.

10.4.1.11 Overfill Protection and Prevention Systems. An approved means or method shall be provided to prevent the overfilling of the storage containers.

10.4.1.12 Physical Protection. Piping and control equipment ancillary to underground containers that is located above ground shall be protected from physical damage in accordance with 7.1.9.3.

10.5 Installation in Vaults Above and Below Ground. (Reserved)

10.6 Indoor Bulk Hydrogen Compressed Gas Systems.

10.6.1 General.

10.6.1.1 The location of bulk hydrogen compressed gas systems shall be in accordance with Table 10.6.1.1.

10.6.1.2* Fire Protection. Fire protection shall be in accordance with the requirements of Section 6.10.

Table 10.6.1.1 Location of Bulk Hydrogen Compressed Gas Systems

	Quantity of Hydrogen	
Location	≥5000 to <15,000 scf (≥142 to <425 Nm^3)	≥15,000 scf (≥425 Nm^3)
In a detached building	A	A
In a gas room, in accordance with Section 6.4	A	Detached building required
Not in a gas room	NA	Detached building required

A: Allowed. NA: Not allowed.

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10.6.2 Detached Buildings.

10.6.2.1 Detached buildings shall be constructed of noncombustible or limited-combustible materials in accordance with the requirements of Section 6.5.

10.6.2.2 Ventilation shall be provided in accordance with the requirements of Section 6.16.

10.6.2.2.1 Outlet openings shall be located at the high point of the room in exterior walls or the roof.

10.6.2.2.2 Inlet and outlet openings shall each have a minimum total area of 1 ft^2/1000 ft^3 (1 m^2/305 m^3) of room volume.

10.6.2.2.3 Discharge from outlet openings shall be directed or conducted to the atmosphere.

10.6.2.3* Explosion control shall be provided in accordance with the requirements of Section 6.9.

10.6.2.4 Electrical equipment shall be in accordance with Article 501 of *NFPA 70, National Electrical Code*, for Class I, Division 2 locations.

10.6.2.5 Heating, if provided, shall be by steam, hot water, or other indirect means except that electrical heating shall be permitted to be used if in compliance with 10.6.2.4.

10.6.3 Hydrogen Gas Rooms.

10.6.3.1 Floors, walls, and ceilings shall be constructed of noncombustible or limited-combustible materials in accordance with the requirements of the building code.

10.6.3.1.1 Interior walls or partitions shall have a fire resistance rating of not less than 2 hours, shall be continuous from floor to ceiling, and shall be anchored to resist movement.

10.6.3.1.2 Not less than 25 percent of the perimeter wall shall be an exterior wall.

10.6.3.1.3 Openings to other parts of the building shall not be permitted.

10.6.3.1.4 Windows and doors shall be in exterior walls only.

10.6.3.2 Ventilation shall be as provided in Section 6.16.

10.6.3.3 Explosion control shall be provided in accordance with the requirements of Section 6.9.

10.6.3.4 There shall be no sources of ignition from open flames, electrical equipment, or heating equipment.

10.6.3.5 Electrical equipment shall be in accordance with Article 501 of *NFPA 70, National Electrical Code*, for Class I, Division 2 locations.

10.6.3.6 Heating, if provided, shall be by steam, hot water, or indirect means except that electrical heating shall be permitted to be used if in compliance with 10.6.3.5.

Chapter 11 Bulk Liquefied Hydrogen Systems

11.1* General.

11.1.1 The storage, use, and handling of bulk liquefied hydrogen in liquefied hydrogen storage systems shall be in accordance with the provisions of Chapters 1 through 11, as applicable.

11.1.2 Portable containers having a total liquefied hydrogen content of less than 39.7 gal (150 L) in compliance with the requirements of Chapter 8 shall not be required to comply with Chapter 11.

11.2 Design of Bulk Liquefied Hydrogen Systems.

11.2.1 Fire Protection of Structural Supports.

11.2.1.1 Steel supports in excess of 18 in. (457 mm) in height shall have a minimum 2-hour fire resistance rating in accordance with ASTM E 1529, *Determining the Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*.

11.2.1.2 Containers shall be marked in accordance with the provisions of Section 8.4 and as follows:

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11.2.2 Pressure Relief Devices. Stationary and portable containers and tanks shall be provided with pressure relief devices in accordance with the requirements of 8.2.4 and 11.2.2.1 through 11.2.2.3.

11.2.2.1 Pressure relief devices serving stationary containers shall be in accordance with the provisions of 8.2.4.6.1 and arranged to discharge unobstructed to the outdoors.

11.2.2.2 Hydrogen venting systems discharging to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*.

11.2.2.3 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.

11.2.3* Piping, Tubing, and Fittings.

11.2.3.1 Piping and tubing shall be in accordance with the requirements of ASME B31.12, *Hydrogen Piping and Pipelines*.

11.2.3.2 Piping or tubing used at operating temperatures below –20°F (–29°C) shall be fabricated from materials meeting the impact test requirements of ASME B31.12, *Hydrogen Piping and Pipelines*, when tested at the minimum operating temperature to which the piping will be exposed when in service.

11.2.3.3 Joints in piping and tubing shall be in accordance with the requirements of ASME B31.12, *Hydrogen Piping and Pipelines*.

11.2.3.4 Brazing materials, where used, shall have a melting point above 1000°F (538°C).

11.2.3.5 Aluminum piping systems and components external to the storage vessel shall not be used with liquefied hydrogen, except for ambient air vaporizers.

11.2.3.6* Means shall be provided to minimize exposure of personnel to piping operating at low temperatures and to prevent air condensate from contacting piping, structural members, and surfaces not designed for cryogenic temperatures.

11.2.3.6.1 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.

11.2.3.6.2 The insulation material and outside shield shall be designed to prevent deterioration of the insulation due to normal operating conditions.

11.2.3.7 Uninsulated piping and equipment that operates at liquefied hydrogen temperatures shall not be installed above

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asphalt or other combustible materials or surfaces in order to prevent the contact of liquid air with such materials.

11.2.3.8 Drip pans shall be allowed to be installed under uninsulated piping and equipment to retain and vaporize condensed liquid air.

11.2.4 Equipment Assembly.

11.2.4.1 Installation of bulk liquefied hydrogen systems shall be supervised by personnel knowledgeable about the applicable standards and the construction and use of the system to be installed.

11.2.4.2 Storage containers, piping, valves, regulating equipment, and other accessories shall be accessible and shall be protected against physical damage and tampering.

11.2.4.2.1 An emergency shutoff valve shall be located in liquid supply lines as close to the container as practical.

11.2.4.2.2 Containers exceeding 2000 gal (7570 L) capacity shall be provided with an automatic emergency shutoff valve.

11.2.4.2.2.1 The automatic shutoff valve shall be operated by a remotely located, manually activated shutdown control.

11.2.4.2.2.2 The shutoff valve shall be connected to the primary container by means of welded connections without the use of flanges or other appurtenances except that a manual shutoff valve equipped with welded connections is allowed to be installed immediately upstream of the automatic shutoff valve to allow for maintenance of the automatic valve.

11.2.4.2.2.3 Connections downstream of the shutoff valve shall be in accordance with ASME B31.12, *Hydrogen Piping and Pipelines*.

11.2.4.3 Cabinets or enclosures containing hydrogen control equipment shall be ventilated to prevent any accumulation of hydrogen gas.

11.2.5 Liquefied Hydrogen Vaporizers.

11.2.5.1* Heat supplied to a liquefied hydrogen vaporizer shall be by indirect means utilizing a transfer medium.

11.2.5.2* 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.

11.2.6 Electrical Systems. Electrical wiring and equipment shall be in accordance with Table 11.2.6 and *NFPA 70, National Electrical Code*.

11.2.6.1 Where equipment approved for Class I, Group B atmospheres is not commercially available, the equipment used shall meet at least one of the following:

(1) Purged or ventilated in accordance with NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*
(2) Intrinsically safe

11.2.6.2 Electrical equipment installed on mobile supply trucks or tank cars from which the storage container is filled shall not be subject to 11.2.6.1.

11.2.7 Bonding and Grounding. The bulk liquefied hydrogen system shall be electrically bonded and grounded.

11.2.8 Stationary Pumps and Compressors.

11.2.8.1 Valve Isolation.

11.2.8.1.1 Valves shall be installed such that each pump or compressor can be isolated for maintenance.

Table 11.2.6 Electrical Area Classification

Location	Division	Extent of Classified Area
The bulk liquefied hydrogen system fill connection, pressure relief vent outlets, or other points on the system where hydrogen is vented to the atmosphere under the designed operating conditions	1	Within 3 ft (1 m) of the system fill connection, system pressure relief vent outlets or, other points of release when the system is operating as designed
	2	Between 3 ft (1 m) and 25 ft (7.6 m) from the system fill connection, system pressure relief vent outlets, or other points of release when the system is operating as designed

11.2.8.1.2 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.

11.2.8.2 Foundation Design and Construction.

11.2.8.2.1 Foundations used for supporting pumps and equipment shall be designed and constructed to prevent frost heaving.

11.2.8.2.2 The structural aspects of such foundations shall be designed and constructed in accordance with the provisions of the building code.

11.2.8.3 Emergency Shutdown System Operation. When an emergency shutdown (ESD) is required, activation of the ESD system shall shut down operation of all pumps and compressors.

11.2.8.4 Pump or Compressor Venting.

11.2.8.4.1 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.

11.2.8.4.2 Pressure relief devices used to serve pumps or compression equipment shall be connected to a vent pipe system in accordance with 11.2.2.2.

11.2.8.5* Pressure Monitoring. The pressure on the pump or compressor discharge shall be monitored by a control system.

11.2.8.5.1 Discharge pressures in excess of the equipment design pressures shall cause the pump or compressor to shut down.

11.2.8.6 Protection of Transfer Piping, Pumps, and Compressors. Transfer piping, pumps, and compressors shall be protected from vehicular damage.

11.2.9 Emergency Shutdown System. An ESD system shall be provided at the bulk source to stop the flow of liquid when actuated.

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11.2.9.1 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.

11.2.9.2 Reactivation of the ESD system after ESD shall require that the ESD system be manually reset.

11.2.9.3 The ESD system shall be identified by means of a sign.

11.3 Location of Bulk Liquefied Hydrogen Systems.

11.3.1 General.

11.3.1.1 Stationary storage containers shall be located so that they are accessible from mobile supply equipment.

11.3.1.2* Diking shall not be used to contain a liquid hydrogen spill.

11.3.1.3 Storage sites shall be placarded as follows:

WARNING:
LIQUEFIED HYDROGEN
FLAMMABLE GAS
NO SMOKING — NO OPEN FLAMES

11.3.2 Specific Requirements.

11.3.2.1 The location of bulk liquefied hydrogen systems, as determined by the quantity of liquefied hydrogen, shall be in accordance with Table 11.3.2.1.

11.3.2.2* The minimum distance from bulk liquefied hydrogen systems of indicated capacity shall be in accordance with Table 11.3.2.2.

Table 11.3.2.1 Location of Bulk Liquefied Hydrogen Systems

	Quantity of Hydrogen			
Location	**MAQ**	**>MAQ to 300 gal (>170.32 to 1135.5 L)**	**>300 to 600 gal (>1135.5 to 2271 L)**	**>600 gal (>2271 L)**
Outdoors	A	A	A	A
In a detached building	A	A	A	NA
In a gas room	A	A	NA	NA
Inside a building (not in a gas room or detached building) and exposed to other occupancies	A	NA	NA	NA

MAQ: Maximum allowable quantity. A: Allowed. NA: Not allowed.

Table 11.3.2.2 Minimum Distance from Bulk Liquefied Hydrogen Systems to Exposures

	Total Bulk 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**
Group 1						
1. Lot lines	25	7.6	50	15	75	23
2. Air intakes [heating, ventilating, or air-conditioning equipment (HVAC), compressors, other]	75	23	75	23	75	23
3. Wall openings Operable openings in buildings and structures	75	23	75	23	75	23
4. Ignition sources such as open flames and welding	50	15	50	15	50	15
Group 2						
5. Places of public assembly	75	23	75	23	75	23

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Table 11.3.2.2 *Continued*

	Total Bulk 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
Group 3						
6. Building or structure						
(a) Buildings 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) Buildings of combustible construction						
(1) Sprinklered building or structure	50	15	50	15	50	15
(2) Unsprinklered building or structure	50	15	75	23	100	30.5
7. Flammable gas storage or systems (other than hydrogen) above or below ground	50	15	75	23	75	23
8. Between stationary liquefied hydrogen containers	5	1.5	5	1.5	5	1.5
9. 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
10. Hazardous materials storage or systems including liquid oxygen storage and other oxidizers, above or below ground	75	23	75	23	75	23
11. Heavy timber, coal, or other slow-burning combustible solids	50	15	75	23	100	30.5
12. Wall openings						
Unopenable openings in buildings and structures	25	7.6	50	15	50	15
13. Inlet to underground sewers	5	1.5	5	1.5	5	1.5
14. Utilities overhead, including electric power, building services, or hazardous materials piping systems						
(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 must 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).

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11.3.2.2.1 The distances in 1, 6, 7, 9, 10, and 11 in Table 11.3.2.2 shall be permitted to be reduced by two-thirds, but to not less than 5 ft (1.5 m), for insulated portions of the system.

11.3.2.2.2* The distances in 1, 6, 7, 9, 10, and 11 in Table 11.3.2.2 shall be permitted to be reduced by the use of fire barrier walls having a fire resistance rating of not less than 2 hours when constructed in accordance with 8.7.2.1 and 11.3.2.2.

11.3.2.2.3 The fire barrier or the insulated liquefied hydrogen tank shall interrupt the line of sight between uninsulated portions of the liquefied hydrogen storage system and the exposure.

11.3.2.2.4 The fire barrier wall shall not have more than two sides at 90 degree (1.57 rad) directions or not more than three sides with connecting angles of not less than 135 degrees (2.36 rad).

11.3.2.2.4.1* The connecting angles between fire barrier walls shall be permitted to be reduced to less than 135 degrees (2.36 rad) for installations consisting of three walls when in accordance with 8.13.2.7.2.

11.3.2.2.4.2* When fire barrier walls of three sides are used, piping and control systems serving stationary tanks shall be located at the open side of the enclosure created by the barrier walls to provide access for filling and ventilation.

(A) Vertical tanks shall be located at a distance not less than one tank diameter from the enclosing walls.

(B) Where horizontal tanks are used, the distance to any enclosing wall shall be not less than one-half the length of the tank.

11.3.2.3 Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 11.3.2.2 than the distances given for the storage system.

11.3.2.4 The minimum distance of container fill connections from parked vehicles shall be 25 ft (7.6 m).

11.3.2.5 Fire department access to outdoor storage areas where bulk systems are installed shall be provided and maintained in accordance with NFPA 1, *Fire Code*.

11.3.3 Installation of LH2 Inside Buildings Other Than Detached Buildings and Gas Rooms. Portable liquefied hydrogen (LH2) containers of 39.7 gal (150 L) or less capacity where housed inside buildings, not located in a gas room, and exposed to other occupancies shall comply with the following minimum requirements:

(1) Containers shall be located 20 ft (6.1 m) from all classes of flammable or combustible liquids and combustible materials such as excelsior or paper.
(2) Containers shall be located 25 ft (7.6 m) from ordinary electrical equipment and other sources of ignition, including process or analytical equipment. *(See Section 8.7.)*
(3) Containers shall be located 50 ft (15 m) from intakes for ventilation, air-conditioning equipment, or compressors.
(4) Containers shall be located 50 ft (15 m) from storage or use of other flammable gases or storage or use of incompatible gases.
(5) Containers shall be protected against physical damage in accordance with the requirements of 8.6.5.
(6) Containers shall be secured in accordance with the requirements of 8.6.3.
(7) Welding or cutting operations and smoking shall be prohibited while hydrogen is in the room, and signs shall be provided as required by 6.12.2.2.
(8) Ventilation shall be provided in accordance with the requirements of Section 6.16.
(9) Pressure relief devices on stationary or portable containers shall be vented directly outdoors or to an exhaust hood. *(See 8.2.4.6.)*

11.4 Design Considerations at Specific Locations.

11.4.1 Outdoor Locations.

11.4.1.1 Roadways and yard surfaces located below liquefied hydrogen piping as well as areas located under the fill connections and delivery vehicles' uninsulated hydrogen piping from which liquid air is able to drip shall be constructed of noncombustible materials.

11.4.1.1.1 Asphalt and bitumastic paving shall be assumed to be combustible.

11.4.1.1.2 Expansion joints and fillers used in the construction of concrete slabs shall be of noncombustible materials.

11.4.1.2 Weather protection shall be constructed in accordance with the requirements of Section 6.6 and the building code.

11.4.1.3 Lighting shall be provided for nighttime transfer operation, and supplemental lighting shall be provided where required by Section 8.12.

11.4.1.4* User storage sites shall be fenced or otherwise secured and posted to prevent entry by unauthorized personnel.

11.4.1.4.1 Administrative controls shall be allowed to be used to control access to individual storage, use, and handling areas located in secure facilities not accessible by the general public.

11.4.1.4.2 At least two means of egress shall be provided from any fenced area.

11.4.2 Aboveground Tanks.

11.4.2.1 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 11.4.2.2.

11.4.2.2 Construction of the Vacuum Jacket (Outer Vessel).

11.4.2.2.1 The vacuum jacket used as an outer vessel for storage tanks in liquid hydrogen service shall be of welded steel construction designed to withstand the maximum internal and external pressures to which it will be subjected under operating conditions to include conditions of emergency pressure relief of the annular space between the inner and outer vessel.

11.4.2.2.2 The jacket shall be designed to withstand a minimum collapsing pressure differential of 30 psi (207 kPa).

11.4.2.3 Vacuum Level Monitoring.

11.4.2.3.1 A connection shall be provided on the exterior of the vacuum jacket to allow measurement of the pressure within the annular space between the inner and outer vessels.

11.4.2.3.2 The connection shall be fitted with a bellows-sealed or diaphragm-type valve equipped with a vacuum gauge tube that is shielded to protect against damage from impact.

11.4.3 Underground Tanks. Underground tanks for the storage of liquid hydrogen shall be in accordance with this subsection.

11.4.3.1 Construction. Storage tanks for liquid hydrogen shall be designed and constructed in accordance with Section VIII

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of ASME *Boiler and Pressure Vessel Code* and shall be vacuum jacketed in accordance with 11.4.3.1.1.

11.4.3.1.1 Vacuum Jacket Construction.

11.4.3.1.1.1 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.

11.4.3.1.1.2 Portions of the vacuum jacket installed below grade shall be designed to withstand anticipated soil, hydrostatic, and seismic loading.

(A) Material. The vacuum jacket shall be constructed of stainless steel or other approved corrosion-resistant material.

(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.

11.4.3.2 Location. Tanks shall be located in accordance with 11.4.3.2.1 through 11.4.3.2.4.

11.4.3.2.1 Underground storage tanks shall not be located beneath buildings.

11.4.3.2.2 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.

11.4.3.2.3 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).

11.4.3.2.4 A minimum distance of 1 ft (0.3 m), shell to shell, shall be maintained between adjacent underground tanks.

11.4.3.3 Depth, Cover, and Fill.

11.4.3.3.1 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.

11.4.3.3.2 The concrete shall extend a minimum of 1 ft (0.3 m) horizontally beyond the footprint of the tank in all directions.

11.4.3.3.3 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.

11.4.3.3.4 The vertical extension of the vacuum jacket required for service connections shall be allowed to extend above grade.

11.4.3.4 Anchorage and Security. Tanks and systems shall be secured against accidental dislodgment due to seismic events or flooding.

11.4.3.5 Venting of Underground Tanks. Vent pipes for underground storage tanks shall be in accordance with 11.2.2.2.

11.4.3.6 Underground Liquid Hydrogen Piping.

11.4.3.6.1 Underground liquid hydrogen piping shall be vacuum jacketed.

11.4.3.6.2 Unjacketed piping shall not be buried and shall exit the tank annular space above grade.

11.4.3.7 Overfill Protection and Prevention Systems. An approved means or method shall be provided to prevent the overfilling of storage tanks.

11.4.3.8 Vacuum Level Monitoring. An approved monitoring method shall be provided to indicate vacuum degradation within the vacuum jacket(s).

11.4.3.9 Physical Protection. Piping and control equipment ancillary to the underground tank located above ground shall be protected from physical damage in accordance with 8.6.5.

11.4.3.10 Tanks Not in Service. Tanks not in service shall be maintained in accordance with 11.4.3.10.1.

11.4.3.10.1 Corrosion protection shall be maintained in operation.

11.4.4 Detached Buildings.

11.4.4.1 Explosion Control.

11.4.4.1.1 Detached buildings containing more than 300 gal (1136 L) of liquefied hydrogen shall be constructed of noncombustible or limited-combustible materials in accordance with the requirements of the building code.

11.4.4.1.2 Explosion control shall be provided in accordance with the requirements of Section 6.9.

11.4.4.2 Ventilation. Ventilation shall be provided in accordance with the requirements of Section 6.16 and 11.4.4.2.1 through 11.4.4.2.4.

11.4.4.2.1 Inlet openings shall be located within 18 in. (0.46 m) of the floor in exterior walls only.

11.4.4.2.2 Outlet openings shall be located at the high point of the room in exterior walls or the roof.

11.4.4.2.3 Both the inlet and outlet vent openings shall have a minimum total area of 1 ft^2/1000 scf (1 m^2/300 Nm^3) of room volume.

11.4.4.2.4 Discharge from outlet openings shall be directed or conducted to a location that allows for dissipation of the exhaust air in the ambient surroundings away from air intakes and occupied spaces.

11.4.4.3* Ignition Sources. There shall be no sources of ignition within the room or area where the hydrogen system is installed.

11.4.4.4 Heating.

11.4.4.4.1 Heating, if provided, shall be by indirect means such as steam or hot water.

11.4.4.4.2 Electrical heating in accordance with Section 8.8 shall be allowed.

11.4.5 Gas Rooms.

11.4.5.1 Heating, if provided, shall be by steam, hot water, or other indirect means.

11.4.5.2 Electrical heating in accordance with Section 8.8 shall be allowed.

11.5 Cargo Transport Unloading.

11.5.1 Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 11.3.2.2 than the distances given for the storage system.

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11.5.2 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.

11.5.3 Cargo vehicles equipped with air-brake interlock in front of the unloading connection to protect against drive-aways shall be engaged such that the interlock is activated.

11.5.4 Mobile hydrogen supply units shall be electrically bonded to the storage system before hydrogen is discharged from the supply unit.

11.5.5 The transfer systems shall be capable of depressurizing to facilitate disconnection. Bleed connections shall be connected to a hydrogen venting system in accordance with 11.2.2.2.

11.5.6 Prohibitions on smoking or the use of open flame shall be in accordance with 11.3.1.3.

11.5.7 An emergency shutoff valve shall be provided in accordance with 8.14.11.2.3.1.

Chapter 12 Gas Generation Systems

12.1 General. Systems used to generate gases shall be in accordance with Chapters 1 through 6 and Chapter 12.

12.1.1 Sufficient space shall be provided around generators for safe maintenance and egress.

12.1.2 Waste gases shall be vented outdoors away from structures and personnel.

12.1.3 Piping shall be installed in accordance with ANSI/ASME B31.3, *Process Piping*.

12.2 Corrosive Gases. (Reserved)

12.3 Flammable Gases — Gaseous.

12.3.1* Hydrogen.

12.3.1.1 Listed and approved hydrogen-generating and -consuming equipment shall be in accordance with the listing requirements and manufacturers' instructions.

12.3.1.2 Such equipment shall not be required to meet the requirements of Chapter 7.

12.3.2 Hydrogen Generation Systems.

12.3.2.1 The installation and interconnection of hydrogen generation equipment shall be in accordance with 12.3.2.

12.3.2.2 Permanently installed hydrogen generation systems with rated capacity to generate greater than 0.08 lb/hr (36 g/hr) but less than 55 lb/hr (25 kg/hr) shall be installed in accordance with the requirements of 12.3.2.

12.3.2.2.1 Systems that generate hydrogen in excess of the quantity indicated in 12.3.2.2 shall be constructed, installed, and operated in accordance with nationally recognized standards.

12.3.2.3 Fuel processing equipment integral to listed fuel cell appliances installed in accordance with NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems*, shall not be required to meet 12.3.2.

12.3.2.4 General Siting Requirements. Hydrogen generation system(s) shall be installed in accordance with Chapters 1 through 7 and Chapter 10 of this code, and the system(s) shall be installed as follows:

(1) The system shall be placed on a firm foundation that is capable of supporting the equipment or components as in accordance with ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*.
(2) The system shall be anchored, located, and protected so that the system and equipment will not be adversely affected by rain, snow, ice, freezing temperatures, wind, seismic events, and lightning.
(3)*The system shall be protected against access by unauthorized persons commensurate with the location and installation environment. Fire department access shall be provided.
(4) The system shall be located outside potentially hazardous areas defined by *NFPA 70, National Electrical Code*, Article 500 unless listed and approved for such areas.
(5) Vent terminations from hydrogen generation systems shall be in accordance with Section 6.15.
(6) Setbacks of hydrogen generation system equipment from exposures shall be in accordance with Table 10.3.2.1(a), Table 10.3.2.1(b), or Table 10.3.2.1(c).
(7) A hydrogen generation system and associated hydrogen storage not exceeding a total of 400 scf (11.33 Nm^3) shall not be required to have fire-rated separation.
(8) All safety-related controls shall comply with NFPA 79, *Electrical Standard for Industrial Machinery*.

12.3.2.5 Outdoor and Rooftop Installations.

12.3.2.5.1 For outdoor or rooftop installations, a hydrogen generation system and related components shall be designed and constructed for outdoor installation.

12.3.2.5.1.1 Hydrogen reformers or gasifiers shall not be installed on rooftops or in penthouse areas of occupied structures.

12.3.2.5.1.2 The installation of listed or approved reformers or gasifiers shall be allowed, provided the listing or approval is specific to rooftop installations.

12.3.2.5.2 The area classification around hydrogen generation system outlets that exhaust flammable gas in concentrations greater than 25 percent LFL shall be in accordance with Article 500 or 505 of *NFPA 70, National Electrical Code*.

12.3.2.5.3 For units installed on rooftops, the roofing material under and within 12 in. (305 mm) horizontally of a fuel cell power system or component shall be noncombustible or shall have a Class A rating in accordance with the building code.

12.3.2.6 Indoor Installations. A hydrogen generation system installed indoors shall be in accordance with 12.3.2.8.3.

12.3.2.7 Electrolyzers.

12.3.2.7.1 Electrolyzers shall be tested and approved in accordance with ISO/DIS 22734, *Hydrogen generators using water electrolysis process*.

12.3.2.7.2 With the exception of gaseous hydrogen, electrolyzers that contain or utilize hazardous materials as defined by the building code shall be designed and installed to contain such materials in accordance with the building code.

12.3.2.8 Catalytic Reforming–Based Hydrogen Generation Systems.

12.3.2.8.1 Siting and Interconnecting. Siting and interconnection of catalytic reformer–type hydrogen generation systems shall be in accordance with 10.2.8.2 as modified or appended by 12.3.2.8.

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12.3.2.8.2 Outdoor and Rooftop Installations.

12.3.2.8.2.1 The area containing the catalytic reformer system and associated conditioning equipment shall be located such that HVAC air intakes, windows, doors, and other openings into buildings cannot be exposed to the following:

(1) Hazardous atmospheres
(2) Toxic gases in excess of applicable OSHA exposure limits

12.3.2.8.2.2 Exhaust Outlets.

(A) The exhaust outlet(s) from process areas or areas that contain fuel-bearing components of a catalytic reforming system shall be located at least 50 ft (15 m) from HVAC air intakes, windows, doors, and other openings into buildings.

(B) The exhaust outlet(s) shall not be directed onto walkways or other paths of travel for pedestrians.

12.3.2.8.2.3 Process air intakes to a hydrogen generation system shall be located so the plant is not adversely affected by other exhausts, gases, or contaminants.

12.3.2.8.2.4 Security barriers, fences, landscaping, and other enclosures shall not affect the required process air flow into the hydrogen generation system and its components.

12.3.2.8.3 Indoor Installations.

12.3.2.8.3.1 A catalytic reformer–type hydrogen generation system and its associated components that are not located in areas designed for industrial uses shall be located in a room that meets the conditions of 7.6.3.1(1) through 7.6.3.1(6).

12.3.2.8.3.2 The area containing the gasifier and associated conditioning equipment shall be located such that HVAC air intakes, windows, doors, and other openings into buildings cannot be exposed to the following:

(1) Hazardous atmospheres
(2) Toxic gases in excess of applicable OSHA exposure limits

12.3.2.8.3.3 The room shall be separated from the remainder of the building by floor, wall, and ceiling construction that has at least a 1-hour fire resistance rating in accordance with ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, or UL 263, *Fire Tests of Building Construction and Materials*.

12.3.2.8.3.4 Electrical and piping penetrations and joints associated with the room shall be sealed with approved materials that have a 1-hour fire resistance rating.

12.3.2.8.3.5 Openings between the room and other occupied spaces shall be protected by fire doors and dampers.

12.3.2.8.3.6 Fire doors shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives*, and shall have a minimum fire resistance rating equivalent to that of the barrier.

12.3.2.8.3.7 Fire dampers shall be installed in accordance with NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*.

12.3.2.8.3.8 Each room shall be provided with egress in accordance with NFPA *101*, *Life Safety Code*.

12.3.2.8.4 Fuel Piping and Hydrogen Storage for Catalytic Reforming–Based Hydrogen Generation Systems.

12.3.2.8.4.1 Piping for natural gas, compressed natural gas, LP-Gas, or other liquid fuels shall be in accordance with NFPA 54, *National Fuel Gas Code*; NFPA 58, *Liquefied Petroleum Gas Code*; or NFPA 30, *Flammable and Combustible Liquids Code*, as applicable.

12.3.2.8.4.2 Hydrogen piping, valves, and fittings from the catalytic reforming–based hydrogen generation equipment to the hydrogen storage system shall conform to ASME B31.12, *Hydrogen Piping and Pipelines*.

12.3.2.8.4.3 An accessible shutoff valve shall be located in the fuel piping to the catalytic reforming–based hydrogen generation system's power system within 6 ft (1.8 m) of the storage container.

12.3.2.8.4.4 The fuel piping to the catalytic reforming–based hydrogen generation system's power system shall be provided with a second accessible shutoff valve that is located within 6 ft (1.8 m) of the power system, unless the power system is enclosed by a room with a 1-hour fire resistance rating.

12.3.2.8.4.5 If the power system is enclosed by a room with a 1-hour fire resistance rating, the shutoff valve shall be located outside the room.

12.3.2.8.4.6 Indoor Installation of Reforming Systems.

(A) For indoor installation of a reforming system, where the fuel supply is stored outdoors, an automatic shutoff valve interlocked with gas detection shall be located outside the building that houses the power system.

(B) The valve and the detector shall be installed such that the valve will close upon detection of a concentration of greater than 25 percent LFL.

12.3.2.8.4.7 Piping, valves, regulators, or other equipment shall be located so that it is not subject to physical damage or shall otherwise be protected against physical damage.

12.3.2.8.4.8 Backflow prevention shall be provided to preclude inducing external atmospheres into the catalytic reforming systems.

12.3.2.8.4.9 The output of catalytic reformer systems, which typically contains significant quantities of carbon monoxide and other toxic substances, shall be controlled.

(A) The output from the final element of conditioning equipment shall be handled as hydrogen gas unless residual toxic content remains that would exceed applicable OSHA exposure limits in the event of a leak, in which case the requirements of 12.3.2.8.4.9 shall apply.

(B) Materials for outlet interface piping shall be selected based on both the temperature and the chemical composition of the gas.

12.3.2.8.5 Ventilation and Exhaust for Catalytic Reforming–Based Hydrogen Generation Systems.

12.3.2.8.5.1 Pressurized portions of process exhaust system piping shall be in accordance with ASME B31.12, *Hydrogen Piping and Pipelines*.

12.3.2.8.5.2 With the exception of units located outdoors, catalytic reforming–based hydrogen generation systems shall be provided with a source of ventilation, exhaust, and makeup air in accordance with this chapter.

12.3.2.8.5.3 The ventilation and exhaust system shall be designed to provide a negative or neutral pressure in the room, with respect to the building.

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12.3.2.8.5.4 If mechanical ventilation is required, a control interlock shall be provided to shut down the unit upon loss of ventilation.

12.3.2.8.5.5 Ventilation Air.

(A) A separate mechanical ventilation system shall be provided for the area where a catalytic reforming–based hydrogen generation system's power system is located.

(B) If it can be verified, natural ventilation shall be permitted to provide all required ventilation and makeup air.

(C) The inlet air vent shall be designed to prevent foreign matter from entering.

12.3.2.8.5.6 Exhaust Systems. As required by the manufacturer's instructions and the product listing, a process exhaust system shall be installed to carry combustion and reforming process by-products such that all emissions are exhausted to an approved location.

12.3.2.8.5.7* Process Purging and Venting. Process purging and vents shall conform to the following:

(1) Pressure equipment and piping intended to be purged, pressure regulators, relief valves, and other potential sources of combustible gas shall be vented to the outside of the building.
(2) The vent shall be designed to prevent entry of water or foreign objects.
(3) The vent gas shall be directed so as to not create additional hazards to the building openings, such as windows, doors, or HVAC intakes.

12.3.2.8.6 Fire Protection for Catalytic Reforming–Based Hydrogen Generation Systems. The fire protection requirements of NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems*, shall apply, in addition to the following:

(1) A carbon monoxide detector shall be installed in the catalytic reformer system enclosure, the cabinet exhaust system, or the room that encloses the installation.
(2) Where installed in a room containing a catalytic reformer system, the location of the detector shall be approved.

12.3.2.8.7 Small Catalytic Reforming–Based Hydrogen Generation Systems.

12.3.2.8.7.1 Scope. Small catalytic reforming–based hydrogen systems shall comply with 12.3.2.8.7.

12.3.2.8.7.2 Outdoor Installations.

(A) The exhaust outlets of the system shall be located at least 50 ft (15 m) from HVAC air intakes, windows, doors, and other openings into buildings.

(B) The exhaust outlet(s) shall not be directed onto walkways or other paths of travel for pedestrians.

12.3.2.8.7.3 Indoor Installations.

(A) Clearances from combustible construction and other combustible materials shall be in accordance with manufacturers' instructions; NFPA 31, *Standard for the Installation of Oil-Burning Equipment*; NFPA 54, *National Fuel Gas Code*; or NFPA 58, *Liquefied Petroleum Gas Code*.

(B) Indoor use of catalytic reforming systems that operate without ventilation air from the outside shall be provided with limit controls that will not permit room ambient oxygen levels to drop below 18 percent unless it can be demonstrated by other means that the oxygen level will not drop below 18 percent.

(C) The exhaust system materials shall be compatible with the exhaust gas and any resulting condensate.

(D) Catalytic reforming systems using a flammable liquid as a fuel shall be located outside unless they meet the requirements for indoor installations in Chapters 1 through 8 or meet all the requirements in 7.6.3.1(1) through 7.6.3.1(6) and the following:

(1) The catalytic reforming system enclosure plus the connected indoor liquid fuel piping shall contain less than 5 gal (0.019 m^3) of liquid fuel during all modes of operation, standby, and shutdown.
(2) The bulk fuel storage shall be located outside.
(3) The indoor fuel piping shall be of solid pipe or tube or all-welded, soldered, or brazed construction up through the catalytic reforming enclosure.
(4) The catalytic reforming system shall be equipped with leakage detection and automatic isolation of the indoor fuel piping from the outdoor bulk fuel supply upon detection of fuel leakage using pump stoppage, valve closure, or other appropriate means as determined by the manufacturer.
(5) Outdoor bulk fuel storage located at an elevation above the fuel cell power system shall be equipped with an automatic isolation valve at the tank.

(E) Catalytic reforming systems that store hydrogen shall be installed in accordance with the manufacturers' instructions and Chapter 10.

(F) Fire Protection. The requirements of Section 10.6.1.2 shall not apply to 8.8 lb/hr (4 kg/hr) or smaller systems except as modified herein.

12.3.2.8.8 Combustible Gas Detection.

12.3.2.8.8.1 Combustible gas detection shall be installed in accordance with 8.1.5.4 through 8.1.5.8 of NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems*, except where the fuel gas system is listed for indoor use and the fuel is odorized.

12.3.2.8.8.2 Listed catalytic reformer systems that fall within the scope of 12.3.2.8.7 shall not require a written fire prevention and emergency plan.

12.3.2.9 Requirements for Installation of Gasifiers.

12.3.2.9.1 Gasifier systems shall comply with the requirements of Chapters 1 through 7 and Chapter 10 and the modifications identified in Chapter 12.

12.3.2.9.2* Siting and Interconnection of Gasifiers.

12.3.2.9.2.1* Gasification systems contain conditioning equipment to cool and scrub the gas prior to delivery as a fuel; the conditioning equipment shall comply with 12.3.2.9.2.1(A) and 12.3.2.9.2.1(B).

(A) Materials for conditioning equipment shall be selected based on both the temperature and the chemical composition of the gas.

(B) The output from the final element of conditioning equipment shall be handled as hydrogen gas unless residual toxic content remains that would exceed applicable OSHA exposure limits in the event of a leak, in which case the requirements of this section shall be applied.

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12.3.2.9.2.2 The area classification around the gasification equipment shall be in accordance with Article 500 or 505 of *NFPA 70, National Electrical Code*.

12.3.2.9.2.3 Gasifier systems shall be isolated from public access areas based on a risk assessment of potential exposure to the following:

(1) Atmospheres containing flammable gas in excess of 25 percent of the LFL should a leak event occur
(2) Thermal radiation from flare stacks
(3) Toxic constituents in the fuel should a leak event occur

12.3.2.9.2.4 In no case shall this distance (hereinafter referred to as the "gasifier hazard area") be less than the distance specified in 7.9.2.2.

12.3.2.9.2.5 Air intakes to the gasifier systems shall be located so the equipment is not adversely affected by other exhausts, gases, or contaminants.

12.3.2.9.2.6 Security barriers, fences, landscaping, or other obstacles shall be provided to define the gasifier hazard area and prevent access by unauthorized persons.

12.3.2.9.2.7 Warning Signals.

(A) Warning signals (strobes or rotating lights) shall be provided at all gasifier hazard area access points.

(B) These signals shall be tied to the detection systems outlined in 12.3.2.8.4.6(B) to warn of hazardous conditions.

12.3.2.9.2.8 The controller for the gasifier process control system shall be located in a safe area, isolated from the gasifier hazard area.

12.3.2.9.3 Outdoor Installations. The area containing the gasifier and associated conditioning equipment shall be located such that HVAC air intakes, windows, doors, and other openings into buildings cannot be exposed to the following:

(1) Hazardous atmospheres
(2) Toxic gases in excess of applicable OSHA exposure limits

12.3.2.9.4 Indoor Installations.

12.3.2.9.4.1* Buildings for gasifier equipment shall be highly ventilated and include pressure relief panels to prevent overpressure from deflagrations.

12.3.2.9.4.2 Security barriers, fences, landscaping, or other obstacles shall be provided in the vicinity of the relief panels to prevent access to the potentially hazardous outlet areas.

12.3.2.9.4.3 For gasifiers in separate buildings, the building shall be isolated from other structures such that HVAC air intakes, windows, doors, and other openings into buildings cannot be exposed to the following:

(1) Hazardous atmospheres.
(2) Toxic gases in excess of applicable OSHA exposure limits

12.3.2.9.4.4 Gasifiers that occupy a portion of a building shall be separated from other occupancies in accordance with Section 7.9.

12.3.2.9.5 Process Systems for Gasifiers.

12.3.2.9.5.1 Piping, valves, and fittings from the gasifier chamber to the end use or storage system shall conform to ANSI/ASME B31.3, *Process Piping*.

12.3.2.9.5.2 Backflow prevention shall be provided to preclude inducing external atmospheres into the gasifier systems.

12.3.2.9.5.3 Manual Shutoff Valve.

(A) A manual flow shutoff valve shall be provided at a point outside the gasifier hazard area/building and prior to the end user/storage area.

(B) This valve shall be monitored by the gasifier process control system and shall trigger an emergency shutdown of the gasifier process when moved from the full open position.

12.3.2.9.5.4 Emergency stop capability shall be available both at the process control system controller location and at access points to the gasifier hazard area and building.

12.3.2.9.5.5 Activation of the emergency stop system shall do the following:

(1) Isolate the gasifier from all downstream users and storage facilities
(2) Immediately halt the flow of feedstock
(3) Depressurize the gasifier chamber and associated gas conditioning equipment

12.3.2.9.5.6 Vented gas from the gasifier process shall be routed to a flare stack sited in a location where the radiant flux does not pose a risk to personnel or a risk of ignition of combustible materials, in accordance with Chapter 10.

12.3.2.9.5.7 The emergency stop capability shall be provided by an independent controller from the main process controller.

12.3.2.9.6 Hazard Detection and Fire Protection for Gasifiers.

12.3.2.9.6.1 Flammable gas detection shall be provided in the vicinity of major gasifier components.

(A) For indoor installations, detection shall also be provided in areas where hydrogen could collect in the event of a leak.

(B) To minimize the potential of deflagration at an indoor installation, the process shall be shut down if the gas level exceeds 25 percent of the LFL.

12.3.2.9.6.2* Toxic Gas Detection.

(A) Toxic gas detection shall be provided in the gasifier hazard area or building for all gas constituents that, when released, could reach the OSHA PEL, OSHA ceiling limit, or STEL.

(B) This detection capability shall include detection of carbon monoxide as a minimum.

12.3.2.9.6.3* Thermal Detection.

(A) Thermal detectors shall be provided throughout the gasifier area to detect fires and activate the fire suppression system and initiate a gasifier shutdown.

(B) The detection system shall comply with *NFPA 72, National Fire Alarm and Signaling Code*.

(C) Ultraviolet/infrared (UV/IR) flame detection shall be provided in the vicinity of the gasifier vessel and all downstream equipment in which the gas temperature exceeds 80 percent of the lowest autoignition temperature of a contained constituent that exceeds 3 percent of the gas mix by volume.

12.3.2.9.6.4 Detection Devices and Visual Warning System.

(A) Detection devices shall be connected to visual warning devices.

(B) Activation of emergency stop for detected hazards other than fire shall be as recommended by the manufacturer or as required by local regulatory requirements.

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12.3.2.9.6.5* Fire suppression systems for gasifiers shall be selected to avoid imposing excessive thermal distress on the high-temperature components, which could cause distress to the equipment and contribute to a larger or extended fire situation.

12.4 Flammable Gases — Cryogenic. (Reserved)

12.5 Oxidizing Gases. (Reserved)

12.6 Other Gases. (Reserved)

12.7 Pyrophoric Gases. (Reserved)

12.8 Toxic and Highly Toxic Gases. (Reserved)

12.9 Unstable Reactive Gases. (Reserved)

Chapter 13 Insulated Liquid Carbon Dioxide Systems

13.1 General. The storage, use, and handling of liquid carbon dioxide in insulated systems shall be in accordance with the provisions of Chapter 13 and Chapters 1 through 7 as applicable.

13.1.1* Pressure Relief Devices. Containers used for liquid carbon dioxide shall be equipped with pressure relief devices piped from the uppermost part of the containers and communicating with the vapor space.

13.1.1.1 Physical Protection.

13.1.1.1.1 Pressure relief devices shall be located to minimize tampering, damage, and obstruction to flow.

13.1.1.1.2 The inlet and outlet of the relief devices shall not be blocked by a valve or plug during normal operation.

13.1.1.2 Vent Pipe Systems. Pressure relief devices shall be piped to the outdoors where the discharge will not impinge on the structure, personnel, or means of egress and will not create a hazardous concentration of carbon dioxide.

13.1.1.2.1 Pressure relief devices from portable DOT 4L containers that are not a component of a stationary system shall not be required to meet the requirements of 13.1.1.2.

13.1.1.2.2* Vent piping systems serving pressure relief devices shall be protected from water intrusion to prevent moisture or solid carbon dioxide from collecting and freezing and interfering with the operation of the pressure relief device.

13.1.1.2.3 Vent piping systems serving pressure relief devices shall be designed to prevent backflow restrictions exceeding 10 percent backpressure on the pressure relief device under full flow conditions.

13.1.2 Pressure and Level Indicators.

13.1.2.1 Cylinders, containers, and tanks shall be provided with a pressure gauge and a level gauge or device for indicating the quantity of liquid carbon dioxide.

13.1.2.2 These devices shall be designed for the temperatures and pressures associated with liquid carbon dioxide service.

13.1.2.3 Where cylinders, containers, and tanks are in locations remote from the filling connection, a means to determine when the containers have been filled to their design capacity shall be provided and shall be verifiable from the filling connection.

13.1.3 Piping Systems.

13.1.3.1 Carbon dioxide piping shall be located and supported to protect against damage from strain on piping and fittings; the effects of expansion, contraction, and vibration; mechanical damage; and heat sources.

13.1.3.2 Piping, tubing, and hoses and fittings shall be designed to a bursting pressure of at least four times the system design pressure.

13.1.4* Materials of Construction. Materials of construction shall be employed for potential exposure to a temperature of –109.3°F (–78.5°C).

13.1.5 Operating Instructions. Operating instructions shall account for potential exposure of personnel to extremely low temperatures in accordance with 13.2.3.

13.2 Small Insulated Liquid Carbon Dioxide Indoor Systems.

13.2.1* Container foundations or floors in multistoried buildings shall be designed to support the weight of the system at its full capacity in accordance with the building code.

13.2.2* Rooms or areas where container systems are filled and used indoors or in enclosed outdoor locations shall be provided with a gas detection and alarm system that is capable of detecting and notifying the building occupants of a gas release that creates carbon dioxide vapors in excess of its PEL.

13.2.2.1* Activation of the gas detection system shall initiate an audible alarm within the room or area in which the system is installed.

13.2.2.2 Subsection 13.2.2 shall not apply to manufacturer locations where containers are filled indoors and distributed for use.

13.2.2.3 Activation of the gas detection system shall sound a local alarm to notify persons responsible for system operation of a hazard condition in the area in which the system is installed.

13.2.3 A warning sign shall be posted at the entrance to the building, room, enclosure, or confined area where the container is located.

13.2.3.1 The warning sign shall be at least 8 in. (200 mm) wide and 6 in. (150 mm) high and state the following:

CAUTION — CARBON DIOXIDE GAS.
Ventilate the area before entering.
A high carbon dioxide (CO_2) gas concentration in this area can cause suffocation.

13.3 Small Insulated Liquid Carbon Dioxide Outdoor Systems.

13.3.1 Container systems located in enclosed spaces shall be in accordance with Section 13.2 for indoor systems.

13.3.1.1* Aboveground outdoor locations shall not be required to be provided with a gas detection and alarm system in accordance with 13.2.2 where the system is unenclosed.

13.3.1.1.1 To be considered unenclosed, enclosures constructed to limit access or otherwise provide a visual or architectural barrier for the installation shall be constructed in accordance with the requirements in Section 6.6 for weather protection or with the following:

(1) The enclosure shall be constructed without a roof or overhead cover.

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(2) Supports and walls shall not obstruct more than three sides nor more than 75 percent of the perimeter of the storage or use area, with 25 percent of the perimeter being open to the atmosphere.

13.3.1.1.2 Enclosures that do not meet the requirements of 13.3.1.1 shall be permitted when constructed in accordance with the following:

(1) The enclosure shall be constructed without a roof or overhead cover.
(2) Continuous mechanical exhaust ventilation shall be provided.

13.3.1.1.2.1 Where mechanical exhaust ventilation is provided, it shall be in accordance with the following:

(1) The exhaust system shall be installed in accordance with the requirements of the mechanical code.
(2) The exhaust system shall be designed to consider the density of the potential vapors released with exhaust taken from a point within 12 in. (305 mm) of the floor.
(3) The location of both the exhaust and the inlet air openings shall be designed to provide air movement across all portions of the enclosure to prevent the accumulation of vapors.
(4) The rate of exhaust ventilation shall be not less than 1 scf/min per square foot (0.028 Nm^3/min per square meter) of floor area within the enclosure.

13.4 Large Indoor Insulated Liquid Carbon Dioxide Systems. (Reserved)

13.5 Large Outdoor Insulated Liquid Carbon Dioxide Systems.

13.5.1 Location. Outdoor stationary large insulated liquid carbon dioxide systems shall be located in accordance with Table 13.5.1.

13.5.1.1 Point-of-Fill Connections. Point-of-fill connections serving stationary containers filled by mobile transport equipment shall not be positioned closer to exposures than the minimum distances in Table 13.5.1.

Table 13.5.1 Minimum Separation Distance Between Outdoor Stationary Large Insulated Liquid Carbon Dioxide Containers and Exposures

Exposure	Minimum Distance ft	Minimum Distance m
(1) Buildings, regardless of construction type	2	0.6
(2) Wall openings other than building exits	2	0.6
(3) Air intakes	10	3.1
(4) Property lines	5	1.5
(5) Places of public assembly (assembly occupancies)	50	15
(6) Nonambulatory patient areas	50	15
(7) Combustible materials, e.g., paper, leaves, weeds, dry grass, debris	15	4.5
(8) Incompatible hazardous materials	20	6.1
(9) Building exits	10	3.1

13.5.2 Fire Barriers. A 2-hour fire barrier wall shall be permitted in lieu of the distances specified by Table 13.5.1 when in accordance with the provisions of 13.5.2.1 through 13.5.2.4.

13.5.2.1 The fire barrier wall shall be without openings or penetrations.

13.5.2.1.1 Penetrations of the fire barrier wall by conduit or piping shall be permitted provided that the penetration is protected with a firestop system in accordance with the building code.

13.5.2.2 The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage system.

13.5.2.3 The fire barrier wall shall be located not less than 5 ft (1.5 m) from any exposure.

13.5.2.4 The fire barrier wall shall not have more than two sides at approximately 90 degree (1.57 rad) directions or not more than three sides with connecting angles of approximately 135 degrees (2.36 rad).

Chapter 14 Storage, Handling, and Use of Ethylene Oxide for Sterilization and Fumigation

14.1 General. The storage, handling, and use of ethylene oxide for sterilization and fumigation shall be in accordance with the provisions of Chapters 1 through 7, as applicable.

14.2 Receiving and Unloading Ethylene Oxide Containers.

14.2.1 Scope. This subsection shall apply to the handling of both full and empty ethylene oxide containers at a facility, including the following:

(1) Handling of the containers between the truck and the dock
(2) Inspecting containers at the dock
(3) Handling of the containers within the facility

14.2.2 Procedures.

14.2.2.1 Drums shall not be lifted by placing the forks under the chime rings on the drums.

14.2.2.2 Prior to the unloading of ethylene oxide containers, the vehicle engine shall be turned off, the brakes set, and the wheels chocked.

14.2.2.3 Smoking or open flames shall not be permitted within 25 ft (7.62 m) of any area where ethylene oxide containers are handled.

14.2.2.4 Ethylene oxide cylinders shall be secured to hand trucks or lift trucks during movement.

14.2.2.5 Ethylene oxide containers shall be kept upright at all times.

14.2.2.5.1 Containers shall not be stacked or rolled.

14.2.2.6 Immediately after offloading, ethylene oxide containers shall be inspected and the following checks performed:

(1) An examination for evidence of damage to the container or valves
(2) A confirmation that the valves are equipped with valve outlet plugs or caps
(3) An inspection of the container labeling to confirm that each container is labeled as containing ethylene oxide
(4) *A leak test of the container, including valves and fuse plugs

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14.2.2.6.1 Ethylene oxide containers shall not be moved to storage until the inspection is complete.

14.2.2.7 In the event that any container fails incoming inspection, the ethylene oxide supplier shall be notified.

14.2.2.7.1 If a leaking container is found, the facility procedures for handling ethylene oxide leaks and spills shall be followed.

14.3 Storage of Ethylene Oxide.

14.3.1 General.

14.3.1.1 Ethylene oxide containers shall be kept upright at all times.

14.3.1.2 Ethylene oxide containers shall not be stacked.

14.3.2 Indoor Storage.

14.3.2.1 Storage Within Sterilization Buildings.

14.3.2.1.1* The maximum quantity of ethylene oxide stored in a sterilization building shall be 10,000 lb (4536 kg).

14.3.2.1.2 The construction of all such sterilization buildings shall comply with Section 14.11.

14.3.2.1.3 Rooms within sterilization buildings shall be classified for purposes of ignition source control in accordance with 14.7.1.1.

14.3.2.1.4 Heated indoor storage areas shall be arranged so that stored cylinders or other containers cannot be spot heated or heated above 125°F (51.7°C).

14.3.3 Storage Outside of Buildings.

14.3.3.1 Location of Storage Outside of Buildings. Storage outside of buildings shall be located in accordance with 7.10.2 and 7.10.3.

14.3.3.2 Outdoor Storage Areas.

14.3.3.2.1 Outdoor storage areas shall have a minimum of 25 percent of the perimeter open to the atmosphere.

14.3.3.2.2 This open space shall be permitted to incorporate chain link fence, lattice construction, open block, or similar materials for the full height and width of the opening.

14.3.3.2.3 Storage areas shall be kept clear of dry vegetation and combustible materials for a minimum distance of 15 ft (4.6 m).

14.3.3.2.4 Cylinders stored outside shall not be placed on the ground (earth) or on surfaces where water can accumulate.

14.3.3.2.5 Storage areas shall be provided with physical protection from vehicle damage.

14.3.3.2.6* Storage areas shall be permitted to be covered with canopies of noncombustible construction.

14.4 Piping Systems.

14.4.1 Scope.

14.4.1.1 This section shall apply to ethylene oxide piping systems, including pipe, tubing, flanges, gaskets, valves, fittings, flexible connectors, and to the pressure-containing parts of other components, such as expansion joints and strainers, and devices used to mix, separate, distribute, meter, and control the flow of ethylene oxide.

14.4.1.2 This section shall not apply to scrubber and vent systems.

14.4.2 Materials for Piping, Valves, and Fittings.

14.4.2.1 Materials.

14.4.2.1.1 All metallic materials used shall be as specified in ANSI/ASME B31.3, *Process Piping*.

14.4.2.1.2 The requirements of the hazardous materials section shall apply.

14.4.2.1.3 The following restrictions shall also apply:

(1) All metallic materials used shall have a minimum melting point greater than 1500°F (815.6°C).
(2) No furnace butt-welded steel product shall be used.

14.4.2.2* Joining Methods.

14.4.2.2.1 Joints shall be made gastight and shall be welded, flanged, brazed, or threaded.

14.4.2.2.2 Joints shall be welded where located in concealed spaces within buildings.

14.4.2.2.3 The requirements in 14.4.2.2.3.1 through 14.4.2.2.3.4 shall apply.

14.4.2.2.3.1 Welding.

(A) All welding processes and procedures shall be in conformance with ANSI/ASME B31.3, *Process Piping*.

(B) The Oxy-Fuel Gas Welding (OFW) procedure shall not be used on any component or system fabricated to this code.

14.4.2.2.3.2 Brazing.

(A) All brazing processes and procedures shall be in strict conformance with ANSI/ASME B31.3, *Process Piping*.

(B) All braze alloys shall have a minimum melting point of 1000°F (537.8°C).

(C) The failure of the braze joint in the event of a fire exposure shall not in any way result in the release of additional fuel that can accelerate or spread the existing fire.

14.4.2.2.3.3 Soldering.

(A) Soldering shall not be used for pressure containment or structural purposes.

(B) Soldering for hermetic or environmental sealing purposes as part of a mechanical sealing system shall be permitted.

(C) The failure of any soldering application in the event of a fire shall not allow a release of fuel that can accelerate or spread the existing fire.

14.4.2.2.3.4 Threading. Threaded joints shall be made with a thread sealant or lubricant compatible with ethylene oxide.

14.4.3* Preparation for Dismantling of Piping.

14.4.3.1 Any piping and valves that have been used to transport ethylene oxide to or from a sterilizer to the emission control or release point shall be drained and purged prior to dismantling.

14.4.3.2 The piping shall be purged free of flammable concentrations of ethylene oxide prior to cutting or welding on the lines.

14.4.3.3 The piping shall be inspected for evidence of polymers prior to cutting or welding.

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14.4.3.4 If found, all polymers shall be removed prior to cutting or welding.

14.4.4 Valves.

14.4.4.1 Valves shall be designed for a minimum operating gauge pressure of 150 psi (1030 kPa).

14.4.4.2 All materials used, including valve seat discs, packing, seals, and diaphragms, shall be in accordance with 14.4.2.

14.4.5 Testing. Pressure piping systems shall be tested in accordance with ANSI/ASME B31.3, *Process Piping*, prior to use.

14.4.6* Identification. Ethylene oxide lines shall be identified.

14.5 Gas Dispensing Areas.

14.5.1 General. In addition to the requirements in Section 14.3, the requirements in 14.5.1.1 through 14.5.1.3 shall apply to areas where ethylene oxide is dispensed from containers.

14.5.1.1 Ethylene oxide storage shall be permitted in dispensing areas.

14.5.1.2* Indoor dispensing areas shall be equipped with a continuous gas detection system that provides an alarm when ethylene oxide levels exceed 25 percent of the LFL (7500 ppm).

14.5.1.3* Exhaust ventilation shall be installed in all indoor dispensing areas used for ethylene oxide.

14.5.1.4 Exhaust ventilation shall comply with the following:

(1) Mechanical ventilation shall be operated continuously at a rate of not less than 1 scf/min·ft^2 (0.3 Nm^3/min·m^2) of floor area of dispensing area.
(2) Exhaust ventilation shall not be recirculated within a room or building unless under the following conditions:
    (a) Where the air is treated to reduce the ethylene oxide concentration to below that which represents a hazard, recirculation shall be permitted.
    (b) Controls shall be provided to ensure the performance of the treatment and recirculation system.
(3) The ventilation system shall be designed to prevent accumulation of ethylene oxide anywhere in the dispensing area.

14.5.2 Ethylene Oxide Containers.

14.5.2.1 No more than two ethylene oxide containers shall be connected to each sterilizer.

14.5.2.2 Before connections are made, containers shall be grounded.

14.5.2.3 The ethylene oxide supply line shall have a reverse flow prevention device to prevent contamination of the supply container where automatic switchover of containers is used.

14.5.2.4 Each ethylene oxide piping system from the containers to the process chamber shall have two remotely operated shutoff valves in the flow stream.

14.5.2.4.1 The valve required in 14.5.2.4 closest to the container shall be located 5 ft (1.5 m) or less from the container.

14.5.2.4.2 The valves shall be operable from the sterilizer control room or other location outside the dispensing area.

14.5.2.5 Any supply piping containing liquid ethylene oxide that can be isolated shall be equipped with a pressure relief device.

14.5.3 Nitrogen System.

14.5.3.1 Nitrogen used for head space pressurization shall be no less than 99.0 percent nitrogen and shall contain no impurities that are chemically incompatible with ethylene oxide.

14.5.3.2 A reverse flow prevention device shall be provided to prevent ethylene oxide from entering the nitrogen supply system.

14.5.3.3 A particulate filter shall be provided to prevent rust from being introduced into an ethylene oxide container.

14.5.3.4 Refillable containers shall be pressurized with nitrogen to a gauge pressure of 50 psi (345 kPa) prior to disconnection and shipment to the supplier.

14.5.4 Vaporizer.

14.5.4.1 Liquid Flow Control Valve.

14.5.4.1.1 A valve shall be provided to control liquid flow to the vaporizer.

14.5.4.1.2 This valve shall be permitted to be one of the valves required in 14.5.2.4.

14.5.4.2* Temperature Recording Device.

14.5.4.2.1 An indicating or recording device shall be provided at the control panel to demonstrate that the ethylene oxide temperature is within the range of 60°F (16°C) to 200°F (93.3°C).

14.5.4.2.2 An alarm shall be provided for out-of-range conditions.

14.5.5 Liquid Ethylene Oxide Piping. Ethylene oxide shall not be piped outside the confines of the process area.

14.6 Operations.

14.6.1 Operating Procedures Manual.

14.6.1.1 Each facility shall prepare and maintain an operating procedures manual covering facility start-up, operation, and shutdown.

14.6.1.2 Operating procedures manuals shall include procedures for the safe operation of the facility under normal and nonroutine operation conditions.

14.6.1.3 Operating procedures manuals shall be accessible to facility operators at all times.

14.6.1.4 Operating procedures manuals shall include operator actions to be taken if toxic or flammable concentrations of ethylene oxide are detected in the facility.

14.6.1.5 Operating procedures manuals shall include procedures for purging and inerting equipment and piping.

14.6.1.6 Operating procedures manuals shall include procedures for addressing leakage and spills of ethylene oxide.

14.6.2* Sterilizer Operation.

14.6.2.1* Purging. The vessel shall be purged to reduce the ethylene oxide concentration to less than 25 percent of the LFL prior to opening the chamber door.

14.6.2.2* Postcycle Ventilation. A nonrecirculating ventilation system or equivalent means shall be provided to prevent ethylene oxide accumulation due to product outgassing prior to and during unloading of the sterilizer.

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14.6.2.3 Cycle Abort.

14.6.2.3.1 Ethylene oxide sterilizers shall be equipped with a manually initiated cycle abort feature accessible to the operator.

14.6.2.3.2 This cycle abort feature also shall be operable from outside the sterilizer area.

14.6.2.3.3 A key-locked device shall not be permitted.

14.6.2.3.4 The cycle abort operation shall allow for the controlled removal of flammable concentrations of ethylene oxide from the sterilizer.

14.6.3 Area Monitoring for Ethylene Oxide. Ethylene oxide sterilizer areas shall be monitored continuously for ethylene oxide concentrations.

14.6.3.1 The gas detection system shall provide an audible and visual warning signal to indicate when concentrations of ethylene oxide reach a level of 25 percent of the LFL of ethylene oxide.

14.6.3.2* The gas detection system shall automatically shut off the supply at the ethylene oxide containers when the concentration of ethylene oxide exceeds 25 percent of the lower limit of flammability.

14.6.4 Emergency Stop.

14.6.4.1 An emergency stop device shall be provided to halt all operating equipment, including valves, rotating equipment, and heating apparatus on the sterilizer and gas dispensing equipment.

14.6.4.2 The emergency stop shall be activated by a manually initiated feature accessible in the control room or at the control panel.

14.7 Electrical Installation.

14.7.1 Area Electrical Classification.

14.7.1.1 The sterilizer room, gas dispensing room, ethylene oxide container storage area, aeration rooms, and emission control area shall be classified as a Class I, Division 2, Group B area in accordance with *NFPA 70*, *National Electrical Code*, unless under the conditions of 14.7.1.1.1.

14.7.1.1.1 Aeration rooms shall be permitted to be unclassified electrically where it is demonstrated that flammable concentrations of ethylene oxide cannot occur during all normal and nonroutine operating conditions, including power failure.

14.7.1.2 The interior of the sterilization vessel shall be classified Class I, Division 1, Group B.

14.7.2* Static Electricity Control. All piping shall be bonded to an earth ground.

14.7.3 Grounding Requirements. All equipment shall be grounded in accordance with *NFPA 70*, *National Electrical Code*, Article 250.

14.8 Sterilizer Construction.

14.8.1* Vessel. Sterilizers operating at gauge pressure of 15 psi (100 kPa) or higher shall be designed, built, and stamped in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII.

14.8.2 Rotating Equipment. Rotating equipment exposed to flammable concentrations of ethylene oxide shall be designed to prevent sparking and localized overheating of surfaces during normal and nonroutine operation.

14.8.3 Pressure Relief Device. A pressure relief device, set to open at the sterilizer's design pressure, shall be installed on each sterilizer.

14.8.3.1 Pressure relief devices shall be inspected annually for corrosion or accumulation of material (such as polymer buildup) that could prevent operation.

14.8.3.2 The point of discharge of the pressure relief device shall not be located in an area where potential ignition sources exist or where ethylene oxide vapors could re-enter the building.

14.8.3.3 Shutoff valves shall not be installed in relief device discharge piping.

14.9 Disposal and Emissions.

14.9.1* Scope. This section shall apply to the disposal and emission of ethylene oxide from sterilization buildings.

14.9.2 Wet Scrubbers. Where a wet scrubber is used, the following requirements shall apply:

(1) Wet scrubbing systems shall be designed so that scrubber solution cannot enter ethylene oxide vent or process lines.
(2) Sources of pure ethylene oxide liquid shall be prevented from being fed directly to scrubber systems designed only for ethylene oxide gas treatment.

14.9.3 Flare Stacks. Where a flare stack is used, the following requirements shall apply:

(1) Flame arresters shall be installed to prevent flame flashback into the sterilizer.
(2) Flare stack failure shall initiate a shutdown of the flare stack feed and an audible alarm.

14.9.4 Catalytic Converter. Where a catalytic converter is used, it shall be designed to shut down or be bypassed if the temperature exceeds the maximum temperature determined by the catalyst supplier.

14.9.5* Oxidizing Emission Control Devices.

14.9.5.1 General.

14.9.5.1.1 All interlocks and safeguards shall be in place before sterilization begins.

14.9.5.1.2 Sterilization products that sit idle in the sterilization or aeration room shall be periodically washed or vented.

14.9.5.1.3 Confined spaces shall be vented to the outside after power loss.

14.9.5.1.4 Regular preventive maintenance shall be performed.

14.9.5.2 Sterilizers Equipped with Back-Vent Systems Connected to Emission Control Devices.

14.9.5.2.1 Sterilizers equipped with a back-vent system connected to an oxidizing emission control device shall be in accordance with 14.9.5.2.1.

14.9.5.2.1.1* Engineering controls shall be provided to ensure that residual ethylene oxide concentration at the entrance to the oxidizing emission control device does not exceed 25 percent of the LFL (0.75 percent by volume).

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(A) The sterilization chamber shall be equipped with gas detection to monitor the concentration of ethylene oxide within the sterilization chamber.

(B) A safety interlock shall be provided to prevent the backvent system from opening if the concentration of ethylene oxide in the sterilization chamber exceeds the predetermined limits required by the operating procedures specified in 14.6.1.1.

(C)* Exhaust duct systems used to convey ethylene oxide vapors shall be in accordance with the mechanical code.

14.9.5.3 Piping used to convey ethylene oxide to the sterilization process shall not be purged to an oxidizing emission control device.

14.10 Maintenance.

14.10.1 General Requirements. A written program shall be developed for the following maintenance activities:

(1) Confined space entry
(2) Purging of equipment and piping
(3) Welding (hot work) permit system
(4) Lockout/tagout
(5) Preventive maintenance for key equipment

14.10.2 Maintenance Manuals. Manuals shall be accessible to facility operators and maintenance personnel at all times.

14.11 Construction.

14.11.1 Scope.

14.11.1.1 This section covers the construction, ventilation, and heating of structures that house ethylene oxide storage, dispensing, and use.

14.11.1.2 These structures shall be used exclusively for ethylene oxide storage, dispensing, and use and for the housing of other materials having similar hazards, or they shall be permitted to be rooms attached to or located within buildings used for other purposes.

14.11.2 Separate Structures or Buildings.

14.11.2.1 Construction of Structures or Buildings. Separate structures or buildings shall be one story in height and shall have walls, floors, ceilings, and roofs constructed of noncombustible or limited-combustible materials.

14.11.2.1.1 Exterior walls, ceilings, and roofs shall be constructed in one of the following ways:

(1) Of lightweight material designed for explosion venting
(2)* Of heavy construction, such as solid brick masonry, concrete block, or reinforced concrete construction, provided there are explosion venting windows or panels in the walls or roofs

14.11.2.1.2 The floor of such structures or buildings shall not be located below ground level.

14.11.2.1.3 Any space beneath the floor shall be of solid fill, or the perimeter of the space shall be entirely unenclosed.

14.11.2.2* Structure or Building Ventilation. The structure or building shall be provided with general ventilation through the use of air supply inlets and exhaust outlets.

14.11.2.2.1 These inlets and outlets shall be arranged to provide movement of well-mixed air throughout the space.

14.11.2.2.2 Air circulation shall be at least 1 scf/ft^2 (0.3 Nm^3/m^2) of floor area and shall be permitted to be provided by natural or mechanical means.

14.11.2.3 Structure or Building Heating. Heating shall be by electrical appliances listed for Class I, Group B, Division 2 locations in accordance with *NFPA 70, National Electrical Code*, or shall be by means of steam or hot water radiation or other heating transfer medium with the heat source located in one of the following locations:

(1) Outside the building
(2) In a separate room with a 2-hour fire resistance rating pressurized relative to the remainder of the building

14.11.2.4 Sterilization Rooms. The sterilization room shall be provided with Protection Level 2 and Protection Level 4 controls as specified by the building code.

14.11.2.4.1 Sterilizing rooms with quantities of hazardous materials, including ethylene oxide, in quantities less than the MAQ per control area as established by the building code shall not be required to have Protection Level 2 and Protection Level 4 controls.

14.11.2.5* Explosion Control. Explosion control shall be provided in accordance with Section 6.9.

14.11.2.5.1 When explosion venting is provided, interior walls and other walls of the sterilization room not designed as explosion venting shall be designed to withstand an overpressure of at least 100 psf (4.8 kPa).

14.12 Fire Protection.

14.12.1 Sprinklers. Facilities using ethylene oxide shall be protected by an automatic sprinkler system in accordance with Section 6.10.

14.12.1.1 Ethylene Oxide Storage Areas. Ethylene oxide storage areas shall be equipped with a deluge system in accordance with NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems.*

Chapter 15 Acetylene Cylinder Charging Plants

15.1 General. This chapter shall apply to plants that are engaged in the generation and compression of acetylene and in the charging of acetylene cylinders, either as their sole operation or in conjunction with facilities for charging other compressed gas cylinders.

15.1.1 This chapter shall not apply to plants that only produce and compress acetylene for chemical operations or to plants that only produce and compress acetylene below a gauge pressure of 15 psi (103 kPa).

15.2 Location. Portions of plants housing acetylene generation and charging and acetylene cylinder storage operations where Protection Level controls are supplied shall be located in accordance with the requirements of the building code.

15.2.1 Cylinder Storage.

15.2.1.1 Charged cylinders shall be stored outside the charging room or out of doors in accordance with the requirements of Chapter 7 of this code.

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15.2.1.2 Acetylene cylinders located in the charging room awaiting transportation shall be located not less than 15 ft (4.6 m) from the acetylene charging manifolds.

15.2.2 Mobile Acetylene Trailer Systems (MATS) General.

15.2.2.1 MATS fire areas used for charging or discharging operations shall be separated from each other by not less than 30 ft (9.1 m) or by fire barriers or fire walls.

15.2.2.1.1 Where fire barriers are used to separate outdoor MATS fire areas without weather protection, the fire barriers shall be not less than 2-hour fire-resistive construction and shall separate individual fire areas by line of sight.

15.2.2.1.2 Where fire barriers are used to separate outdoor MATS fire areas covered by weather protection constructed in accordance with the requirements of Section 6.6, the fire barriers shall be full height walls without openings extending from the foundation to the roof and constructed of not less than 2-hour fire-resistive construction. The allowable area occupied by weather protection shall be in accordance with the requirements of the building code.

15.2.2.1.3 Where MATS are installed indoors in a MATS building, fire walls, fire barriers, or 2-hour fire-rated exterior walls are permitted to be used to separate MATS fire areas. Walls shall be constructed in accordance with the requirements of the building code.

15.2.2.1.4 Where process needs require removing the heat of solution of acetylene as determined by ambient temperature and cylinder charging rates, provisions shall be made for a cylinder cooling process water spray system and water run-off.

15.2.2.1.5 An electrical grounding system for the acetylene piping shall be provided in accordance with the *NFPA 70, National Electrical Code*.

15.2.2.1.6 The trailer chassis shall be connected to the grounding system before connections are made to the piping system.

15.2.3 MATS Charging and Discharging Stations.

15.2.3.1 MATS charging and discharging stations, including the mobile acetylene trailer and fill connections, shall be located a minimum distance of:

(1) Not less than 25 ft (7.6 m) from property lines.
(2) Not less than 50 feet (15.2 m) from buildings of combustible construction.
(3) Not less than 15 ft (4.6 m) from buildings of noncombustible construction not associated with the filling or discharging of the mobile acetylene trailer.
(4) Not less than 15 ft (7.6 m) horizontal distance from the vertical plane below the nearest overhead electrical utility power lines.
(5) Not less than 15 ft (4.6 m) horizontal distance from the vertical plane below overhead piping containing flammable liquids, oxidizing materials, or flammable gases other than acetylene.
(6) Not less than 50 ft (15.2 m) from air intakes.

15.2.3.1.1 The minimum required distances, except for air intake openings, shall not apply when fire barriers without openings or penetrations having a minimum fire resistance rating of 2 hours interrupt the line of sight between the discharge and the exposure.

15.2.3.2 Flexible transfer hoses used for charging or discharging of MATS shall have a minimum burst pressure of 10,000 psig (69,000 kPa).

15.2.3.3 The charging site shall be posted with a sign with the following or equivalent wording:

ACETYLENE — FLAMMABLE GAS

NO SMOKING — NO OPEN FLAMES

15.3 Building-Related Controls.

15.3.1 Buildings where acetylene operations are conducted shall be constructed of noncombustible or limited-combustible materials.

15.3.2* Single-Story Buildings. Acetylene cylinder charging plants shall be limited to single-story buildings without basements or crawl spaces.

15.3.3* Buildings or rooms housing acetylene operations, excluding calcium carbide storage rooms, shall be provided with explosion control in accordance with Section 6.8 of this code.

15.3.4 Exits shall be provided for areas with Protection Level controls in accordance with the building code.

15.3.5 Location of Acetylene Operations Within Multiple-Occupancy Buildings.

15.3.5.1* Portions of plants housing multiple occupancies that include acetylene operations shall be permitted to be used for charging of other gases provided that oxidizing gas operations are located at least 20 ft (6 m) from flammable gas operations.

15.3.5.2 The 20 ft (6 m) separation distance shall not be required to be met if charging of oxidizing gas cylinders or storage of such filled cylinders is separated from charging or storage of flammable gas cylinders by a masonry wall at least 5 ft (1.5 m) high having a fire resistance rating of at least 1 hour.

15.3.5.3 When mixed-occupancy buildings are to be separated by the use of occupancy separations, fire-resistive separations shall be provided in accordance with the building code.

15.3.6 Ventilation. Rooms housing acetylene operations shall be provided with mechanical exhaust or fixed natural ventilation in accordance with Section 6.16.

15.3.6.1 Reduction in Ventilation. Mechanical exhaust ventilation shall be permitted to be reduced below the rate specified in Section 6.16, provided that full ventilation is automatically restored when the acetylene concentration exceeds 25 percent of the lower flammable limit (LFL) when measured by a gas detection system in accordance with 15.3.10.

15.3.6.2 Calcium carbide storage rooms shall be ventilated in accordance with the building code.

15.3.7 Heating.

15.3.7.1 Heating equipment in operating areas shall be of either the steam or hot water type.

15.3.7.2* Electric heaters listed for installation in hazardous locations shall be allowed to be used in operating areas regulated by 15.3.8.2 when installed and used in accordance with the manufacturer's instructions and the listing.

15.3.7.3 Boilers, water heaters, and other heating equipment containing one or more of the following potential hazards

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shall be located in a separate building or room not directly communicating with areas devoted to acetylene operations:

(1) Open flames
(2) Release of sparks or spark generation during operation
(3) Exposed surface temperatures exceeding the lowest autoignition temperature of any of the materials present

15.3.7.4 Buildings or rooms used for acetylene operations, excluding calcium carbide storage rooms and cylinder storage areas, shall be maintained at a temperature above 40°F (4.4°C) during time of operation.

15.3.8 Electrical Equipment.

15.3.8.1 Rooms containing electrical equipment and wiring not conforming with 15.3.8.2 shall be separated from acetylene operations by an unpierced wall.

15.3.8.2 Electrical equipment and wiring in rooms housing acetylene operations, except rooms used exclusively for calcium carbide storage, shall conform to *NFPA 70, National Electrical Code*, Article 501, for Class I, Division 2 locations.

15.3.8.3 An emergency electrical shutoff switch shall be provided to shut off acetylene compressors and generators.

15.3.8.3.1 A shutoff switch shall be located at each exterior exit door, horizontal exit door, and door to exit enclosures from the fill plant.

15.3.8.3.2 Each exit door provided with a shutoff switch shall be marked with a sign indicating the location of the shutoff switch.

15.3.8.3.3 When the shutoff switch is located on the outside of the door, the inside of the door shall be marked with a sign to indicate that the switch is located outside the room served.

15.3.8.3.4 The signage shall indicate the following:

WARNING: Generator and Compressor [*other equipment as necessary*] Emergency Shutoff Switch [*indicate whether switch is located inside room or outside room at exit*]

15.3.9 Fire Protection.

15.3.9.1 MATS. Fire protection requirements for MATS shall apply to charging or discharging stations located indoors or outdoors.

15.3.9.1.1* A deluge sprinkler system shall be provided for MATS fire areas used as indoor and outdoor charging and discharging stations.

15.3.9.1.2 Deluge sprinkler systems shall provide a minimum design density of 0.3 gpm per square foot over the MATS fire area being protected.

15.3.9.1.3 The deluge system shall be able to be activated automatically by a fast-acting fire detection system and also by manual actuator.

15.3.9.1.3.1 Manual activation controls shall be identified and marked with a sign and shall be positioned for use in an emergency.

15.3.9.1.3.2 Fire protection equipment and manual activation controls serving the MATS fire protection system shall not be blocked or obstructed.

15.3.9.1.4 Existing acetylene charging and discharging stations shall be protected by an automatic deluge sprinkler system in accordance with 15.3.9.1 not later than January 1, 2015. See also Section 1.4.

15.3.9.1.4.1 The requirements of 15.3.9.1.1 shall not apply to existing indoor or outdoor facilities, equipment, structures, or other installations where MATS are charged or discharged that existed or were approved for construction or installation prior to the effective date of this code, providing the MATS are protected with an automatic sprinkler system with a minimum design density of not less than 0.25 gpm per square foot (10.1 L/min per square meter).

15.3.9.1.5 At least one listed portable fire extinguisher rated in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, at not less than 20 B:C shall be mounted on each mobile acetylene trailer.

15.3.9.2 Indoor Areas. Buildings or portions thereof required to comply with Protection Level controls serving or using containers other than those regulated by 15.3.9.1 shall be protected by an approved automatic sprinkler system in accordance with Section 6.10.

15.3.9.2.1* Automatic sprinkler systems shall be prohibited in rooms or areas used exclusively for the following:

(1) Calcium carbide storage
(2) Calcium carbide transfer operations
(3) Acetylene generation

15.3.9.2.2 Fire protection equipment shall be identified and located so that it is readily visible and accessible in an emergency.

15.3.10* Gas Detection System. Indoor areas in which acetylene operations are conducted shall be provided with a listed or approved flammable gas detection system.

15.3.10.1 Gas detection systems shall not be required for indoor areas used exclusively for calcium carbide storage or for structures equipped with fixed natural ventilation in accordance with Section 6.16 or constructed as weather protection in accordance with the requirements of Section 6.6 of this code.

15.3.10.2 System Design.

15.3.10.2.1 The flammable gas detection system shall be listed or approved for use with acetylene and any other flammable gases used in the room.

15.3.10.3 Operation. The gas detection system shall be designed to activate when the level of flammable gas exceeds 25 percent of the LFL for the gas or mixtures present at the anticipated normal temperature and pressure (NTP).

15.3.10.3.1 Activation of Gas Detection System. Activation of the gas detection system shall result in the following:

(1) Initiation of distinct audible and visual alarm signals both inside and outside of the operations room
(2) Activation of the mechanical ventilation system when reduced mechanical ventilation is provided to increase the ventilation to a rate not less than 1 scf/min/ft^2 (0.03 Nm^3/min/0.09 m^2)
(3) Shutdown of the gas generation system when the concentration of flammable gas equals or exceeds 50 percent of the LFL

15.3.10.3.2 Failure of Gas Detection System. Failure of the gas detection system shall result in activation of the mechanical ventilation system, cessation of acetylene generation, and the sounding of a trouble signal in an approved location.

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15.4 Design, Installation, and Testing.

15.4.1 Equipment.

15.4.1.1* Acetylene Generator Design. Acetylene generators shall be designed by competent, experienced persons knowledgeable of the chemical and physical properties of acetylene and calcium carbide and the fundamentals of pressure vessel design.

15.4.1.2 Installation.

15.4.1.2.1 Acetylene generators shall be installed within a room or building not exceeding one story in height.

15.4.1.2.2 The installation of acetylene generators in two-story buildings or rooms with mezzanines shall be permitted provided that the second story or mezzanine is used only for charging the generators with calcium carbide.

15.4.1.2.3 Outdoor installations shall be permitted where generators are protected from rain, freezing, and groundwater.

15.4.1.2.4 The foundation under a generator shall be constructed so that the generator will be level and piping shall be supported and arranged so that excessive strain is not placed on the generator or the piping connections.

15.4.1.2.5 When water is supplied to the generator through a piped connection, means shall be provided to prevent overfilling of the generator.

15.4.1.2.6 Generators served by a connected water supply system shall be equipped with a means to prevent the backflow of acetylene from the generator into the water supply.

15.4.1.2.7 Piping used to transport calcium carbide residue from acetylene generators shall be equipped with a means to prevent backflow of residue into the generators during periods when the generators are not in operation.

15.4.1.3 Venting of Generator.

15.4.1.3.1 Operating Pressure. The maximum permissible generating pressure shall be a gauge pressure of 15 psi (103 kPa).

15.4.1.3.1.1 Pressure Relief Devices. Each generator shall be provided with one or more pressure relief devices.

(A) The pressure relief device(s) shall prevent pressure from exceeding the allowable pressure rating of the generator due to chemical reaction or thermal exposure.

(B) The maximum setting of the generator pressure relief device(s) shall be a gauge pressure of 18 psi (124 kPa).

15.4.1.3.2 Vent Pipes.

15.4.1.3.2.1 The vent pipes shall be sized so that the pressure relief device served is allowed to operate at its full design flow.

15.4.1.3.2.2 The relief vent piping shall be installed without traps and in such a manner that condensation does not accumulate in the vent piping.

15.4.1.3.2.3 Vent pipes shall be constructed so that obstructions are not caused by rain, snow, ice, insects, or wildlife.

15.4.1.3.2.4 Vent pipes shall terminate in an exhaust hood or at a point outside the building.

(A) The termination point for exhaust ducts serving vent pipes located in a hood shall be located in accordance with the *Uniform Mechanical Code* for product-conveying duct.

(B) Vent pipes terminating outside the building shall be in accordance with 7.3.1.5 of this code.

15.4.1.3.2.5 Generator chamber relief pipes shall not be interconnected but shall lead separately to the outdoors.

15.4.1.3.2.6 The use of multiple pressure relief devices serving the same section of a gas generator shall be allowed.

(A)* When multiple pressure relief devices are connected to a common vent line or manifold, the cross-sectional area of the common vent line or manifold shall not be less than the aggregate cross-sectional venting area of the individual pressure relief devices connected.

15.4.1.4* Gasholder. Gasholders shall be permitted to be located outdoors or inside of buildings.

15.4.1.4.1 Outdoors. The gasholder shall be located at least 50 ft (15 m) from places of public assembly and any flammable liquid or flammable gas storage and at least 25 ft (7.6 m) from any source of ignition, line of adjoining property that is able to be built upon, or public way.

15.4.1.4.2 Indoors.

15.4.1.4.2.1 Indoor gasholders shall be located in a room that complies with the requirements of Sections 15.2 and 15.3.

15.4.1.4.2.2 This room shall be permitted to house other acetylene equipment.

15.4.1.5 Installation of Gasholder.

15.4.1.5.1 The gasholder shall be equipped with inlet and outlet shutoff valves located and arranged so that they are able to be closed in an emergency.

15.4.1.5.2* The gasholder shall not be located beneath or in a location where it is exposed to the failure of electric power lines, piping containing all classes of flammable or combustible liquids, or piping containing other flammable gases.

15.4.1.5.3 The gasholder shall be marked as follows:

WARNING: ACETYLENE — FLAMMABLE GAS — DANGER — KEEP FIRE AND OPEN FLAMES AWAY

15.4.1.5.4 Weeds and grass within 25 ft (7.6 m) of the gasholder shall be kept cut, and the cuttings shall be removed.

15.4.1.6* Low- and Medium-Pressure Purifiers and Driers. Purifiers and driers shall have inlet and outlet shutoff valves located and arranged so that they are able to be closed in an emergency.

15.4.1.7 Drain Lines from Low- and Medium-Pressure Acetylene Systems. Drain lines from low- and medium-pressure [a gauge pressure of 15 psi (103 kPa) and lower] acetylene systems shall be permitted to be piped to an indoor drain where the effluent liquid drained from the system is visible to the operator from the drain valve location.

15.4.1.8 Acetylene Compressors and High-Pressure Driers Installation.

15.4.1.8.1 Drain Lines, Vents, and Equipment.

15.4.1.8.1.1 Drain Lines from High-Pressure Acetylene Systems.

(A)* Drain lines from high-pressure [pressure above a gauge pressure of 15 psi (103 kPa)] acetylene oil separators, condensate traps, and driers shall be piped outdoors to a location not less than:

(1) 25 ft (7.6 m) from building openings
(2) 25 ft (7.6 m) from sources of ignition
(3) 10 ft (3 m) from combustible material
(4) 50 ft (15.2 m) from air intakes

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

(C) Drain lines from high-pressure acetylene systems where source pressures have been reduced to medium gauge pressure [15 psi (103 kPa) and lower] shall be permitted to be piped to an indoor drain where the effluent liquid drained from the system is visible to the operator from the drain valve location.

15.4.1.8.1.2 Pressure Relief Device Vent Pipes. Vent lines serving equipment provided with pressure relief devices shall be in accordance with 15.4.1.3.2.

15.4.1.8.2 Compressors.

15.4.1.8.2.1 Inlet and Outlet Piping Control Valves. The inlet and outlet piping of compressors shall be provided with shutoff valves located and arranged so that they are able to be closed in an emergency.

15.4.1.8.2.2 Pressure Relief Device Vent Pipes. Vent lines serving pressure relief valves shall be in accordance with 15.4.1.3.2.

15.4.1.8.2.3 Automatic Shutdown.

(A) Inlet Lines. Inlet lines shall meet the following requirements:

(1) *Pressure Switches.* The suction line to the compressor shall be provided with a pressure switch or device capable of automatically shutting down the compressor when the suction pressure falls below a pressure not less than 1 in. of water column (0.25 kPa) above atmospheric pressure.
(2) *Isolation of Pressure Switches.* Shutoff valves shall not be installed on the inlet or suction line between the compressor and the pressure switch or device.

(B)* Discharge Lines. Discharge lines shall meet the following requirements:

(1) The discharge line from the compressor shall be provided with a pressure switch or device to automatically shut down the compressor when the discharge pressure reaches the maximum allowable operating gauge pressure of the system or 400 psi (2800 kPa), whichever is less.
(2) When provided, valves installed between the compressor and the pressure switch or device shall be equipped with positive lock-open devices to ensure that the valves are maintained in a locked open position when the compressor is in operation.
(3) Such lock-open devices shall be visible to the operator.

15.4.1.9 Compressor Design.

15.4.1.9.1 Compressors shall be designed and constructed for acetylene service.

15.4.1.9.2 Compressors shall be constructed so that the acetylene is cooled during and after each stage of compression.

15.4.1.9.3 Where compressors use water as a cooling medium, the flow of water from the cooling jackets and intercoolers shall be visible to the operator.

15.4.1.9.4 Pressure and Temperature Indicators.

15.4.1.9.4.1 Pressure Gauges. A pressure gauge shall be provided on the discharge piping following each stage of compression.

15.4.1.9.4.2 Temperature Indicators. A temperature indicator shall be provided on the final discharge piping at the point where the gas at service pressure exits the compressor.

15.4.1.9.5 A pressure relief device shall be provided on the discharge piping following each stage of compression.

15.4.1.9.5.1 The pressure relief device in the final compression stage shall be set at a gauge pressure not greater than 450 psi (3100 kPa).

15.4.1.9.5.2 Shutoff valves shall not be allowed between pressure relief devices and the compressor piping.

15.4.1.9.6 Transmission belts, where used in compressor rooms, shall be provided with static eliminators or be of the static-conducting type.

15.4.1.10 Acetylene Piping.

15.4.1.10.1 Piping systems shall be designed, fabricated, tested, and maintained in accordance with ASME B31.3, *Process Piping.*

15.4.1.10.1.1 Acetylene piping shall be identified in accordance with ASME A13.1, *Scheme for the Identification of Piping Systems.*

15.4.1.10.1.2 Acetylene piping shall be braced and supported for the coincident internal or external pressure, temperature, vibration, or other structural loads expected under service conditions.

15.4.1.10.1.3 Pipe fittings shall conform to the requirements of 15.4.1.13.4.

15.4.1.10.2 Piping for Pressure Not Exceeding a Gauge Pressure of 15 psi (103 kPa).

15.4.1.10.2.1 Piping and fittings shall be steel, wrought iron, malleable iron, or copper alloys meeting the requirements of 15.4.1.13.4.2.

15.4.1.10.2.2 Pipe of nominal size 6 in. (152 mm) and less shall be a minimum of Schedule 40, and all pipe fittings shall have a minimum rating of a gauge pressure of 125 psi (861 kPa).

15.4.1.10.2.3 Piping shall be pneumatically tested at 110 percent of the maximum design pressure using inert gas or air as the test medium.

(A) Hydrostatic testing shall be allowed in lieu of pneumatic testing.

(B) When piping is tested hydraulically, the test pressure shall be not less than 150 percent of the design pressure.

15.4.1.10.3 Piping for Pressure Exceeding a Gauge Pressure of 15 psi (103 kPa).

15.4.1.10.3.1 Piping shall be steel or wrought iron, and fittings shall be steel, malleable iron, ductile iron, or copper alloys meeting the requirements of 15.4.1.13.4.2.

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15.4.1.10.3.2 Pipe of nominal size 1 in. (25 mm) and less shall be not less than Schedule 80.

15.4.1.10.3.3 All pipe of nominal sizes 1¼ in. (32 mm) and 1½ in. (38 mm) shall be not less than Schedule 160.

15.4.1.10.3.4 Pipe fittings shall have a minimum working pressure of a gauge pressure of 3000 psi (20,684 kPa).

15.4.1.10.3.5 Bourdon tubes of pressure gauges shall be steel or copper alloys meeting the requirements of 15.4.1.13.4.2.

15.4.1.10.3.6 Pressure gauges shall be protected by a device that stops a detonation flame and limits the rise in pressure on the pressure gauge side to prevent Bourdon tube deformation.

15.4.1.10.3.7 Piping shall be hydrostatically tested at a gauge pressure of not less than 4500 psi (31,026 kPa).

15.4.1.10.3.8 Pressure relief valves, pressure gauges, diaphragm valves, regulators, and flash arresters shall not be required to be hydrostatically tested.

15.4.1.10.3.9 Flexible transfer hoses shall have a minimum burst gauge pressure of 10,000 psi (69,000 kPa).

15.4.1.11 Cylinder Charging Leads. Cylinder charging leads shall have a burst pressure rating of a gauge pressure not less than 10,000 psi (68,948 kPa) and shall be constructed of metallic or nonmetallic materials compatible for use in acetylene service.

15.4.1.12 Acetylene Cylinder Charging Manifolds, Solvent Equipment, and Mobile Acetylene Trailer Systems.

15.4.1.12.1 Cylinder charging manifolds shall be provided with a shutoff valve and a blow-down valve.

15.4.1.12.1.1* The blow-down valve shall either be arranged to vent the manifold to the outdoors in accordance with 7.3.1.5 or the discharge shall be returned to a low- or medium-pressure acetylene system with the pressure rating and capacity to contain both the maximum pressure and volume released from the manifold.

15.4.1.12.2 A check valve shall be installed in the pipeline at each cylinder charging manifold and in each cylinder charging lead.

15.4.1.12.2.1 Check valves shall not be required on charging leads used to charge individual cylinders on mobile acetylene trailer systems equipped with manifold systems serving multiple containers.

15.4.1.12.3 Pressure gauges shall be protected by a device that stops a detonation flame and limits the rise in pressure to prevent Bourdon tube deformation.

15.4.1.12.4 Each cylinder charging manifold outlet shall be provided with a shutoff valve.

15.4.1.12.5 Cylinder charging manifolds shall be arranged so that stress in the cylinder charging leads is limited to prevent failure when connected for charging or transportation.

15.4.1.12.6 Acetylene cylinders connected to charging manifolds shall have provisions for cooling by water spray applied from a manually activated spray nozzle system, where needed for removing the heat of solution of acetylene, as determined by ambient temperature and cylinder charging rate.

15.4.1.13 Equipment and Piping.

15.4.1.13.1 Equipment and piping (generators, compressors, and manifolds) employed in acetylene operations shall be electrically continuous and bonded to the system grounding electrode, in accordance with *NFPA 70, National Electrical Code*.

15.4.1.13.2 Generators, compressors, and pressure relief devices shall be marked with their capacities, pressure ratings, the manufacturer's name and address, and the model or serial numbers.

15.4.1.13.3 The capacity and operating pressure of this equipment shall not exceed the rating for which it is designed.

15.4.1.13.4 Alloys.

15.4.1.13.4.1 Unalloyed copper, silver, or mercury shall not be used where they are able to be exposed to acetylene or to liquids containing acetylene in solution.

15.4.1.13.4.2 Copper alloys containing more than 65 percent copper shall not be used where they are able to be exposed to acetylene, unless such alloys have been found to be compatible in the specific application by experience or by test.

15.4.2 Process.

15.4.2.1 The charging site shall be posted with a sign with the following or equivalent wording:

ACETYLENE — FLAMMABLE GAS — NO SMOKING — NO OPEN FLAMES

15.4.2.2 Electrical equipment shall be in accordance with *NFPA 70, National Electrical Code*.

15.4.2.3 MATS Discharge Stations.

15.4.2.3.1 Flexible transfer hoses used for withdrawal of acetylene shall be pressure rated as follows:

(1) For pressures greater than a gauge pressure of 15 psi, hoses shall have a minimum burst gauge pressure of 10,000 psi (69,000 kPa).
(2) For gauge pressures of 15 psi (103 kPa) or less, hoses shall be rated for a minimum working gauge pressure of 125 psi (860 kPa) and a minimum burst gauge pressure of 500 psi (3450 kPa).

15.4.2.3.2 Signs. Acetylene cylinder shipping and receiving docks and plant entrances shall be posted with a sign declaring the following or equivalent prohibition:

WARNING: NO OPEN FLAMES
SMOKING STRICTLY PROHIBITED

15.5 Process Operations.

15.5.1 Operating Instructions.

15.5.1.1 Generator operating instructions shall be displayed in a conspicuous place near the generator or otherwise be kept convenient for ready reference by the operator.

15.5.1.2 Operating instructions shall include procedures for operation as well as shutdown procedures that are to be used in the event of an emergency.

15.5.2 Acetylene cylinders that have provisions for caps shall not be required to have caps in place when in the acetylene cylinder charging plant.

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15.5.3 Charging Procedures.

15.5.3.1 To prevent liquefaction (condensation) of acetylene, its pressure shall not exceed the values for the corresponding acetylene temperatures shown in Table 15.5.3.1.

Table 15.5.3.1 Maximum Acetylene Pressure According to Acetylene Temperature

Temperature		Gauge Pressure	
°F	°C	psi	kPa
–5	–20.5	200	1400
0	–17.8	220	1500
10	–12.2	260	1800
20	–6.7	305	2100
30	–1.1	360	2500
≥37	≥2.8	400	2800

15.5.3.2 Valves for charging cylinders shall be operated in such a sequence that the cylinder valves are opened first at the start of charging operations and closed last at the end of charging operations.

15.5.3.3 Where process needs require removing the heat of solution of acetylene as determined by ambient temperature and cylinder charging rates, provisions shall be made for a cylinder cooling process water spray system and water runoff.

15.5.4 Combustible Waste. Self-closing metal waste receptacles shall be provided for greasy, oily rags and waste materials.

15.5.5 Powered Industrial Trucks. Powered industrial trucks shall be in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations.*

15.6 Maintenance. (Reserved)

15.7 Special Problems — Raw Materials.

15.7.1 Calcium Carbide.

15.7.1.1 Drums and Containers.

15.7.1.1.1 Calcium carbide shall be stored in packages meeting U.S. Department of Transportation or Transport Canada regulations or in containers approved by the AHJ.

15.7.1.1.2 Containers for calcium carbide shall be marked using the following or equivalent wording:

WARNING: CALCIUM CARBIDE

15.7.1.2 Storage Areas.

15.7.1.2.1 Calcium carbide storage areas shall not be used for the storage of flammable materials or flammable compressed gases.

15.7.1.2.2 Each area of the plant where calcium carbide is handled, stored, or used shall be posted with notices using the following or equivalent wording:

WARNING: CALCIUM CARBIDE —
DANGEROUS IF NOT KEPT DRY —
KEEP WATER AND FLAMES AWAY

15.7.1.2.3 Calcium carbide storage areas shall be arranged so that defective containers are able to be removed promptly.

15.7.1.2.4 Calcium carbide containers shall be supported so that those portions of the containers containing calcium carbide will not come in contact with the ground or with groundwater.

15.7.1.2.4.1 Locations subject to flooding shall be provided with a means to protect the containers from exposure to water.

15.7.1.2.4.2 Protection from the ground shall be provided by one or more of the following:

(1) Concrete or asphalt paved storage pads
(2) Dry, well-drained ground protected with timbers, pallets, or gravel arranged to elevate the containers above expected surface water

15.7.1.2.5 Calcium carbide storage shall be located not less than 10 ft (3 m) from any line of adjoining property that is able to be built upon.

15.7.1.2.6 Exposed water, steam, or condensate lines shall not be permitted in rooms or buildings devoted exclusively to calcium carbide storage in drums.

15.7.1.2.6.1 Unopened bulk calcium carbide containers that have accumulations of ice and snow shall be permitted to be stored in such rooms or buildings.

15.7.1.2.7 Calcium carbide storage buildings shall be constructed in accordance with the building code.

15.7.1.2.7.1 Rooms or areas where the quantity of calcium carbide exceeds the maximum allowable quantity per control area shall be provided with Protection Level controls.

15.7.1.3 Handling. Locations where calcium carbide is transferred from transport containers to generator hopper loading carts or systems shall be protected from rain.

15.7.1.4 Calcium Carbide Residue Disposal.

15.7.1.4.1* The discharge of calcium carbide residue from acetylene generators shall be by one or more of the following means:

(1) Discharge to a public sewer when approved by the AHJ
(2) Discharge to the outdoors into an open sump or pit
(3) Discharge into ventilated containment tanks

15.7.1.4.1.1* When discharging to a public sewer drain, a system shall be in place to ensure that all calcium carbide is reacted and that no free acetylene is available to create hazardous atmospheres in sewer lines. Direct connection of acetylene generators to the public sewer shall not be allowed. When discharge to the public sewer is allowed under 15.7.1.4.1(1), connections from acetylene generators shall be constructed to provide an air gap between the point of discharge from the drain of the generator and the point of entry to the sewer.

(A) Calcium carbide residue shall be discharged into outdoor open sump pits or other ventilated receptacles.

(B) Such receptacles shall be permitted to have clear water connections to public sewers if such disposal means is approved by the AHJ.

15.7.1.4.1.2 When discharging to sumps, pits, or other receptacles, the point of discharge shall be located outdoors not less than 25 ft (7.6 m) from sources of ignition and the lot line of adjoining property that is able to be built upon.

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

15.7.1.4.1.3 Collection in containment tanks shall be allowed indoors when the tanks are equipped with an exhaust system that transports vapors to a point outside the building in which the tanks are located.

15.7.1.4.1.4 Exhaust collection systems shall be in accordance with the *Uniform Mechanical Code*, and the duct serving such systems shall be classified as a product-conveying duct.

15.7.1.4.1.5 Containment tanks installed outdoors shall not be required to be equipped with an exhaust system.

15.7.1.4.2 Calcium carbide residue pits and ponds shall be within a fenced area or posted around their perimeters with signs declaring the following or equivalent warning:

WARNING: NO TRESPASSING — NO SMOKING — NO OPEN FLAMES

15.7.2 Solvent Equipment.

15.7.2.1 Solvent storage containers shall be constructed and installed in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

15.7.2.2 Aboveground solvent storage containers in excess of one 55 gal (208 L) drum allowed for use shall be located at least 25 ft (7.6 m) from the storage of acetylene cylinders and other flammable gas cylinders.

15.7.2.3 Solvent containers in use shall be provided with secondary containment flammable gases.

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.1.1.2(1) For regulations on the transportation of gases, see 49 CFR 100–185, "Transportation," and *Transportation of Dangerous Goods Regulations*.

A.1.1.2(3) Bulk compressed gas and cryogenic fluid system installations are intended to be covered by the requirements of this code. Instrumentation and alarms that are attendant to the system and designed to interface with the application in a health care facility are to be retained within the purview of NFPA 99, *Health Care Facilities Code*.

A.1.1.2(5) For information, see NFPA 52, *Vehicular Gaseous Fuel Systems Code*, or NFPA 58, *Liquefied Petroleum Gas Code*.

A.1.1.2(6) The storage and use of compressed gases and cryogenic fluids outside the boundaries of laboratory work areas are covered by this code.

A.1.1.2(11) NFPA 55 is used as the source document for the fundamental requirements for compressed hydrogen gas (GH2), or liquefied hydrogen gas (LH2) system installations. Correlation between NFPA 55 and NFPA 2, *Hydrogen Technologies Code*, is the responsibility of the two technical committees involved. The installation requirements for bulk GH2 or LH2 are viewed as fundamental provisions. On the other hand, use-specific requirements for designated applications such as vehicular fueling are not resident in NFPA 55 and are under the purview of the NFPA 2 Technical Committee. Where there are specific provisions or controls included in NFPA 55, the specific controls of NFPA 55 will govern except that modifications made to provisions that have been extracted can be followed when the modifications have been made within NFPA's extract procedure as indicated in the *Manual of Style for NFPA Technical Committee Documents*.

A.1.2 Reference is made to other material-specific standards published by NFPA where appropriate. The material-specific standards are limited in number, and controls are focused on select materials through the use of those standards. NFPA 55 is intended to be generic and applicable to all materials in the gaseous or cryogenic state.

A.2.3.6 Applicable equivalent regulations apply in the country of use.

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.3.3.1 Absolute Pressure. Measured from this reference point, the standard atmospheric pressure at sea level is an absolute pressure of 14.7 psi (101.3 kPa).

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A.3.3.2 Acetylene. Acetylene when compressed and packaged into cylinders is dissolved in a solvent, typically acetone or dimethylformamide (DMF). The solvent is absorbed into a porous material that fills the inside of an acetylene cylinder. This method of packaging is unique to acetylene, and the U.S. Department of Transportation prohibits the use of acetylene cylinders for any other gases.

A.3.3.6.4 Use Area. Piping systems are used to transport gas (and liquids) from a point of storage to the actual point of use where the gas is deployed. Piping alone does not create a condition of "use" where the material is being consumed or otherwise released from a closed pipe system. On the other hand, piping that connects to "process equipment," which is acting to raise or lower the energy in the system, or that either consumes or releases the material must be viewed as "active," and as a result the material is viewed as being "placed into action" at the point of delivery or connection to the process equipment.

A.3.3.8 Assembly Occupancy. Assembly occupancies might include the following:

(1) Armories
(2) Assembly halls
(3) Auditoriums
(4) Bowling lanes
(5) Club rooms
(6) College and university classrooms, 50 persons and over
(7) Conference rooms
(8) Courtrooms
(9) Dance halls
(10) Drinking establishments
(11) Exhibition halls
(12) Gymnasiums
(13) Libraries
(14) Mortuary chapels
(15) Motion picture theaters
(16) Museums
(17) Passenger stations and terminal of air, surface, underground, and marine public transportation facilities
(18) Places of religious worship
(19) Pool rooms
(20) Recreation piers
(21) Restaurants
(22) Skating rinks
(23) Special amusement buildings, regardless of occupant load
(24) Theaters

Assembly occupancies are characterized by the presence or potential presence of crowds with attendant panic hazard in case of fire or other emergency. These are generally open or occasionally open to the public, and the occupants, who are present voluntarily, are not ordinarily subject to discipline or control. Such buildings are ordinarily occupied by able-bodied persons and are not used for sleeping purposes. Special conference rooms, snack areas, and other areas incidental to, and under the control of, the management of other occupancies, such as offices, fall under the 50-person limitation. Restaurants and drinking establishments with an occupant load of fewer than 50 persons should be classified as mercantile occupancies. For special amusement buildings, see 16.4.7 of *NFPA 5000, Building Construction and Safety Code.*

A.3.3.15 Bulk Oxygen System. The bulk oxygen system terminates at the source valve, which is commonly the point where oxygen at service pressure first enters the supply line or a piece of equipment that utilizes the oxygen gas or liquid. The oxygen containers are either stationary or movable, and the oxygen is stored as a compressed gas or cryogenic fluid.

Bulk oxygen systems can be used to supply gas in either its compressed gaseous or liquefied form. Systems that may be used to supply both gaseous and liquid forms are referred to as hybrid systems. The following bulk oxygen systems are typical of those in use:

(1) When the primary supply of the gas as stored is from a compressed gaseous source that is used in the compressed and gaseous form, the bulk oxygen system is said to be a bulk compressed oxygen gas system.
(2) When the primary supply of the gas as stored is in a liquid form and the system is designed to transfer only liquid, the system is said to be a bulk liquefied oxygen system.
(3) When the primary supply of the gas as stored is in a liquid form and the system is designed to transfer or store the gas in a compressed gaseous form, with or without a feature that may also allow the subsequent transfer and use of liquid, the bulk oxygen system is said to be a hybrid bulk oxygen system. For the purposes of the application of the code, a hybrid system is viewed as a bulk liquefied oxygen system.

A.3.3.16 Cathodic Protection. This protection renders a metallic container or piping system or component negatively charged with respect to its surrounding environment.

A.3.3.20 Chime Ring. These rings protect the drum but are not intended for lifting purposes.

A.3.3.30 Cylinder Pack. *Six-packs* and *twelve-packs* are terms used to further define cylinder packs with a specific number of cylinders. The characteristic internal water volume of individual cylinders in a cylinder pack ranges from 1.52 scf to 1.76 scf (43 L to 50 L) or a water capacity of 95 lb to 110 lb (43 kg to 50 kg).

A.3.3.39 Exhausted Enclosure. Such enclosures include laboratory hoods, exhaust fume hoods, and similar appliances and equipment used to retain and exhaust locally the gases, fumes, vapors, and mists that could be released. Rooms or areas provided with general ventilation, in and of themselves, are not exhausted enclosures.

A.3.3.40 Explosion Control. NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, provides guidance on the use of deflagration venting systems in buildings and other enclosures. The primary purpose of a venting system is to relieve the overpressure produced in an explosion to limit the potential damage to the building where the explosion occurs. Although some structural damage can be anticipated, the use of relief venting is expected to prevent massive building failure and collapse. In cases where detonation is probable, venting is often used in conjunction with barricade construction where the pressure-resistant portions of the building have been constructed to resist the pressures anticipated should an explosive event occur. Design of barricade systems is highly specialized and the subject of military standards applicable to the subject. NFPA 69, *Standard on Explosion Prevention Systems*, provides guidance on the use of suppression, ventilation systems, and the limiting of oxidants as a means to prevent the occurrence of an explosion. When relief vents are to be used as a means to provide explosion relief, the fundamental requirements of the building code for structural elements, including snow, wind, and seismic events, should be considered. In some instances, the requirements for wind resistance can impose more rigorous requirements on the relief vents than required by the

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engineering analysis used to determine the relief pressure. In such cases, users must demonstrate that the relief vents will not become airborne or release in such a manner as to create secondary hazards within or external to the building in which they are installed. Specific designs might require approval by the AHJ.

A.3.3.42 Fire Barrier. A fire barrier, such as a wall or floor assembly, might be aligned vertically or horizontally. [**5000,** 2012]

A.3.3.46 Flammable Liquid (Class I). Materials that boil at a temperature of less than 68°F (20°C) are compressed gases. Users are cautioned that the use of the definitions found in NFPA 30, *Flammable and Combustible Liquids Code*, can result in the misclassification of certain liquefied compressed gases as flammable liquids (Class IA). Liquefied hydrogen is classed as a flammable compressed gas by the U.S. Department of Transportation. It is regulated as a cryogenic fluid within this code.

A.3.3.49.1 Compressed Gas. The states of a compressed gas are categorized as follows:

(1) Nonliquefied compressed gases are gases, other than those in solution, that are in a packaging under the charged pressure and are entirely gaseous at a temperature of 68°F (20°C).
(2) Liquefied compressed gases are gases that, in a packaging under the charged pressure, are partially liquid at a temperature of 68°F (20°C). Cryogenic fluids represent a transient state of a gas that is created through the use of refrigeration. Cryogenic fluids cannot exist in the liquid form or partial liquid form at temperatures of 68°F (20°C); hence, they are not "compressed gases" as defined.
(3) Compressed gases in solution are nonliquefied gases that are dissolved in a solvent.
(4) Compressed gas mixtures consist of a mixture of two or more compressed gases contained in a packaging, the hazard properties of which are represented by the properties of the mixture as a whole.

A.3.3.49.6 Inert Gas. Inert gases do not react readily with other materials under normal temperatures and pressures. For example, nitrogen combines with some of the more active metals such as lithium and magnesium to form nitrides, and at high temperatures it will also combine with hydrogen, oxygen, and other elements. The gases neon, krypton, and xenon are considered rare due to their scarcity. Although these gases are commonly referred to as inert gases, the formation of compounds is possible. For example, xenon combines with fluorine to form various fluorides and with oxygen to form oxides; the compounds formed are crystalline solids.

A.3.3.49.9 Other Gas. A gas classified as an "other gas" might be a nonflammable gas or an inert gas.

A.3.3.49.14 Unstable Reactive Gas. Unstable reactive materials are subdivided into five classifications. Class 4 materials are materials that in themselves are readily capable of detonation or explosive decomposition or explosive reaction at normal temperatures and pressures. They include the following:

(1) Materials that are sensitive to localized thermal or mechanical shock at normal temperatures and pressures
(2) Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) of 1000 W/mL or greater

Class 3 materials are materials that in themselves are capable of detonation or explosive decomposition or explosive reaction but require a strong initiating source or heat under confinement before initiation. Class 3 materials include the following:

(1) Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) at or above 100 W/mL and below 1000 W/mL
(2) Materials that are sensitive to thermal or mechanical shock at elevated temperatures and pressures
(3) Materials that react explosively with water without requiring heat or confinement

Class 2 materials are materials that readily undergo violent chemical change at elevated temperatures and pressures, including the following:

(1) Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) at or above 10 W/mL and below 100 W/mL
(2) Materials that react violently with water or form potentially explosive mixtures with water

Class 1 materials are materials that in themselves are normally stable but that can become unstable at elevated temperatures and pressures, including the following:

(1) Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) at or above 0.01 W/mL and below 10 W/mL
(2) Materials that react vigorously with water, but not violently
(3) Materials that change or decompose on exposure to air, light, or moisture

Class 0 materials are materials that in themselves are normally stable, even under fire conditions, including the following:

(1) Materials that have an instantaneous power density (product of heat of reaction and reaction rate) at 482°F (250°C) below 0.01 W/mL
(2) Materials that do not react with water
(3) Materials that do not exhibit an exotherm at temperatures less than or equal to 932°F (500°C) when tested by differential scanning calorimetry

A.3.3.50 Gas Cabinet. Doors and access ports for exchanging cylinders and accessing pressure-regulating controls are permitted to be included as part of a gas cabinet.

A.3.3.56 Hazard Rating. The criteria for hazard rating are as defined in NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response.*

A.3.3.57 Health Care Facilities. Health care facilities include, but are not limited to, hospitals, nursing homes, limited care facilities, clinics, medical and dental offices, and ambulatory health care centers, whether permanent or movable. [**99**, 2012]

A.3.3.58 Immediately Dangerous to Life and Health (IDLH). This level is established by the National Institute for Occupational Safety and Health (NIOSH). If adequate data do not exist for precise establishment of IDLH, an independent certified industrial hygienist, industrial toxicologist, or appropriate regulatory agency should make such determination.

A.3.3.60 ISO Module. The characteristic internal water volume of individual tubular cylinders is 43 scf (1218 L) or a water capacity of 2686 lb (1218 kg). The frame of an ISO container module and its corner castings are specially designed and dimensioned to be used in multimodal transportation service on container ships, special highway chassis, and container-on-flatcar railroad equipment.

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A.3.3.62.1 Ceiling Limit. The ceiling limits utilized are those published in 29 CFR 1910.1000.

A.3.3.62.2 Permissible Exposure Limit (PEL). The maximum permitted time-weighted average exposures to be utilized are those published in 29 CFR 1910.1000.

A.3.3.62.3 Short-Term Exposure Limit (STEL). STEL limits are published in 29 CFR 1910.1000.

A.3.3.70 Mobile Acetylene Trailer System (MATS). This system includes the mobile acetylene trailer, pressure regulator(s), flash arresters, protective devices, meter (optional), and interconnecting piping. The system terminates at the point where acetylene at service pressure enters the user's piping system.

A.3.3.72 Mobile Supply Unit. Examples include ISO modules, tube trailers, and cylinder packs.

A.3.3.76 Normal Temperature and Pressure (NTP). There are different definitions of normal conditions. The normal conditions defined here are the ones most commonly used in the compressed gas and cryogenic fluid industry.

A.3.3.79 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.

A.3.3.81 Protection Level. NFPA uses the concept of protection levels in a manner that is analogous to Group H occupancies in other model codes. Although NFPA 1, *Fire Code*, and *NFPA 5000, Building Construction and Safety Code*, do not have unique occupancy classifications for occupancies containing hazardous materials, Protection Levels 1 to 5 in NFPA codes and standards reflect increased building safety requirements that are applicable to occupancies containing hazardous materials, which generally correlate to the Group H, Division 1 to 5 occupancy classifications in other codes.

A.3.3.85 Secondary Containment. Examples of secondary containment include dikes, curbing, remote impoundment, and double-walled tanks. [**400,** 2013]

A.3.3.88 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.

A.3.3.91 Sterilization Building. This building can include the mechanical room, electrical room, nitrogen tank and vaporizers area, chiller area, preconditioning room or preconditioning cells, conveyance rooms, preheat room, sterilizer room, aeration room or cells, emissions control area, ethylene oxide drum storage room, gas transfer room, shipping and receiving office(s), unprocessed and processed product storage areas, control room, maintenance areas, offices for the process support personnel, and any other rooms or systems as applicable in supporting the sterilization process.

A.3.3.93.2 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.3.3.93.2(a) through Figure A.3.3.93.2(f).

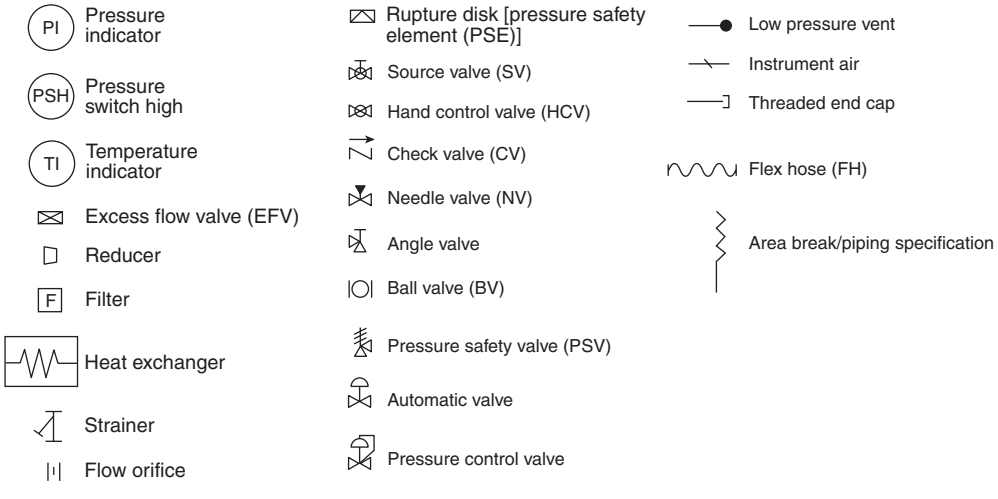


FIGURE A.3.3.93.2(a) Symbol Legend for Figure A.3.3.12(b) through Figure A.3.3.12(f).

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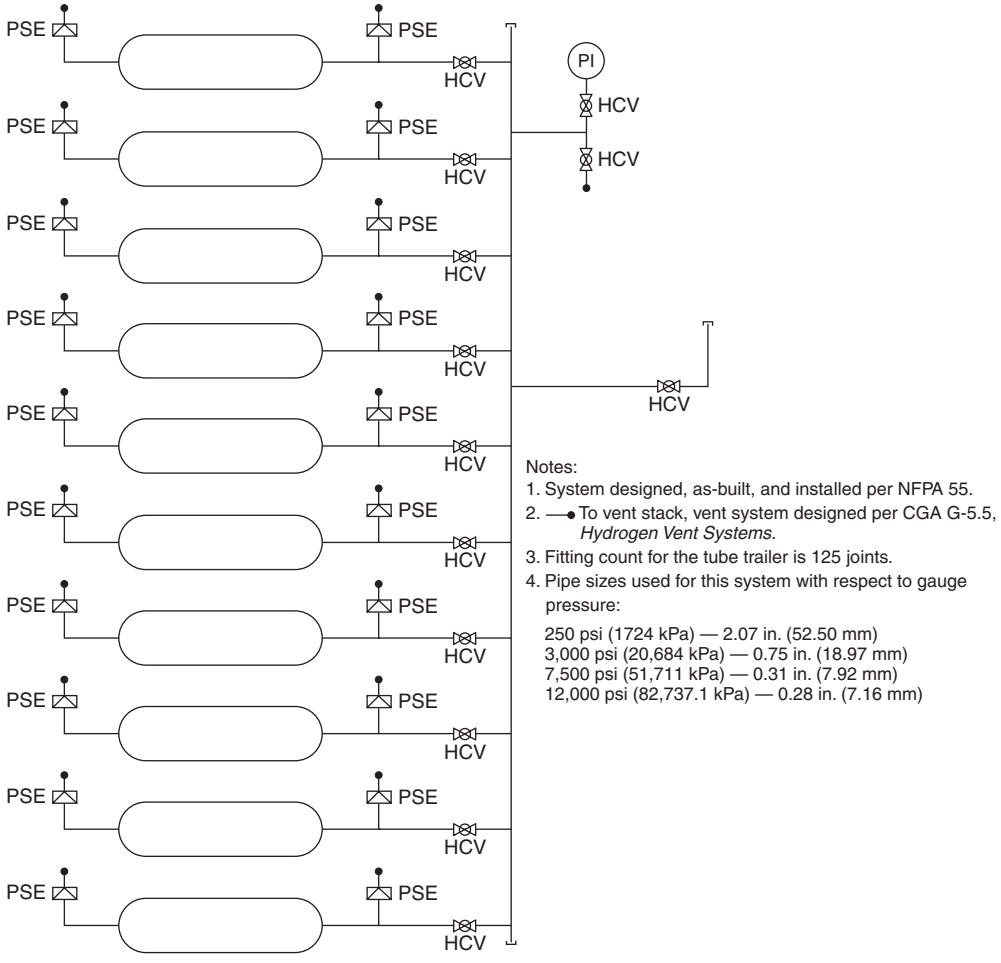


FIGURE A.3.3.93.2(b) Typical Tube Trailer.

A.3.3.93.3 Bulk Inert 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. The containers are either stationary or movable, and the source gas is stored as a compressed gas or cryogenic fluid.

Bulk inert gas systems can be used to supply gas in either its compressed gaseous or liquefied form. Systems that may be used to supply both gaseous and liquid forms are referred to as hybrid systems. The following bulk inert gas systems are typical of those in use:

When the primary supply of the gas as stored is from a compressed gaseous source that is used in the compressed and gaseous form, the bulk inert gas system is said to be a bulk inert compressed gas system.

When the primary supply of the gas as stored is in a liquid form and the system is designed to transfer only liquid, the system is said to be a bulk liquefied inert gas system.

When the primary supply of the gas as stored is in a liquid form and the system is designed to transfer or store the gas in a compressed gaseous form, with or without a feature that may also allow the subsequent transfer and use of liquid, the bulk inert gas system is said to be a hybrid bulk inert gas system.

For the purposes of the application of the code, a hybrid system is viewed as a bulk liquefied inert gas system.

A.3.3.93.4 Bulk Liquefied Hydrogen 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.

A bulk liquefied hydrogen 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 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.

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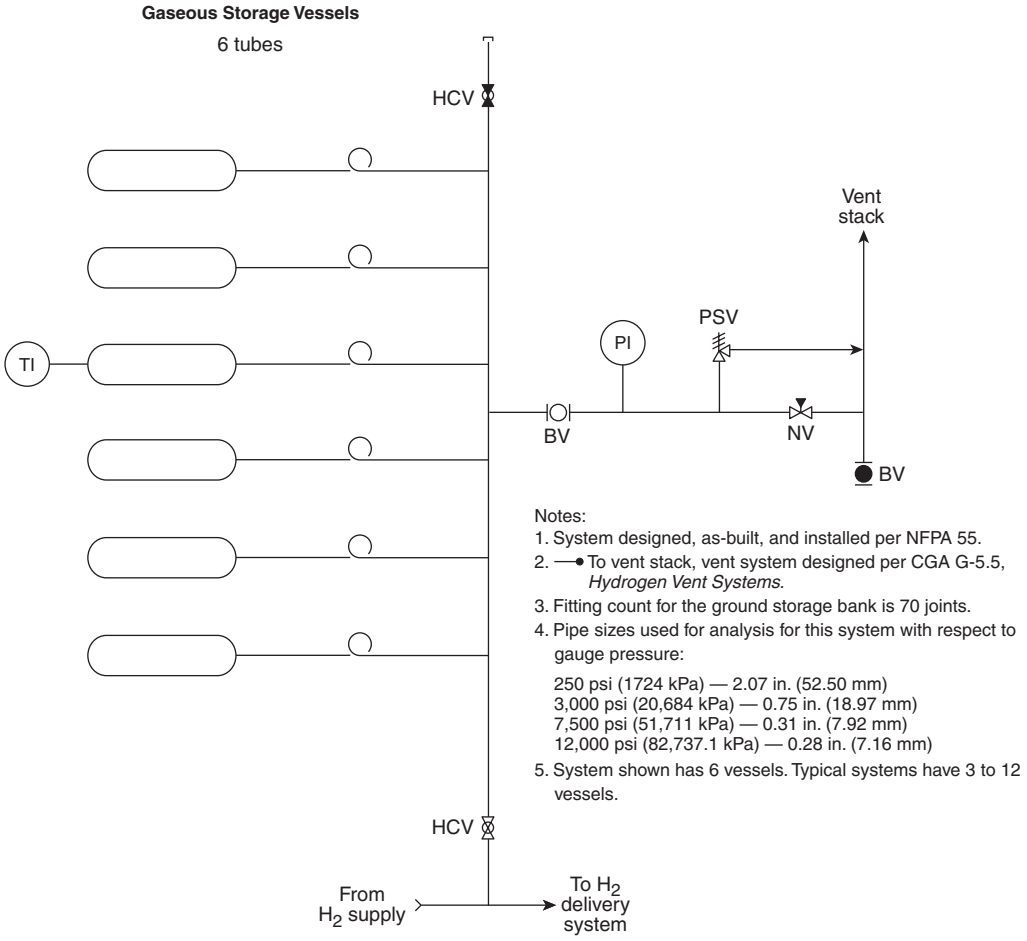


FIGURE A.3.3.93.2(c) Typical Bulk Compressed Gaseous Storage System.

A.3.3.93.5 Compressed Gas System. A compressed gas system can consist of a compressed gas container or containers, reactors, and appurtenances, including pumps, compressors, and connecting piping and tubing.

A.3.3.93.9 Fast-Acting Fire Detection System. Examples for outdoor installations are optical (UV/IR) systems that detect visible flames and do not rely on products of combustion to be transported by the energy of the heat plume to the location of the detector. For indoor installations, examples include high sensitivity smoke detection (HSSD), optical (UV/IR), or other early detection systems.

A.3.3.93.10 Gaseous Hydrogen System. The system includes stationary or portable containers, pressure regulators, pressure-relief devices, manifolds, interconnecting piping, and controls as required.

A.3.3.94.1 Portable Tank. A portable tank does not include any cylinder having less than 1000 lb (453.5 kg) water capacity, cargo tank, tank car tank, or trailers carrying cylinders of over 1000 lb (453.5 kg) water capacity.

A.3.3.94.2 Stationary Tank. A stationary tank does not include a cylinder having less than 1000 lb (453.5 kg) water capacity.

A.3.3.96 Tube Trailer. The characteristic internal water volume of individual tubular cylinders ranges from 43 scf to 93 scf (1218 L to 2632 L) or a water capacity of 2686 lb to 5803 lb (1218 kg to 2632 kg).

A.4.4 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 that the system is removed.

A.4.6.4 There might be additional regulations that must be complied with to notify other agencies. [**400:** A.6.1.3.4]

A.4.7 The hazard potential of a facility is not dependent on any single factor. Physical size, number of employees, and the quantity and the nature of the hazardous materials are important considerations. The level of training can vary with the complexity of the facility under consideration. [**400:** A.6.1.4]

A.4.7.4 Emergency responders can include on-site personnel that have been designated and trained to respond to emergencies, persons from the public sector such as fire

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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)

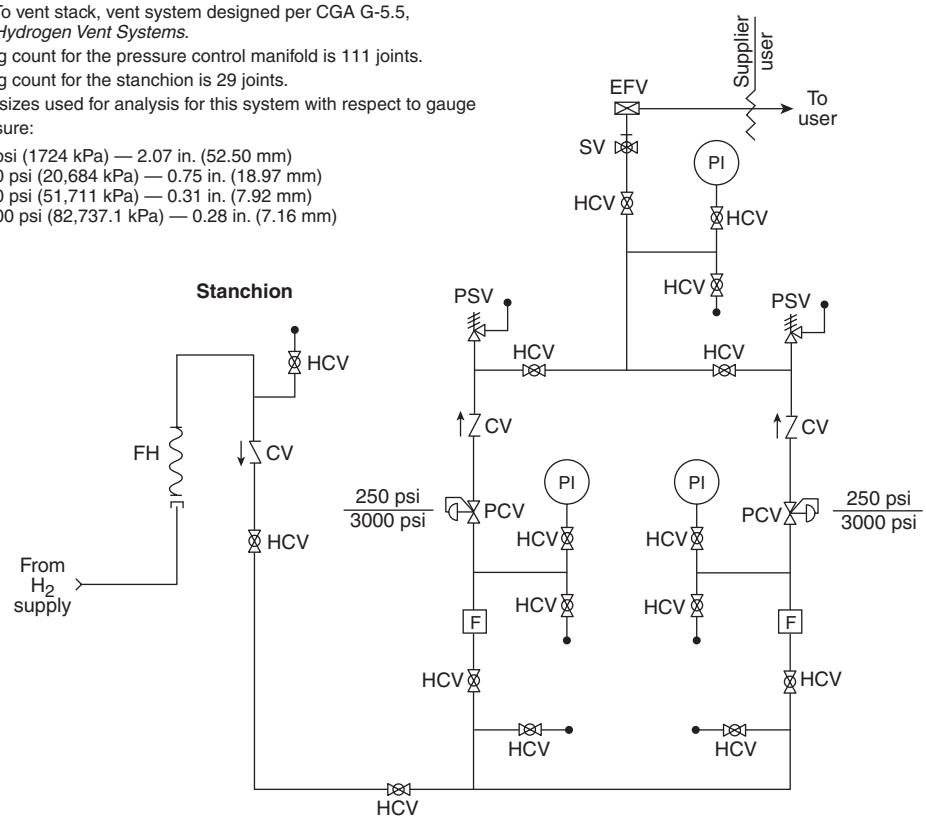


FIGURE A.3.3.93.2(d) Typical Tube Trailer Discharge Stanchion and Pressure Control Manifold.

department personnel, or persons from the private sector that can be contracted or otherwise engaged to perform emergency response duties. (See Annex I in NFPA 400 for additional information.) [**400:**6.1.4.4]

A.4.7.4.1 OSHA describes an Incident Command System as a standardized on-scene incident management concept designed specifically to allow responders to adopt an integrated organizational structure equal to the complexity and demands of any single incident or multiple incidents without being hindered by jurisdictional boundaries. [**400:** A.6.1.4.4.1]

A.4.7.4.2 Responses to releases of hazardous materials where there is no potential safety or health hazard such as fire, explosion, or chemical exposure are not considered emergency responses as defined within the context of this code. [**400:** A.6.1.4.4.2]

A.4.7.4.3 Emergency response training will vary depending on the level of emergency response required and by the requirements of the governmental agency. [**400:** A.6.1.4.4.3]

A.4.9.3.1 The approved powered industrial trucks addressed in NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*, are trucks that are listed by a testing laboratory for the use intended and should be tested and labeled in accordance with ANSI/UL 558, *Standard for Safety Industrial Trucks, Internal Combustion Engine–Powered* or ANSI/UL 583, *Standard for Safety Electric-Battery-Powered Industrial Trucks.* [**400:** A.6.1.5.3.1]

A.4.12 The term *materials* used throughout this section applies to building construction materials and not to hazardous materials, compressed gases, or cryogenic fluids.

A.4.12.1 The provisions of 4.12.1 do not require inherently noncombustible materials to be tested in order to be classified as noncombustible materials. [***101*:** A.4.6.13]

A.4.12.1(1) Examples of such materials include steel, concrete, masonry, and glass. [***101*:** A.4.6.14.1(1)]

A.4.12.2 Materials subject to increase in combustibility or flame spread index beyond the limits herein established through the effects of age, moisture, or other atmospheric condition are considered combustible. *(See* NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, and NFPA 220, *Standard on Types of Building Construction.)* [***101*:** A.4.6.15.2]

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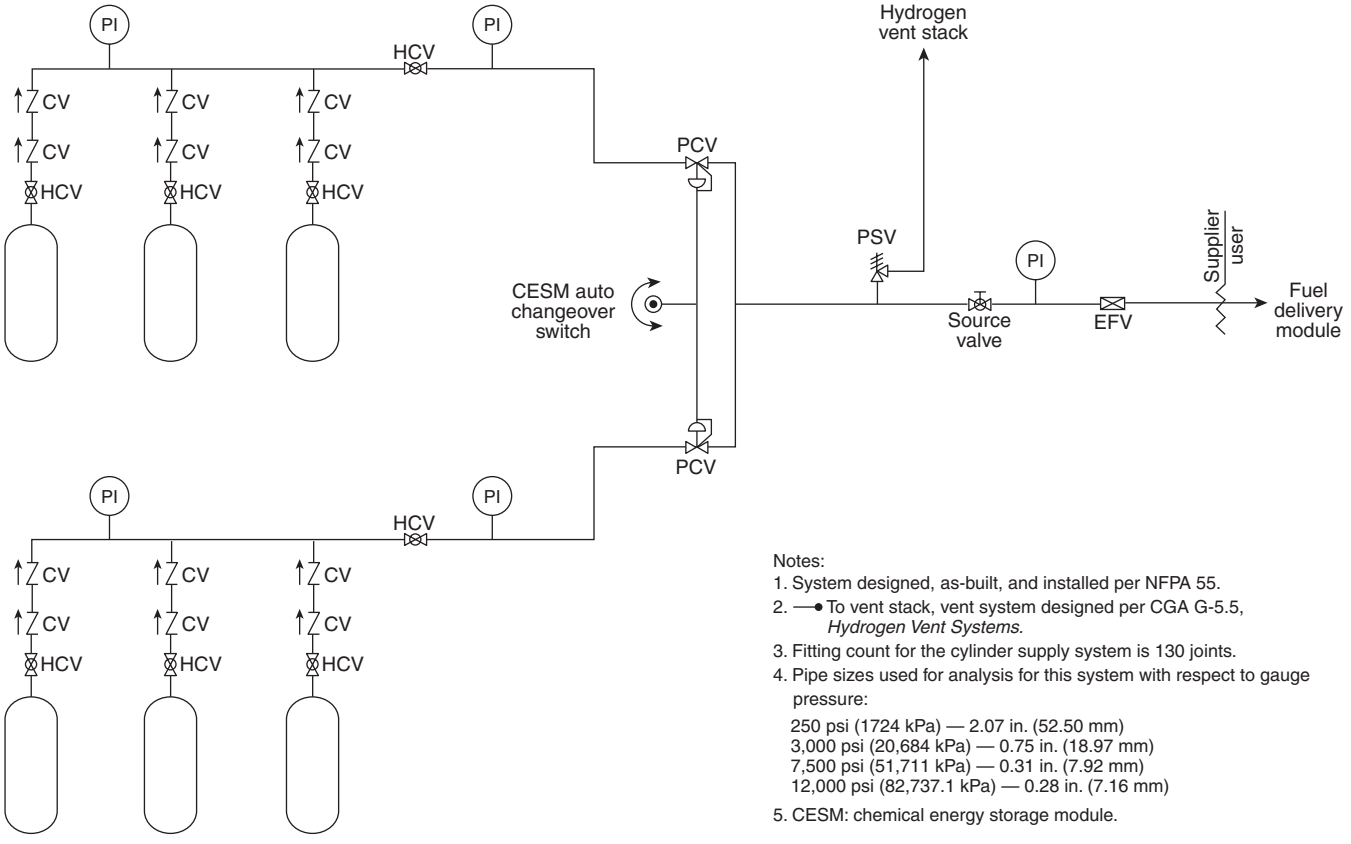


FIGURE A.3.3.93.2(e) Typical Chemical Energy Storage Module (CESM).

A.5.1.1 Not all hazardous materials are placed into the high hazard category, and some of these materials have been recognized as being of low ordinary hazard, depending on their nature in a fire. Inert compressed gases and cryogenic fluids are one example; there are others. Compressed gases and cryogenic fluids represent the gas phase of an array of hazardous materials. As the genre of hazardous materials is expanded, there are other materials in hazard categories or hazard classes that may in fact be high hazard materials by definition, but which in some cases do not have a MAQ and, therefore, are not required to comply with the requirements for high hazard occupancies. Examples of such materials are Class IIIB combustible liquids, Class 1 unstable reactive materials (including gases), Class 1 water-reactive solids and liquids, Class 1-3 water-reactive gases, Class 1 oxidizing solids and liquids, and Class IV and V organic peroxides.

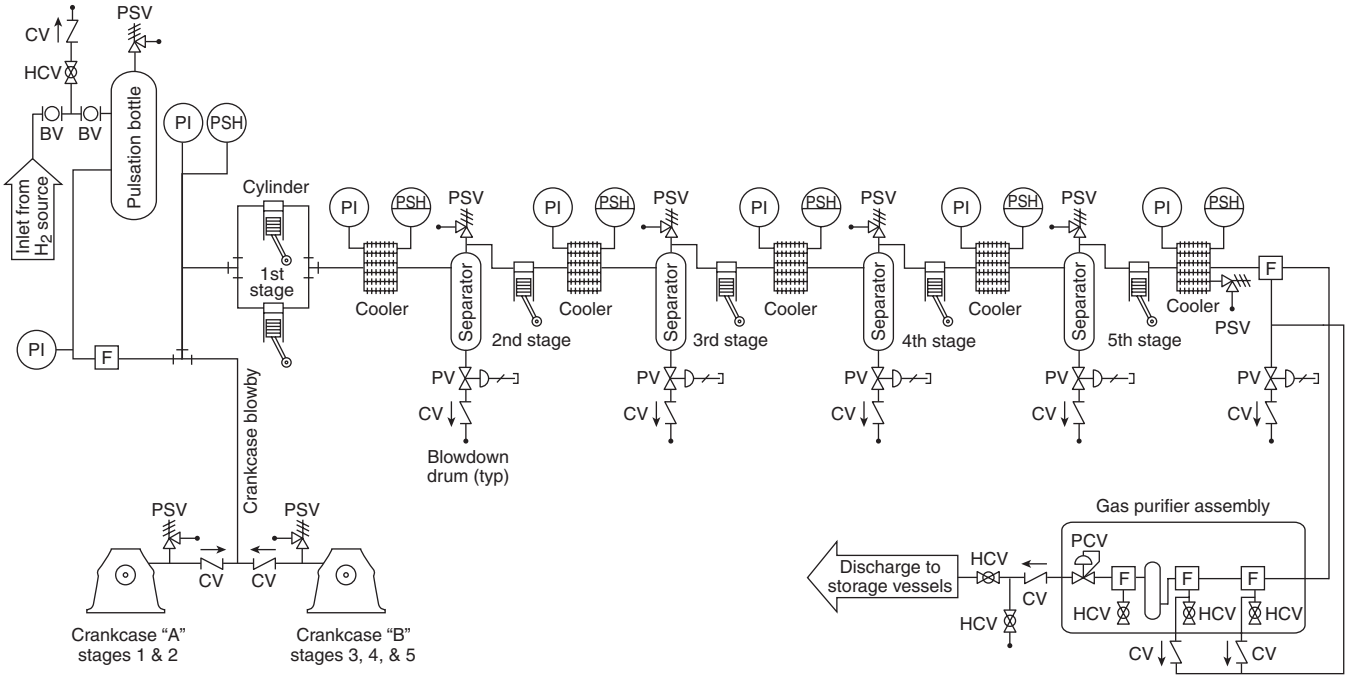
A.6.5 Bulk hydrogen compressed gas systems terminate at the source valve. In cylinder filling or packaging operations, cylinders located on filling manifolds located downstream of the source valve are not considered to be part of the bulk gas system. For definitions of source valve and bulk hydrogen compressed gas system, see 3.3.88 and 3.3.93.2. Additional requirements for source valves can be found in Section 6.19.

A.6.7 Electrical and electronic equipment and wiring for use in hazardous locations as defined in Article 500 of *NFPA 70*, *National Electrical Code*, should meet the requirements of Articles 500 and 501 of *NFPA 70*. Note that Article 505 also details requirements for this equipment and wiring in hazardous locations and uses a zone classification method rather than the division method of Article 500.

A.6.8 Under the requirements of 29 CFR 1910.38 established by OSHA regulations, employers must establish an employee alarm system that complies with 29 CFR 1910.165. The requirements of 29 CFR 1910.165 for the employee alarm system include, but are not limited to, systems that are capable of being perceived above ambient noise or light levels by all employees in the affected portions of the workplace. Tactile devices may be used to alert those employees who would not otherwise be able to recognize the audible or visual alarm. The alarm system can be electrically powered or powered by pneumatic or other means. State, local, or other governmental regulations might also establish requirements for employee alarm systems.

A.6.10 The intent of this section is to require a water-based fire extinguishing system to keep vessels containing compressed gases cool in the event of an exposure fire, thereby minimizing the likelihood of a release and associated consequences. Accordingly, alternative fire extinguishing systems, such as dry-chemical or gaseous agent systems, should not be substituted.

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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.3.3.93.2(f) Typical Compressor Module.

A.6.19 Figure A.6.19 shows three possible locations of the source valve.

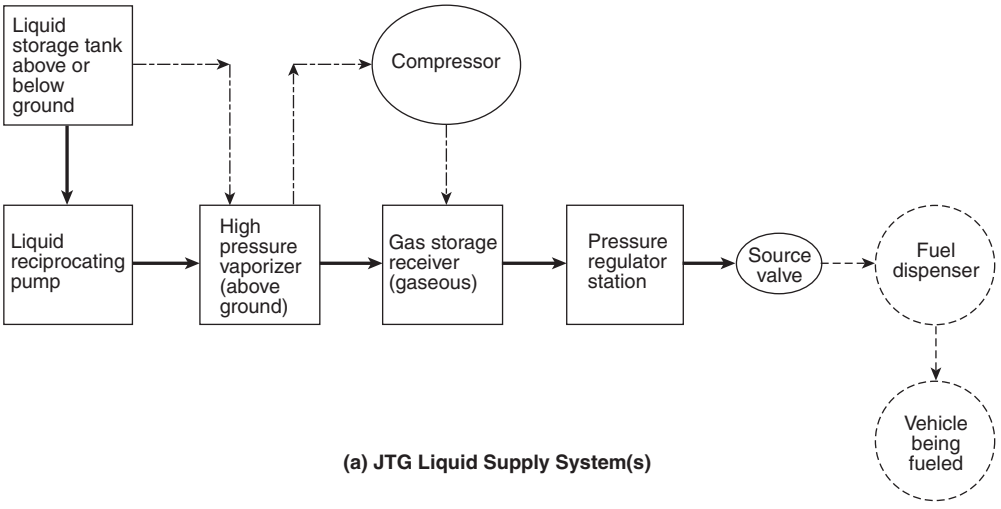
A.7.1.3 For information on insulated nitrous oxide systems, see CGA G-8.1, *Standard for Nitrous Oxide Systems at Consumer Sites.*

A.7.1.4 The compressed gas system equipment referenced is intended to include fuel cell applications, generation of hydrogen from portable or transportable hydrogen generation equipment, batteries, and similar devices and equipment that utilize hydrogen for the purpose of power generation. It does not include hydrogen production facilities intended to produce hydrogen used for distribution or repackaging operations operated by gas producers, distributors, and repackagers.

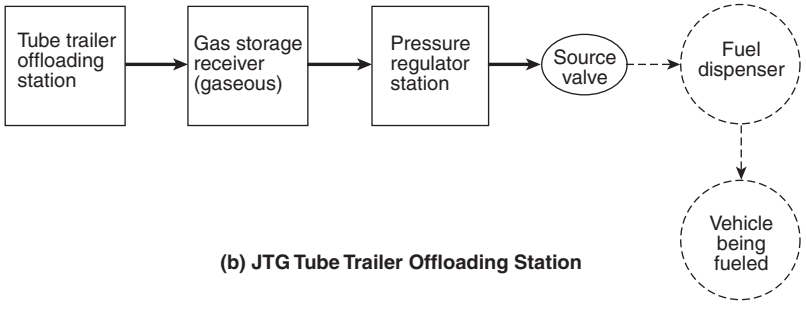
A.7.1.5 Numerous metal hydrides are currently being tested for gaseous hydrogen storage applications. While certain Class D extinguishing agents have been effective on some metal hydride materials, they have not been tested on the wide range of hydrides. It is crucial to understand any adverse chemical reactions between the hydride and the agent prior to using the fire suppressant. Additionally, it is important to understand that the application should be limited to small incipient stage fires. Larger fires would require the use of personal protective equipment in the application of the extinguishing agent.

A.7.1.9.2 The goal of this requirement is to prevent unauthorized personnel or those unfamiliar with gas storage systems from tampering with the equipment as well as to prevent the inadvertent or unauthorized removal or use of compressed gases from storage areas. Where the compressed gases are located in an area open to the general public, a common practice is to fence and lock the storage or use area, with access restricted to supplier and user personnel. When the storage or use area is located within the user's secure area and is not accessible by the general public, it is not always necessary to fence or otherwise secure the individual gas storage or use areas. Personnel access patterns may still mandate that the system be fenced, as determined by the supplier and the user.

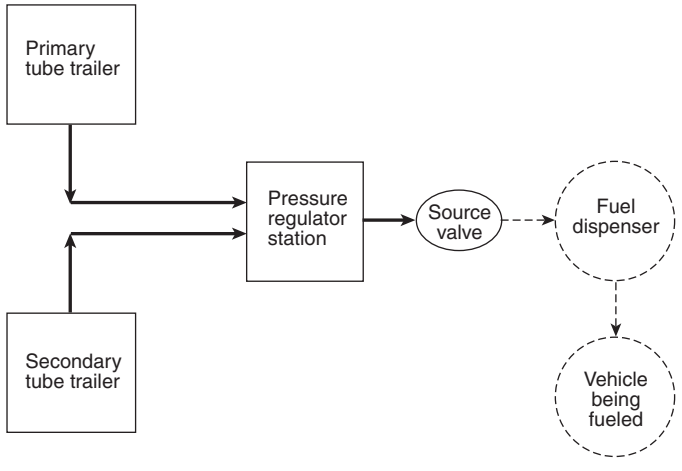
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(a) JTG Liquid Supply System(s)



(b) JTG Tube Trailer Offloading Station



(c) JTG Tube Trailer Supply System

Piping within the scope of NFPA 55
Piping within the scope of NFPA 52
Optional piping within the scope of NFPA 55

FIGURE A.6.19 Three Examples of Source Valve Locations.

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A.7.1.11.2 Figure A.7.1.11.2 is a schematic showing the separation distances required by 7.1.11.2.

A.7.1.11.2.5 Analysis of gas mixtures often includes the analysis of individual cylinders that have been disconnected from the filling manifolds. The analysis procedure is a production step where cylinders of many different types and contents are processed. It is not unusual for an individual gas mixture to contain gases otherwise deemed to be incompatible in the pure state. For example, a mixture of hydrogen and air is routinely manufactured for use as a calibrating gas mixture used to validate the operation of flammable gas detection systems. Analytical operations involving incompatible gases, which may be located within an individual laboratory, typically require that the gases being analyzed be connected to individual work stations or analytical instruments as the process is conducted. The typical analytical process is an attended process where technicians have "hands on" control of the cylinder under examination, which serves to mitigate events that may otherwise occur in unattended operations, including storage or the use of an unattended source of supply.

A.7.1.11.3 Clearance is required from combustible materials to minimize the effects of exposure fires to the materials stored or used. The requirement to separate the materials from vegetation should not be interpreted to mean that the area is maintained free of all vegetation. In some settings, gas systems are located on grounds that are maintained with formal landscaping. Some judgment must be exercised to determine whether the vegetation poses what might be viewed as an exposure hazard to the materials stored. Cut lawns, formal landscaping, and similar vegetation do not ordinarily present a hazard and should be allowed. On the other hand, tall, dry grass or weeds and vegetation that fringes on the border of an urban–wildland interface might be viewed as a hazard.

A.7.1.11.10.1 Electrical devices can include pressure transducers, signal transmitters, shutoff controls, and similar devices. Some of these devices may be nonincendive and suitable for use in hazardous areas. Flammability of gases is not the only concern with respect to electrical circuits, because piping serving systems in use can act as conductors of electrical energy, exposing unrelated portions of the system to electrical hazards if improperly installed.

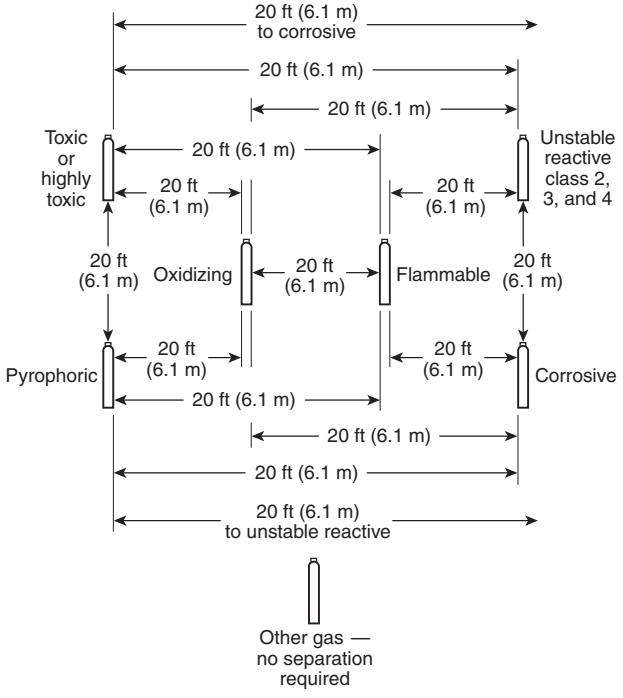


FIGURE A.7.1.11.2 Separation of Gas Cylinders by Hazard.

A.7.1.15.3 The gas supplier should be consulted for advice under these circumstances.

A.7.1.18.1.2 Underground piping systems are those systems that are buried and in contact with earth fill or similar materials. Piping located in open-top or grated-top trenches is not considered to be underground although it may be below grade.

A.7.3.1.11.1.1 In operations where an automatic emergency shutoff valve is activated by a control system that is operated from a remote station or by remote station software, the software system should be designed to provide a visual indication of the emergency shutdown control system. The visual emergency shutdown function should be able to be identified by trained operators and recognizable to emergency response personnel.

A.7.3.1.12.1 An approved means of leak detection and emergency shutoff is one way of meeting the requirements for excess flow control.

Bulk cryogenic fluids are not subject to the requirements for excess flow control based on a health hazard ranking due to cold temperature when installed in accordance with the requirements of Chapters 8 or 9. Bulk cryogenic fluids that are vaporized and distributed as a compressed gas downstream of the source valve are subject to the requirements for excess flow control if the gas has either a health hazard rating of Class 3 or 4 based on corrosivity or toxicity, a flammability hazard ranking of Class 4, or a reactivity ranking of Class 3 or 4.

A.7.3.1.12.1.2 When distributed systems are employed, the excess flow control system located at the bulk source may be sized to operate at a release rate greater than any single point of use or branch connection. Additional points of excess flow control may be required throughout the system in order to provide shutdown in the event of a failure in any single system branch. Such systems will generally be designed to operate when flow exceeds the capacity of the point(s) of use served.

A.7.5.2.1.1 Portions of the system upstream of the source valve include the containers or bulk supply as well as control equipment designed to control the flow of gas into a piping system. The piping system downstream of the source valve is protected by excess flow control should failure occur in the piping system and is not required to be protected by the fire barrier. The fire barrier serves to protect those portions of the system that are the most vulnerable along with the necessary controls used to operate the system.

A.7.6.2.1.1 See A.7.5.2.1.1.

A.7.7.2.1.1 See A.7.5.2.1.1.

A.7.8.3.1.1 See A.7.5.2.1.1.

A.7.9.2.2.1.1 See A.7.5.2.1.1.

A.7.9.3.6 The areas for typical restricted flow orifices are shown in Table A.7.9.3.6.

A.7.9.3.6.2 The formula has been taken from industry publications, including the Scott Specialty Gases *Design and Safety Handbook*. It is based on estimated flow rates for air at 70°F (21°C) discharging to normal atmospheric pressure through an average shape and quality orifice. It can be assumed to be ±15 percent accurate. Correction factors have been built into the formula as presented in 7.9.3.6.2 to accommodate the use of gases other than air (e.g., use of specific gravity data).

A.7.10.1.2.1 See A.7.5.2.1.1.

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Table A.7.9.3.6 Typical Orifice Areas

Orifice Diameter		Area	
in.	cm	$in.^2$	cm^2
0.006	0.015	2.83×10^{-5}	1.83×10^{-4}
0.010	0.025	7.85×10^{-5}	5.06×10^{-4}
0.014	0.036	1.54×10^{-4}	9.93×10^{-4}

A.7.10.2.2.1 See A.7.5.2.1.1.

A.8.2 Pressure vessels of any type can be subject to additional regulations imposed by various states or other legal jurisdictions. Users should be aware that compliance with DOT or ASME requirements might not satisfy all the required regulations for the location in which the vessel is to be installed or used.

A.8.2.3.3 Vaporizers or heat exchangers used to vaporize cryogenic fluids can accumulate a large load of ice during operation. Additional requirements to be considered in the design include snow load for the area where the installation is located as well as the requirements for seismic conditions. The operating conditions of systems vary, and the designer has a responsibility to consider all the loads that might be imposed. Foundations that could be used to support delivery vehicles as well might require special consideration relevant to live loads as well as for the dead loads imposed by the equipment itself.

A.8.2.4.5.1 Pressure relief valves typically are spring-loaded valves where the relief pressure is set by adjustment of a spring. Valves should be made to be tamper resistant in order to prevent adjustment by other than authorized personnel typically found at a retest facility. An ASME pressure relief valve is designed to comply with the requirements of the ASME *Boiler and Pressure Vessel Code* and typically is equipped with a wire and lead seal to resist tampering.

A.8.4.1.1.2 An example of this identification is 360 degree wraparound tape.

A.8.6.2 The purpose of this requirement is to prevent unauthorized personnel or those unfamiliar with cryogenic storage systems from tampering with the equipment. Where the bulk storage system is located in an area open to the general public, a common practice is to fence the system and lock it, with access restricted to supplier personnel and sometimes user personnel. When the bulk storage system is located within the user's secure area and is not open to the general public, it is not always necessary to fence the bulk storage system. Personnel access patterns may still mandate that the system be fenced, as determined by the supplier and the user.

A.8.7.2 It is not uncommon to have inert cryogenic fluids used to provide stage effects for theatrical performances that are conducted within assembly occupancies. The fluids are sometimes placed within these occupancies with special controls, including ventilation systems, fire detection systems, monitors for oxygen deficiency, warning signs, and remote fill indicating devices that indicate tank volume when a remote filling point is provided and stationary tanks are involved. Such installations are normally permitted on a case-by-case basis under the requirements of Section 1.5.

Clearance is required from combustible materials to minimize the effects of exposure fires to the materials stored or used. The requirement to separate the materials from vegetation should not be interpreted to mean that the area is maintained free of all vegetation. In some settings, gas systems are located on grounds that are maintained with formal landscaping. Some judgment must be exercised to determine whether the vegetation poses what might be viewed as an exposure hazard to the materials stored. Cut lawns, formal landscaping, and similar vegetation do not ordinarily present a hazard, and should be allowed. On the other hand, tall, dry grass or weeds and vegetation that fringes on the border of an urban–wildland interface might be viewed as a hazard.

A.8.7.2.1.4.1 See Figure A.8.13.2.7.2.1, which addresses bulk cryogenic systems located in a courtyard. This figure also applies to the case where any or all of the three walls are constructed as fire barrier walls.

A.8.13.2.5 Flood hazard areas typically are identified on either (1) the special flood hazard area shown on the flood insurance rate map or (2) the area subject to flooding during the design flood and shown on a jurisdiction's flood hazard map or otherwise legally designated.

A.8.13.2.6.4.1 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. Cryogenic fluids 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*) 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 cryogenic fluid 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 cryogenic fluids and their ability to quickly absorb heat from the surrounding environment.

A.8.13.2.7.2 The placement of stationary containers is limited with respect to exposure hazards. Table 8.7.2 establishes the minimum separation distance between a building and any stationary tank at 1 ft (0.3 m). Additional limitations are placed on wall openings, air intakes, and other exposures. The material-specific tables for liquid hydrogen and liquid oxygen specify increased distances according to the type of construction adjacent to the tank. A problem arises when courtyards are configured so as to interrupt the free movement of air around a tank where an asphyxiation hazard, a flammable hazard, or an oxygen-enriched environment can be created.

Placement of stationary containers proximate to the wall of the building served is allowable, provided the minimum separation distances for exposure hazards are met. When additional walls encroach on the installation to form a court, the focus of concern shifts away from the exposure hazards associated with the building itself to the hazards associated with personnel due to hazardous atmospheres that can be created due to the lack of free air movement and ventilation.

By specifying the minimum distance between the tank and the encroaching walls that form the court, the circulation of adequate air is ensured. Placing the tank at not less than the height of two of the three encroaching walls results in creating an opening such that the angular dimension between the top of two of the three encroaching walls and the point over which the tank is placed is not greater than 45 degrees, thereby allowing the circulation of air through the space in which the tank is installed.

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A.8.13.2.7.2.1 The separation distances shown in Figure A.8.13.2.7.2.1 are required to provide for ventilation in the space in order to avoid creating a confined space. Chapter 8 is a generic chapter used to establish minimum requirements for all cryogens. Material-specific requirements for oxygen, hydrogen, or other gases might require greater separation distances based on the type of construction or the related exposure. For example, wall number 3 shown in Figure A.8.13.2.7.2.1 could be an exterior building wall, and the gas could be hydrogen. Refer to Table 8.7.2, Table 9.3.2, and Table 11.3.2.2 for specific details regarding building walls, wall openings, air intakes, and similar conditions.

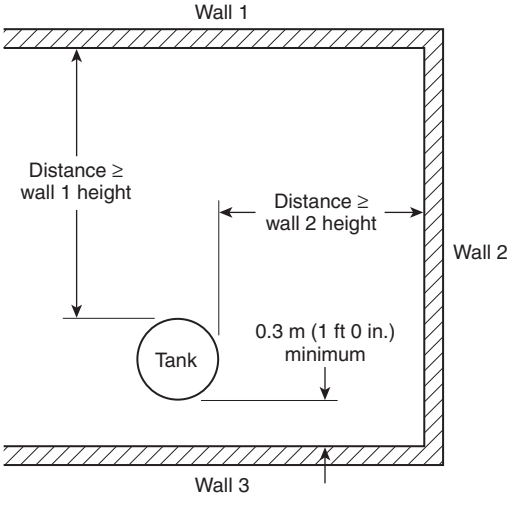


FIGURE A.8.13.2.7.2.1 Bulk Cryogenic System Located in a Courtyard.

A.8.14.1.3.1.1 CGA P-18, *Standard for Bulk Inert Gas Systems at Consumer Sites*, recommends periodic inspection intervals for inert gas systems.

A.8.14.11.2.3.1 In operations where an automatic emergency shutoff valve is activated by a control system that is operated from a remote station or by remote station software, the software system should be designed to provide a visual indication of the emergency shutdown control system. The visual emergency shutdown function should be able to be identified by trained operators and recognizable to emergency response personnel.

A.8.14.11.3.4 The inert cryogens, nitrogen and argon, do not require the installation of a noncombustible spill pad, because they do not typically condense oxygen from the air in sufficient quantities to pose a hazard during transfer.

A.8.14.11.3.4.1 The noncombustible spill pad is provided for liquid helium transfer operations, because the cryogen is at a temperature that is sufficiently low enough to liquefy oxygen, presenting a hazard when in contact with combustible surfaces.

A.9.1 Oxygen gas is colorless, odorless, tasteless, and nontoxic. It comprises about 21 percent of atmospheric air and is about 10 percent heavier than air. At atmospheric pressure and temperatures below –297°F (–182.5°C), oxygen is a liquid. Oxygen is stable in both gas and liquid phases. In the absence of moisture, oxygen in the gaseous or liquid form is noncorrosive.

Oxygen is nonflammable. Ignition of combustible materials occurs more readily in an oxygen-rich atmosphere than in air, and combustion proceeds at a more rapid rate, although no more total heat is released. This code provides for the protection of the bulk oxygen system from involvement by fire from sources apart from the system itself. It is important to locate bulk oxygen systems in well-ventilated locations, since oxygen-rich atmospheres are able to collect temporarily in confined areas in the event of functioning of a pressure relief device or leakage from the system.

A.9.1.1.1 For information on oxygen systems having capacities less than those stated in 3.3.15, see NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes*, and NFPA 99, *Health Care Facilities Code* (Chapters 4 and 8).

A.9.2.1 Compatibility involves both combustibility and ease of ignition. Materials that burn in air will burn violently in pure oxygen at atmospheric pressure and will burn explosively in pressurized oxygen. Also, a number of materials that do not burn in air will do so in pure oxygen or oxygen-enriched atmospheres, particularly under pressure. Metals for containers and piping must be selected carefully, depending on service conditions. Various steels can be used for a number of applications, but some service conditions can call for other materials (typically copper or its alloys) because of their greater resistance to ignition and lower rate of combustion. Data regarding the combustibility and ease of ignition of materials are available in NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*.

Materials that can be ignited in air have lower ignition energies in oxygen. A number of such materials can be ignited by friction at a valve seat or stem packing or by adiabatic compression produced when oxygen at high pressure is rapidly introduced into a system initially at low pressure. Other recognized ignition mechanisms include particle impact, mass impact, static electric discharge, electrical arc, fresh metal exposure, resonance, and piloted ignition.

A.9.3.2 Figure A.9.3.2 serves to illustrate the separation distances between bulk oxygen systems and exposures.

These distances do not apply where fire barriers having a minimum fire resistance rating of 2 hours interrupt the line of sight between uninsulated portions of the bulk oxygen storage installation and the exposure. The fire barriers protect uninsulated oxygen storage containers or supports, control equipment, and system piping (or parts thereof) from external fire exposure. Liquid oxygen storage containers are insulated. Such containers can provide line-of-sight protection for uninsulated system components. Interruption of the line of sight means that an "eye" on any part of the uninsulated portion of the bulk oxygen storage installation cannot "see" any part of the exposure.

A.9.3.2.1 The distances required by Table 9.3.2 can be reduced when a fire barrier wall is constructed to shield the oxygen installation from the exposure as well as to limit the exposure of sensitive receptors to the effects of an incident involving the oxygen source. In most circumstances, a fire barrier wall will be needed to allow encroachment on property lines where the adjacent property is suitable for building. The separation distances given in Table 9.3.2 assume that any structure on the adjoining property does not dictate a greater distance.

A.9.4.1.3 Some materials commonly used for low-temperature piping are austenitic chromium–nickel alloy steels, copper, copper–silicon alloys, aluminum, and some brasses and bronzes.

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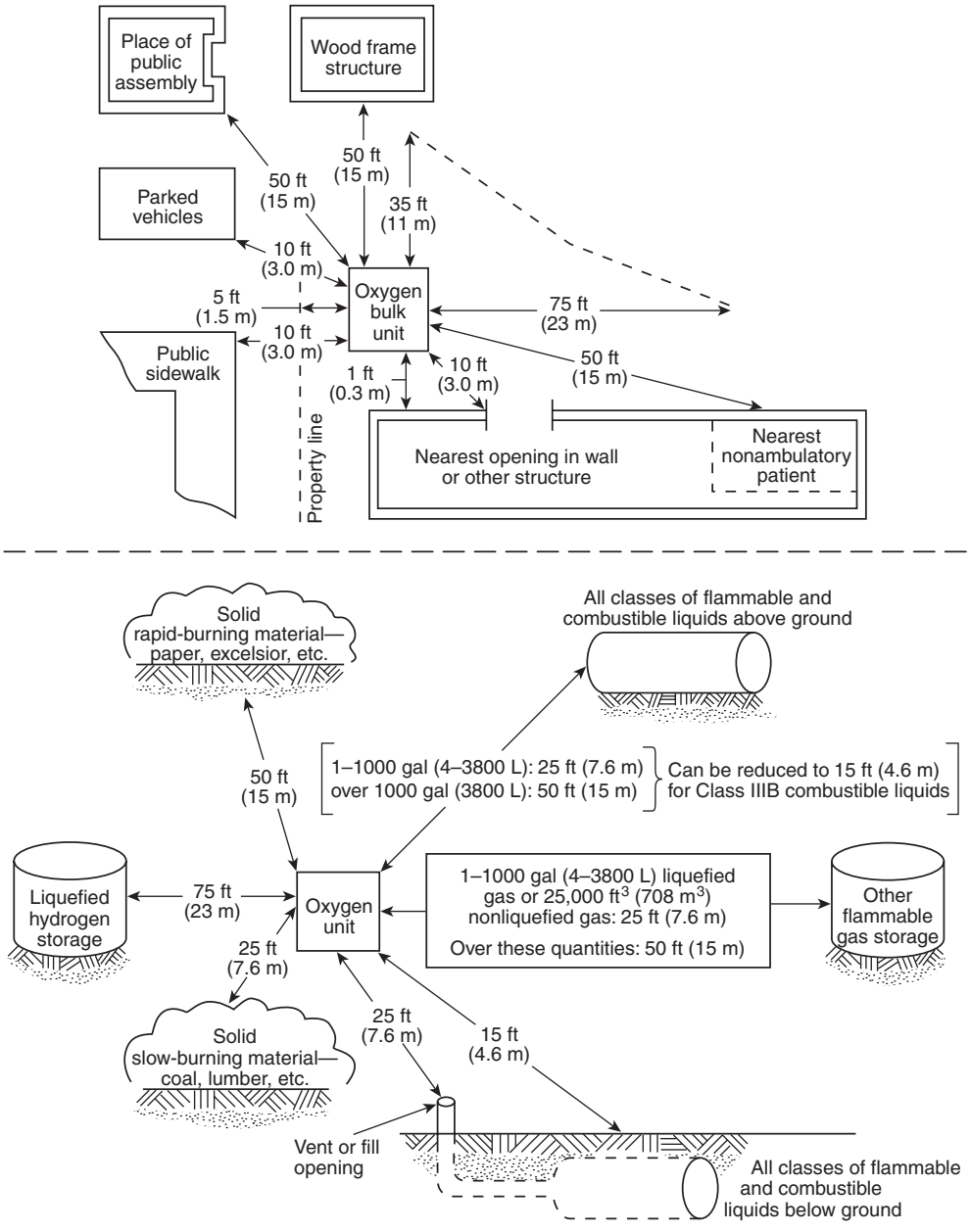


FIGURE A.9.3.2 Distances Between Bulk Oxygen Systems and Exposures.

A.9.4.5 Bulk oxygen installations are not hazardous (classified) locations as defined by *NFPA 70, National Electrical Code*. The use of general-purpose electrical wiring and equipment should be allowed unless otherwise indicated.

A.10.2.2 Any reference to listed or approved equipment in the noted sections of the IFGC is within the context of the ANSI/ASME B31.3, *Process Piping*, standard and describes a material or component that conforms to the specifications integral to ANSI/ASME B31.3.

A.10.3.2.1 The exposures integral to Table 10.3.2.1(a), Table 10.3.2.1(b), and Table 10.3.2.1(c) have been arranged into groups based on similar risks. The thresholds are applicable to the exposures identified in each group, as follows:

(1) *Group 1 Exposures.* The distances specified are those required to reduce the radiant heat flux level to 500 Btu/hr · ft^2 (1577 W/m^2) at the property line or the distance to a point in the unignited hydrogen jet where the hydrogen content is reduced to a 4 percent mole fraction (volume fraction) of hydrogen, whichever is greater. In all cases the distance required to achieve a 4 percent mole fraction was the greater distance and used to establish the requirements.

(2) *Group 2 Exposures.* The distances specified are those required to reduce the radiant heat flux level to 1500 Btu/hr · ft^2 (4732 W/m^2) for persons exposed a maximum of 3 minutes.

(3) *Group 3 Exposures.* The distances specified are those required to reduce the radiant heat flux level to 6340 Btu/hr · ft^2 (20,000 W/m^2) or the visible flame length for combustible

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materials, or a radiant heat flux level of 8000 Btu/hr · ft^2 (25,237 W/m^2) or the visible flame length for noncombustible equipment. In both cases the visible flame length was used to establish the requirements.

Table 10.3.2.1(a) Exposures Group 1 (a). Lot lines (property lines) are those property lines between parcels and should not be construed to be the imaginary property lines that are drawn for the purposes of protecting the exterior walls of multiple buildings placed on the same lot or parcel. Railroad easements that are not accessible to the public other than by rail travel can be used as a means of spatial separation, with the required separation being measured between the hydrogen system and the nearest railroad track. It should be noted that in these cases, the addition or relocation of track may result in an encroachment that will necessitate relocation of the hydrogen system at the system user's expense.

Where the property on the other side of a property line is determined to be unbuildable or unoccupiable due to natural features including, but not limited to, waterways, terrain, wetlands, or similar features encroachment by the hydrogen system on the property line can be acceptable with the approval of the authority having jurisdiction. Should the property that is encroached upon become buildable or otherwise occupiable, the hydrogen system location should be reevaluated by the system user and the AHJ notified of the results.

Table 10.3.2.1(a) Exposure Group 2(a). The exposed persons of concern are non-work-related persons or members of the public who are not involved with servicing the system, because these persons typically are neither trained nor knowledgeable in the operation of the system, but are on the premises. By comparison, service personnel or those involved with servicing the system are trained and engaged in activities related to the system operation including, but not limited to, inspecting, monitoring system inventory, delivering product, maintenance, or similar functions. Administrative controls, engineering controls, or construction features are typically used to restrict persons other than service personnel from being within the zone of potential exposure. The permit holder is responsible for managing and administering the controls to restrict access. Examples of such controls could include painted lines or signs or physical barriers such as a fence.

A.10.3.2.2.1 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 5000 scf (141.6 Nm^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 5000 scf (141.6 Nm^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 5000 scf (141.6 Nm^3). 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 piping and instrumentation drawings (P&IDs) shown in Figure A.3.3.93.2(a) through Figure A.3.3.93.2(f) for additional information in this regard.

The use of Table 10.3.2.1(b) and Table 10.3.2.1(c) 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.

A.10.3.2.3 The methodology used to determine the distances listed in Table 10.3.2.1(b) and Table 10.3.2.1(c) has been evaluated for piping up to and including internal diameters of approximately 3 in. (76 mm). The establishment of risk-informed separation distances for piping systems with greater internal diameters are subject to a hazard analysis that demonstrates an equivalent level of risk under the provisions of Section 1.5.

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 5000 scf (141.6 Nm^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 psig (20,684 kPa) storage system that supplies a 6000 psig (41,369 kPa) compressor that directly feeds a process with less than 5000 scf (141.6 Nm^3) of intervening storage at a pressure of 6000 psig (41,369 kPa) or less is considered a 3000 psig (20,684 kPa) system.

A.10.3.2.4 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. Distances to assumed lot lines can be disregarded in the application of Table 10.3.2.1(a), Table 10.3.2.1(b), and Table 10.3.2.1(c). The lot lines described under item (a) of Group 1 Exposures in Table 10.3.2.1(a) 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.

A.10.3.2.4.1 As stated by Sandia National Laboratories researchers Houf, Schefer, and Evans in "Evaluation of Barrier Walls 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

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implementation. Additional analysis by Sandia (LaChance, Phillips, and Houf) in a paper titled "Risk Associated with the Use of Barriers in Hydrogen Refueling Stations" provided insights on 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

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. Although an overpressure can be expected due to latent ignition of a flammable cloud, the overpressure is expected to be limited to a localized area. Special designs for overpressure in addition to the structural loads imposed by the building code have not been required.

The function of the fire barrier wall is to protect the exposure from the system and not the converse. The code assumes that other factors will enter into locating any material or structure in proximity to the bulk hydrogen compressed gas system. For example, if a property or lot line is involved opposite the hydrogen installation, the proximity of a building to be constructed on the lot line is regulated by the building code based on the type and occupancy of structure to be constructed.

A.10.3.2.4.1(5)(a) See Figure A.8.13.2.7.2.1, which addresses bulk cryogenic systems located in a courtyard. This figure also applies to the case where any or all of the three walls are constructed as fire barrier walls, provided the distances to walls constructed as fire barrier walls for exposure protection are not less than that required by Table 10.3.2.1(a), Table 10.3.2.1(b), or Table 10.3.2.1(c).

A.10.3.2.4.2 To determine the acceptability of technologies, processes, products, facilities, materials, and uses attending the design, operation or use of such systems, the AHJ is authorized to require the owner or agent to provide, without charge to the jurisdiction, a technical opinion and report. The model fire prevention codes provide the authority for the AHJ to seek technical assistance from independent third parties with expertise in the matter to be reviewed at the submitter's expense. The AHJ is authorized to require design submittals to be prepared by, and bear the stamp of, a registered design professional or professional engineer.

Active means of control could include a means to detect leakage or fire coupled with automatic system shutdown, such as gas or flame detection. The use of gas or flame detection should consider, but is not limited to, the following:

(1) *Gas Detection.* To utilize gas detection as a means of control, the gas sensor would be placed at a point between the bulk hydrogen compressed gas system and the exposure. Gas detection systems may be limited in their ability to detect the presence of hydrogen in the open. They are most effective if the sensor is located within an enclosed space such as an equipment enclosure. If used, gas detection systems should be either listed or approved.
(2) *Flame Detection.* Flame detection systems may include combination UV/IR detection systems and be installed in accordance with the requirements of *NFPA 72, National Fire Alarm and Signaling Code.*

Ultraviolet flame detectors typically use a vacuum photodiode Geiger–Muller tube to detect the ultraviolet radiation that is produced by a flame. The photodiode allows a burst of current to flow for each ultraviolet photon that hits the active area of the tube. When the number of current bursts per unit time reaches a predetermined level, the detector initiates an alarm. [**72:** A.17.8.2]

A single wavelength infrared flame detector uses one of several different photocell types to detect the infrared emissions in a single wavelength band that are produced by a flame. These detectors generally include provisions to minimize alarms from commonly occurring infrared sources such as incandescent lighting or sunlight. An ultraviolet/infrared (UV/IR) flame detector senses ultraviolet radiation with a vacuum photodiode tube and a selected wavelength of infrared radiation with a photocell and uses the combined signal to indicate a fire. These detectors need exposure to both types of radiation before an alarm signal can be initiated. A multiple wavelength infrared (IR/IR) flame detector senses radiation at two or more narrow bands of wavelengths in the infrared spectrum. These detectors electronically compare the emissions between the bands and initiate a signal where the relationship between the two bands indicates a fire. **[72:** A.17.8.2]

A.10.4.1.1.1 Fracture mechanic methods given in recognized standards such as API RP 579, *Recommended Practice for Fitness-for-Service*, or BS 7910, *Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures*, can be used. Additional information is provided in BS 7910, *Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures.*

A.10.4.1.4 Straight threads alone are not considered to be a seal.

A.10.4.1.6.6 Buried utilities include electrical, sewer, water, gas, storm drains, and similar services. A greater distance may be required by the service provided. For example, public utility easements might dictate greater distances.

A.10.4.1.9 Flood hazard areas are typically identified on either (1) the special flood hazard area shown on the flood insurance rate map or (2) the area subject to flooding during the design flood and shown on a jurisdiction's flood hazard map, or are otherwise legally designated.

A.10.6.1.2 Hydrogen fires should not be extinguished until the supply of hydrogen has been shut off because of the danger of re-ignition or explosion. In the event of fire, large quantities of water should be sprayed on adjacent equipment to cool the equipment and prevent involvement in the fire. Combination fog and solid stream nozzles are preferred, to permit widest adaptability in fire control. Small hydrogen fires can be extinguished with dry chemical extinguishers or with carbon dioxide, nitrogen, and steam. Re-ignition can occur if a heated surface adjacent to the flame is not cooled with water or other means.

A.10.6.2.3 For guidance in these construction techniques, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting.*

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A.11.1 For information on gaseous hydrogen systems, see Chapter 10.

A.11.2.3 Some materials acceptable for liquefied hydrogen temperature include austenitic chromium–nickel alloys, certain copper alloys, and aluminum, which retain ductility and do not become brittle at the temperature of liquefied hydrogen.

A.11.2.3.6 Like other cryogenic liquids, liquid hydrogen is susceptible to heat leak. Adding heat to the fluid reduces the net positive suction head (NPSH) to the pump and can reduce the level of sub-cooling or can cause the fluid to flash to vapor. Sub-cooled liquid is the ideal state for pumping liquid hydrogen. As the fluid saturates, the ability to pump decreases. The liquid suction and gas return piping to and from the pump typically is vacuum-jacketed piping. Vacuum-jacketed piping is most commonly used when liquid is to be transferred, because it avoids the potential condensation of air and oxygen enrichment that can occur in piping systems that are insulated with conventional materials. In some cases the liquid may be transferred using uninsulated piping systems. Such systems must be designed in a way that condensed air does not present a contact hazard to personnel or otherwise create a potential flammability hazard due to material contact and the presence of oxygen contained in the condensate.

A.11.2.5.1 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.

A.11.2.5.2 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 can 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.

A.11.2.8.5 Liquid hydrogen supply systems typically store the liquid, a cryogenic fluid, in storage tanks with maximum allowable working pressures (MAWP) that range from of 150 psig to 250 psig. The majority of tanks are limited to 150 psig MAWP. Liquid hydrogen is piped from the tank to a vaporizer that serves as a heat exchanger and to convert the fluid from the liquid to the gaseous state in order to provide a supply of gaseous hydrogen to the user. The gaseous hydrogen supply pressure for such systems is limited to a maximum pressure below that of the of the storage tank MAWP.

When gaseous or liquid hydrogen is required to be supplied at pressures higher than the storage tank MAWP, either pumps or compressors are added to the system to raise the delivered pressure. Pumps are used for delivering hydrogen in the liquid state, while compressors deliver hydrogen in the gaseous state. Additional details on system arrangement and piping systems can be found in CGA H-5, *Installation Standards for Bulk Hydrogen Supply Systems.*

A.11.3.1.2 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, because spilled material will quickly vaporize, thereby mitigating the potential exposure hazard to the other fluids.

A.11.3.2.2 The Occupational Safety and Health Administration (OSHA) established requirements for hydrogen systems in 29 CFR 1910.103. The tabular distances in Annex G reflect those values published in the July 1, 2006 edition of the CFR. The criteria established in Table G.2(a) and Table G.2(b) are based on the 1969 edition of NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 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 as the requirements for compressed gases and cryogenic fluids were broadened.

Throughout those eight revision cycles, the distances were subject to revision as the technology in the use of hydrogen advanced. However, the 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 tables might be accurate, it should be recognized that the OSHA tables in some cases lack clarity, and in other cases hazards recognized by the ongoing evolution of the separation tables have not been acknowledged.

For an example of clarity, consider row 1, "Building or structure," of Table 11.3.2.2. The OSHA table refers to buildings by construction types, including wood frame, heavy timber, ordinary, and fire resistive. The 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 the types in either NFPA 220, *Standard on Types of Building Construction*, or the building code.

Other examples where hazards are 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 table and the distance tables in the 2005 edition of NFPA 55 reveals a number of discrepancies. As the 2010 edition of NFPA 55 was being developed, a collective effort was undertaken by a joint task group established between the NFPA Industrial and Medical Gases Committee and the NFPA Hydrogen Technology Committee. The scope of the Hydrogen Technology Committee's work was to review and verify the separation distances for exposures integral to the distance tables found in NFPA 55. Research on separation distances funded by the U.S. Department of Energy (DOE) and undertaken by Sandia National Laboratories in 2007 focused on the effects of fire and potential explosion due to an inadvertent release of hydrogen. The initial work had as its focus the use of hydrogen as an alternative vehicle fuel; however, the data produced present the case for separation based on radiant heat flux from hydrogen jet flames and flammability envelopes from unintended releases of hydrogen. The work was based on modeling that was then validated against Sandia National Laboratories and SRI International experiments.

As the work continued, it became apparent to the group that a risk-informed approach to separation distance could be developed. At that juncture, the committee developed consequence-based tables for separation as well as a set of risk-informed tables.

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The consequence-based tables present the hazard without regard to probability or frequency. However, there are variables that have not previously been considered in the evolution of the tabular distances.

On the other hand, the risk-informed tables consider the cumulative frequency of accidents and the distance required to prevent an undesired consequence across a spectrum of varying pressures.

Additionally, the fundamental requirements of NFPA 55 prescribe a minimum set of engineering controls and construction features. As the work evolved, it became clear that with mitigation methodology, an unintended release could be minimized or eliminated. The developmental work was focused on using a scientific method to obtain separation distances to verify or revise the tabular distances accordingly.

The OSHA tables 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 has traditionally been the fire official who might not be the only official that exercises regulatory control for installations of this nature.

A.11.3.2.2.2 See NFPA 259, *Standard Test Method for Potential Heat of Building Materials*. Separation distances to exposures in Table 11.3.2.2 should be measured in a direct line of sight or horizontally in the shortest path along the outside of buildings. The 5 ft (1.5 m) distance in Table 11.3.2.2 facilitates maintenance and enhances ventilation.

Table 11.3.2.2 Item 1. Lot Lines. Lot lines (property lines) are those property lines between parcels and should not be construed to be the imaginary property lines that are drawn for the purposes of protecting the exterior walls of multiple buildings placed on the same lot or parcel. Railroad easements that are not accessible to the public other than by rail travel can be used as a means of spatial separation with the required separation being measured between the hydrogen system and the nearest railroad track. It should be noted that in these cases, the addition or relocation of track may result in an encroachment that will necessitate relocation of the hydrogen system at the system user's expense.

Where the property on the other side of a property line is determined to be unbuildable or unoccupiable due to natural features including, but not limited to, waterways, terrain, wetlands, or similar features encroachment by the hydrogen system on the property line can be acceptable with the approval of the authority having jurisdiction. Should the property that is encroached upon become buildable or otherwise occupiable, the hydrogen system location should be reevaluated by the system user and the AHJ notified of the results.

A.11.3.2.2.4.1 See Figure A.8.13.2.7.2.1, which addresses bulk cryogenic systems located in a courtyard. This figure also applies to the case where any or all of the three walls are constructed as fire barrier walls, provided the distances to walls constructed as fire barrier walls for exposure protection is not less than that required by Table 11.3.2.1.

A.11.3.2.2.4.2 Figure A.11.3.2.2.4.2(a) and Figure A.11.3.2.2.4.2(b) illustrate wall enclosures for a hydrogen storage system. The geometry of the three-sided enclosure should not contain any hydrogen release that would be enough to create a significant hazard.

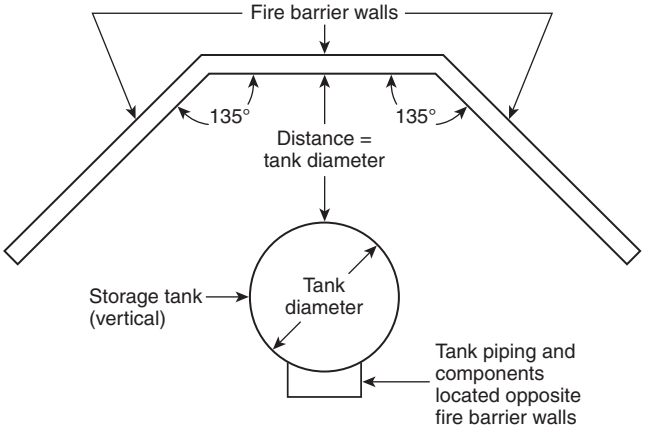


FIGURE A.11.3.2.2.4.2(a) Schematic of Three-Sided Fire Barrier Wall Enclosure for a Vertical Hydrogen Storage System.

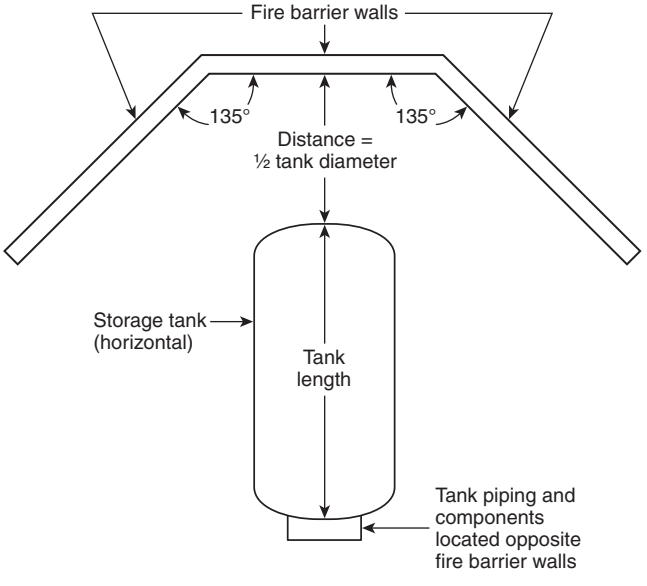


FIGURE A.11.3.2.2.4.2(b) Schematic of Three-Sided Fire Barrier Wall Enclosure for a Horizontal Hydrogen Storage System.

A.11.4.1.4 The basis of this requirement is to prevent unauthorized personnel or those unfamiliar with gas storage systems from tampering with the equipment. Where the LH2 is located in an area open to the general public, a common practice is to fence and lock the storage or use area, with access restricted to supplier and user personnel. When the storage or use is located within the user's secure area and is not accessible by the general public, it is not always necessary to fence or otherwise secure individual gas storage or use areas. Personnel access patterns may still mandate that the system be fenced, as determined by the supplier and the user.

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A.11.4.4.3 Hydrogen fires should not be extinguished until the supply of hydrogen has been shut off because of the danger of re-ignition or explosion. In the event of fire, large quantities of water will normally be sprayed on adjacent equipment to cool the equipment and prevent involvement in the fire. Combination fog and solid stream nozzles are preferred, to permit the widest adaptability in fire control. Small hydrogen fires have been extinguished with dry chemical extinguishers or with carbon dioxide, nitrogen, and steam. Re-ignition can occur if a metal surface adjacent to the flame is not cooled with water or other means.

A.12.3.1 The equipment referenced is intended to include fuel cell applications, generation of hydrogen from portable or transportable hydrogen generation equipment, batteries, and similar devices and equipment that utilize hydrogen for the purpose of power generation. It does not include hydrogen production facilities intended to produce hydrogen used for distribution or repackaging operations operated by gas producers, distributors, and repackagers.

A.12.3.2.4(3) Protection can be integral to the hydrogen generator (locked enclosures, guards, etc.), or the hydrogen generator can be installed in a controlled-access area.

A.12.3.2.8.5.7 Process gases within catalytic reformer systems, in addition to their flammability hazard, can contain significant quantities of carbon monoxide and other toxic substances.

A.12.3.2.9.2 There are two considerations unique to gasification:

(1) Gasifiers typically operate in excess of 2600°F (1425°C). Gas delivery temperature is a strict function of the amount of cooling provided by the system.
(2) The output of the gasifier typically contains significant quantities of carbon monoxide, hydrogen sulfide, and other toxic substances.

A.12.3.2.9.2.1 This equipment consists of piping, valves, vessels, and instrumentation for monitoring of the process.

A.12.3.2.9.4.1 Pressure relief panels should be designed as outlined in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.12.3.2.9.6.2 The inclusion of detection for other potential constituents in the gas flow such as hydrogen sulfide, carbon monoxide, and so on should be based on the volumetric content of such constituents and an assessment of the potential health hazards in the event of a leak. This risk assessment must consider indoor versus outdoor locations, ventilation capabilities, personal protective equipment (PPE) requirements to be imposed for area access, and so on. For carbon monoxide, it is recommended that gas detection be provided for any systems or portions of systems that contain greater than 1 percent concentration by volume in the gas flow. Reference to applicable threshold limit value or PEL information should be made for other toxic constituents.

A.12.3.2.9.6.3 Due to the high temperatures associated with the gasification process, ignition of leaks is likely, especially in the vicinity of the gasifier vessel proper. Hydrogen burns with a nearly invisible flame, so detection and warning systems are necessary to advise personnel when a fire exists. It is recommended that corn straw brooms or cotton rags on poles be readily available for use by personnel entering the area to clear the path of travel for fires.

A.12.3.2.9.6.5 The application of water deluge fire protection against the gasifier vessel and other very hot components must be done carefully to avoid rapid cooling and the associated material stresses that result. The first consideration in controlling a fire near this equipment is to halt the flow of combustible materials (shutting down the feedstock supply and venting the internal pressure to the flare stack). Once the fuel supply is halted, the task of extinguishing the fire is simplified. If water deluge is selected as the fire suppression method, controlling the direction of the spray pattern from the nozzles and the application of spray shields will minimize the thermal distress to susceptible components. Consideration should be given to the application of alternative fire suppression methods, such as water mist, that impose less thermal distress on the equipment. NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, contains additional recommendations applicable to fire protection of gasifiers.

A.13.1.1 The response to carbon dioxide inhalation depends on the degree and duration of exposure, and it varies greatly even in healthy, normal individuals. The medical term for the physiological effects of excess carbon dioxide in the blood is *hypercapnia*. Carbon dioxide can be dangerous even when normal oxygen levels are present. Low concentrations of inspired carbon dioxide can be tolerated for a considerable period of time without noticeable effect or cause merely an unnatural feeling of shortness of breath. Sustained exposure to 5 percent carbon dioxide produces stressful rapid breathing. When the level of inspired carbon dioxide exceeds 7 percent, the rapid breathing becomes labored (dyspnea), and restlessness, faintness, severe headache, and dulling of consciousness occur. At 15 percent, unconsciousness accompanied by rigidity and tremors occur in less than 1 minute, and in the 20 percent to 30 percent range, it produces unconsciousness and convulsions in less than 30 seconds. The reason these effects occur quickly is that the carbon dioxide diffuses in the tissue fluids at a rate approximately 20 times more rapidly than oxygen. High concentrations of carbon dioxide can asphyxiate quickly without warning and with no possibility of self-rescue regardless of the oxygen concentration.

A.13.1.1.2.2 Vent pipes must be protected to prevent the intrusion of water that can freeze and interfere with the operation of the pressure relief device. Covers can be employed to protect the vent pipe against the elements. Carbon dioxide released through vent pipes can be transformed to the solid state through the production of what is dry ice in the form of "snow." It is possible for dry ice to form a plug in the vent line system. For this reason, designers might choose to locate the pressure relief device at the end of a vent line rather than on the unit itself. There are alternative designs that accomplish this intent. It is important that the system designer provide a system that is not susceptible to the formation of ice plugs due to moisture or solid carbon dioxide so that vent lines function as intended.

A.13.1.4 Materials used in the system can become brittle and fail if subjected to low temperatures. Maintain the system at or above the minimum design temperature by appropriate design materials or operating instructions to prevent system failure.

In North America, the majority of the containers in refrigerated carbon dioxide service are fabricated using low-alloy

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carbon steels such as SA-212, SA-515, SA-516, and SA-612. Containers manufactured before 1990 typically had a minimum design metal temperature (MDMT), the lowest temperature at which a container is designed to operate at a given pressure at –20°F (–28.9°C). When the container wall is at an operating temperature colder than the MDMT, it is out of its intended operating condition.

A.13.2.1 The building code establishes requirements for the structure based on loads imposed by the elements of construction as well as for the loads that could be imposed by machinery or equipment. Building owners are responsible for understanding the limitations of loads on the building in which these installations are to be located. A professional engineer representing the building owner might have to make a determination as to the adequacy of the structure regarding the loads that are to be imposed for systems of this nature.

A.13.2.2 Enclosed areas can include indoor as well as outdoor locations such as one with four solid walls and no roof or ceiling. The PEL is established by OSHA in 29 CFR 1910.1000, Table Z-1.

A.13.2.2.1 The American Conference of Governmental Industrial Hygienists (ACGIH), in *TLVs® and BEIs®, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices,* has established threshold limit values (TLVs®). The threshold limit value–time weighted average basis (TLV-TWA®) for CO_2 has been established at 5000 ppm, with a short-term exposure limit (STEL-TLV®) value of 30,000 ppm.

As stated by ACGIH, the TLV-TWA represents a time-weighted average concentration for a conventional 8-hour workday and a 40-hour workweek to which it is believed that nearly all workers can be repeatedly exposed, day after day, without adverse effect. The STEL-TLV is the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to increase the likelihood of accidental injury, to impair self-rescue, or to materially reduce work efficiency, provided that the daily TLV-TWA is not exceeded. The STEL-TLV is not a separate, independent exposure guideline; rather, it supplements the TLV-TWA where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. TLV-STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A.13.3.1.1 Aboveground locations include locations that are above grade. Although some installations may be above ground, the actual grade of the terrain on which the installation is located could result in entrapment of vapors. Designers should avoid locating enclosures in areas where natural terrain features or other impediments serve to act as impediments to the dissipation of vapors should a release occur.

A.14.2.2.6(4) Ethylene oxide containers should be tested for leakage prior to moving them inside a facility. Leak detection solutions can be used to test for leaks around valves and fuse plugs. This is often referred to as a soap test. Inexpensive hand-held leak detection instruments also are available.

A.14.3.2.1.1 Storage of over 5000 lb (2268 kg) of ethylene oxide is also covered by 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals" (OSHA). Hazard analyses are required by OSHA for facilities storing more than 5000 lb (2268 kg) of ethylene oxide in one location. Hazard analyses are recommended for all facilities that store, use, and handle ethylene oxide. Refer to 29 CFR 1910.119 for guidance on conducting such an analysis. The analysis should address the hazards of the operation, identification of any previous incidents, engineering and administrative controls to protect against hazards, consequences of the failure of engineering and administrative controls, facility site, human factors, and qualitative evaluation of the range of possible effects on employee safety and health due to the failure of controls.

A.14.3.3.2.6 The rate of formation of ethylene oxide polymers increases as the temperature increases. Therefore, to minimize polymer formation, ethylene oxide containers should be sheltered from intense sunlight. Ethylene oxide containers should not be stored under plastic sheets. This can produce a greenhouse effect that results in release of the fusible plugs.

A.14.4.2.2 Welding is the preferred method of joining pipe. The use of welding is important in preventing leakage of ethylene oxide. For information on safety in cutting and welding, see NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.*

A.14.4.3 Cleaning the inside of lines used for ethylene oxide is necessary prior to opening the piping system to remove the combustible, oily ethylene oxide by-products (which also contain absorbed ethylene oxide), such as polymers or glycols. These by-products can build up gradually over time.

A.14.4.6 For information on identification of piping, see ASME A13.1, *Scheme for the Identification of Piping Systems.*

A.14.5.1.2 Additional detection at lower levels might be required to meet OSHA requirements (see 29 CFR 1910.1047, "Ethylene Oxide").

A.14.5.1.3 Local exhaust hoods are an effective means used to control ethylene oxide levels at the source of potential release.

A.14.5.4.2 Monitoring of temperature in the ethylene oxide vapor stream provides a means to detect liquid ethylene oxide downstream of the vaporizer. The vaporizer should be equipped with a controller to maintain the desired temperature range for vaporization of ethylene oxide or ethylene oxide mixtures.

A.14.6.2 Sterilization is performed in a closed vessel under controlled conditions of temperature, humidity, pressure, and ethylene oxide gas concentration. The process is a single-pass, batch operation in which a number of steps are performed to complete the cycle. Process cycle parameters can vary widely to meet product sterilization requirements and can use flammable gas mixtures in the sterilizer.

A.14.6.2.1 Lower concentrations of ethylene oxide are required by OSHA (see 29 CFR 1910.1047, "Ethylene Oxide") for personnel exposure.

The use of nitrogen in enclosed spaces can pose an asphyxiation hazard.

A.14.6.2.2 Outgassing, depending on product characteristics, can be of sufficient magnitude to produce flammable mixtures of ethylene oxide.

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A.14.6.3.2 Ethylene oxide gas supply shutoff is a minimum requirement; other operations such as emergency ventilation might also be appropriate.

Additional detection at lower levels can be required to meet the requirements of OSHA (see 29 CFR 1910.1047, "Ethylene Oxide").

A.14.7.2 For information on prevention of static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.14.8.1 Flame arresters should be installed to prevent flame propagation from potential ignition sources external to the vessel. Locations for consideration are the vacuum pump suction line, air inbleed port, relief valve discharge, and other potential problem areas where flashbacks could occur.

A.14.9.1 The emphasis of this section is on those issues specifically related to fire safety. Sterilization facilities are required to comply with federal, state, and local environmental health and safety regulations.

A.14.9.5 Oxidizing emission control devices can include catalytic converters, flares, or other active sources of ignition.

A.14.9.5.2.1.1 Engineering controls can include computer or programmable logic controllers and associated software and hardware that control the sterilization process, safety interlocks, purge systems, gas detection, and monitoring systems. The controls provided are to ensure that the concentration of ethylene oxide at the point where it is released to the emission control device is reduced below 25 percent of its LFL.

A.14.9.5.2.1.1(C) The mechanical code in use by the jurisdiction in which the installation is located is used to establish requirements for the design of the exhaust duct system. Requirements for the duct system can vary depending on the mechanical code in use as well as with the maximum concentration of ethylene oxide to be released to the duct system for any specific process.

A.14.11.2.1.1(2) For information on venting of deflagrations, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.14.11.2.2 To comply with this requirement and OSHA (see 29 CFR 1910.1047, "Ethylene Oxide"), specific local exhaust ventilation might be necessary in storage and dispensing areas, on the sterilizer, and in aeration rooms.

A.14.11.2.5 For information on venting of deflagrations, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.15.3.2 Equipment (industrial) platforms or mezzanines are frequently constructed and placed within generator rooms as a means to access and service hoppers used to gravity feed calcium carbide. The construction of mezzanines and the limits on their size, numbers, and openness are regulated by the building code. Rooms containing mezzanines or industrial platforms do not require that the building be classified as more than one story, provided that they are in accord with the applicable restrictions of the building code.

A.15.3.3 See NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, for guidance in the construction techniques.

A.15.3.5.1 For purposes of this standard, air is not an oxidizing gas.

A.15.3.7.2 The autoignition temperature for acetylene as listed in 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*, is 581°F (305°C). Acetylene is the only material listed as being in Group A at the present time. Electrical equipment is required to comply with the requirements of *NFPA 70, National Electrical Code*, based on class and group designations determined by conditions as well as the material present.

A.15.3.9.1.1 The system should be designed to provide water as a means of cooling the containers located on the trailer that are potentially exposed to fire and not as a means to extinguish the fire. To extinguish a gas fire, the flow of gas must be shut off at the source.

A.15.3.9.2.1 Dry sand is typically located in areas where calcium carbide is stored or used. A 30 gal (114 L) container with scoop is used to isolate the calcium carbide from the atmosphere in the event of fire.

A.15.3.10 A listing standard for gas detection and sensing systems is published by Underwriters Laboratories as UL 2075.

A.15.4.1.1 This section does not govern the design of acetylene generators because of the variable and complex design features of different types of generators.

A.15.4.1.3.2.6(A) The aggregate cross-sectional area of the connected pressure relief devices is the sum of the cross-sectional areas for each of the individual relief devices connected to the manifold.

A.15.4.1.4 Gasholders are intermediate vessels used to collect gas as it is generated, to allow the compressor to operate on a duty cycle based on the rate of gas generation. The gasholder provides a means to collect a variable volume of gas within predefined limits. The gasholder acts as a buffer that provides a reservoir of gas to the compressor when activated. Such a buffer is needed as the rate of gas generation varies, and the rate of production is less consistent than the rate of consumption of the compressor. The compressor draws gas from the reservoir as gas is being compressed. When the gas capacity in the gasholder drops to a predetermined limit, the compressor is automatically shut down to avoid creating suction on the gas generator, which could lead to the entrainment of air. When sufficient gas has been generated and collected in the gasholder, the compressor is reactivated and the compression cycle is repeated.

A.15.4.1.5.2 See NFPA 30, *Flammable and Combustible Liquids Code*.

A.15.4.1.6 See CGA G-1.7, *Standard for Storage and Handling of Calcium Carbide in Containers*, and CGA Safety Bulletin SB-4–1997, *Handling Acetylene Cylinders in Fires*.

A.15.4.1.8.1.1(A) Drain lines are designed to drain condensate or other fluids; they are not "vent" lines that are used to vent or exhaust gases from the system. Drain lines should be piped to the outside of the building to avoid potential evolution of vapors that have been entrained into a liquid discharge. The location and collection of liquid drainage will be controlled by environmental considerations depending on the nature of the discharge. Additional safeguards may be required when high pressure acetylene is vented. Protection against the potential ignition of vented gases due to a static electric discharge should be considered. For further information see NFPA 77, *Recommended Practice on Static Electricity*. The use of rapid opening valves in drain lines should be avoided in order that unintended ignition does not occur.

A.15.4.1.8.2.3(B) Devices or housings placed over the valve, such as clamshells that are released through the use of a lock

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and key, provide a visible means to ensure that the valve is set in the open position. The use of rapid opening valves, such as quarter-turn ball valves, is not recommended due to the potential for adiabatic compression, which can lead to explosive decomposition.

A.15.4.1.12.1.1 Additional safeguards may be required when high pressure acetylene is vented. Protection against the potential ignition of vented gases due to a static electric discharge should be considered. For further information see NFPA 77, *Recommended Practice on Static Electricity*. The use of rapid opening valves in vent lines should be avoided in order that unintended ignition does not occur.

A.15.7.1.4.1 Although users may be allowed to discharge generator waste to the public sewer in some cases, such discharge must be carefully controlled and designed to eliminate the potential to generate acetylene in the sewer system. Most modern plants collect generator waste in collection tanks that are open to the atmosphere and where the waste can be further utilized as a by-product of the production.

A.15.7.1.4.1.1 Direct connections are connections where the discharge piping is hard piped or connected to the drain system without gaps in the piping system or openings where either trace amounts of acetylene can be entrained into the sewer system or unreacted calcium carbide can react with water in the sewer system with no ability to vent the gas formed.

Annex B Attended Operations

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 Introduction. Section 112(r) of the Clean Air Act (CAA) mandates that the U.S. Environmental Protection Agency (EPA) promulgate a regulatory program to prevent accidental releases of regulated toxic and flammable substances and reduce the severity of releases that do occur. The rule, published on June 20, 1996, formally appears in the Code of Federal Regulations as 40 CFR 68 and is officially titled "Accidental Release Prevention Requirements: Risk Management Programs Under Clean Air Act Section 112(r)(7)."

B.1.1 In addition to qualified judgment and expertise, the following three resources must be considered in the selection of alternative release scenarios in evaluating the hazards of any system:

(1) The five scenarios listed in Section 68.28 of 40 CFR 68
(2) The 5-year accident history of all accidental releases from covered processes that resulted in deaths, injuries, or significant property damage on-site or all known off-site deaths, injuries, evacuations, sheltering-in-place, or property or environmental damage
(3) The hazard review or process hazards analysis completed as part of the required prevention program

B.1.2 The five scenarios encompassed in Section 68.28 of 40 CFR 68 of the regulation include the following:

(1) Transfer hose releases due to splits or sudden hose uncoupling (typical of delivery operations)
(2) Process piping releases from failures at flanges, joints, welds, valves and valve seals, and drains or bleeds
(3) Process vessel or pump releases due to cracks, seal failure, or drain, bleed, or plug failure
(4) Vessel overfilling and spill or overpressurization and venting through relief valves or rupture disks
(5) Shipping container mishandling and breakage or puncturing leading to a spill

B.1.3 Based on comparable analysis, it was determined that the most likely alternative release scenario having an off-site impact from compressed gas systems would be a process piping failure that either is outdoors or is indoors and entrained into an unspecified exhaust system. In either case, discharge results in a continuous emission resulting in a plume on-site or off-site. An accidental release of this type might occur due to mechanical failure, corrosion, failure of a piping component such as a joint or valve, or another cause.

B.1.4 The flow rate through a pipe during a release is computed based on the pressure of the cylinder, container, or tank; the liquid head (if a liquid is involved); the fluid density; the line's resistance to flow (based primarily on diameter, length, and number of bends); and the open area available to flow at the exit.

B.2 Parameters. Each parameter, whether selected by the user or preselected, as is typical, is explained in B.2.1 through B.2.5.

B.2.1 Cylinder, Container, or Tank Pressure. The highest normal operating pressure should be used for the tank pressure.

B.2.2 Liquid Head. The liquid head is the amount of pressure exerted by the weight of the liquid column. For most small containers and cylinders, the liquid head is normally small and can usually be ignored.

B.2.3 Fluid Density. Fluid density is the density of the fluid under consideration.

B.2.4 Line Length and Configuration. Line configuration is specific to the configuration under consideration.

B.2.5 Pipe Break Flow Area. Most piping breaks result in less than the full pipe diameter being open to flow. For example, a full-guillotine break is not nearly as likely as a reduced-flow area break or a small leak. It is unlikely that small leaks will have an off-site impact. Therefore, it is appropriate to select as an alternative release case a piping failure characterized by a fraction of the full-open area that is typical of the majority of piping failures while significantly greater than that of a small leak.

For the purposes of calculation, a 20 percent flow rate versus a full bore line break should be used. Statistics indicate that piping failures of this magnitude would be expected to occur between 2 and 10 times as often as a full-guillotine break.

B.3 Calculations. Calculations to demonstrate the "maximum credible worst-case leak" must be engineered, and factors to include the nature of flow must be considered, including whether the gas or vapor flowing is gaseous, liquid, or a two-phase-type flow. Detailed air dispersion models and methods of calculation are available. The choice of the model or methodology, or both, must be established by engineering principles and applied by those versed in such matters.

Annex C Physical Properties of Hydrogen

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Physical Properties. Hydrogen is a flammable gas. It is colorless, odorless, tasteless, and nontoxic. It is the lightest gas known, having a specific gravity of 0.0695 (air = 1.0). Hydrogen diffuses rapidly in air and through materials not normally considered porous.

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C.1.1 Hydrogen burns in air with a pale blue, almost invisible flame. At atmospheric pressure, the ignition temperature of hydrogen–air mixtures has been reported by the U.S. Bureau of Mines to be as low as 932°F (500°C). The flammable limits of hydrogen–air mixtures depend on pressure, temperature, and water vapor content. At atmospheric pressure, the flammable range is approximately 4 percent to 75 percent by volume of hydrogen in air.

C.1.2 Hydrogen remains a gas even at high pressures. It is liquefied when cooled to its boiling point of –423°F (–253°C).

C.1.3 Hydrogen is nontoxic, but it can cause anoxia (asphyxiation) when it displaces the normal 21 percent oxygen in a confined area without ventilation that will maintain an oxygen content exceeding 19.5 percent. Because hydrogen is colorless, odorless, and tasteless, its presence cannot be detected by the human senses.

C.2 Physical Properties. Liquefied hydrogen is transparent, odorless, and not corrosive or noticeably reactive. The boiling point at atmospheric pressure is –423°F (–253°C). It is only 1/14 as heavy as water. Liquefied hydrogen converted to gaseous hydrogen at standard conditions expands approximately 850 times.

Annex D Significant Properties of Ethylene Oxide

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Hazards of Ethylene Oxide. Figure D.1 illustrates the hazards of ethylene oxide.

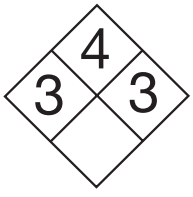
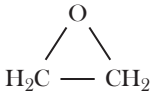


FIGURE D.1 Hazards of Ethylene Oxide.

SYNONYMS: di-methylene oxide; EO; EtO; 1,2-epoxyethane; oxirane

FORMULA: $(CH_2)_2O$



DOT CLASS: Class 2.3, Poisonous gas

SHIPPING LABEL: POISON GAS and FLAMMABLE GAS

ID NO.: UN 1040

CAS NO.: 75-21-8

MOL. WT.: 44.0

STATEMENT OF HAZARDS: Flammable gas. Low ignition energy. Explosive decomposition can occur. Hazardous polymerization can occur. Serious health hazard.

EMERGENCY RESPONSE PERSONAL PROTECTIVE EQUIPMENT: Wear special protective clothing and positive pressure self-contained breathing apparatus.

SPILL OR LEAK PROCEDURES: Eliminate all ignition sources. Releases might require isolation or evacuation. Approach release from upwind. Stop or control the leak, if it can be done without undue risk. Use water spray to cool and disperse vapors, protect personnel, and dilute spills to form nonflammable mixtures. Water solutions are no longer flammable in open areas when diluted to 1 part in 22 parts water. In enclosed areas such as sewers, dilution to 1 part in 100 parts water can be required to eliminate flash potential. Control runoff and isolate discharged material for proper disposal.

FIRE-FIGHTING PROCEDURES: Use flooding quantities of water as fog. Use water spray, dry chemical, "alcohol-resistant" foam, or carbon dioxide. Use water spray to keep fire-exposed containers cool. Explosive decomposition can occur under fire conditions. Fight fire from protected location or maximum possible distance.

HEALTH HAZARDS: Serious health hazard. Can be harmful if absorbed through skin or inhaled. Pulmonary edema can result. Irritating to skin, eyes, and respiratory system.

FIRE AND EXPLOSION HAZARDS: Flammable gas. Volatile flammable liquid below room temperature. Explosive decomposition can occur in vapor or liquid phases. Vapor forms explosive mixtures with air over a wide range. Vapors are heavier than air and can travel to a source of ignition and flash back. Closed containers can rupture violently when heated.

FLASH POINT: –4°F (–20°C)

AUTOIGNITION TEMPERATURE: 804°F (429°C) [AIT in the absence of air: 1058°F (570°C)]

FLAMMABLE LIMITS: LOWER, 3.0 percent; UPPER, 100.0 percent

INSTABILITY AND REACTIVITY HAZARDS: Highly reactive. Hazardous polymerization can occur, especially if contaminated. Reacts with acids, alkalies, salts, combustible materials. Can undergo runaway reaction with water. Many materials can accelerate this reaction.

STORAGE RECOMMENDATIONS: Store in a cool, dry, well-ventilated location. Store away from heat, oxidizing materials, and sunlight. Separate from acids, alkalies, salts, and combustible materials. Outside or detached storage is preferred. Can react in insulation, forming low-molecular-weight polyethylene glycols that can spontaneously heat and ignite at less than 212°F (100°C).

USUAL SHIPPING CONTAINERS: Insulated steel cylinders; pressurized tanks on trucks, rail cars, barges. Safety relief valves required.

PHYSICAL PROPERTIES: Colorless gas with sweet ether-like odor.

MELTING POINT: –170°F (–112°C)

BOILING POINT: 51°F (11°C)

SPECIFIC GRAVITY: 0.89 at 0°C

SOLUBILITY IN WATER: Soluble

VAPOR DENSITY: 1.51

VAPOR PRESSURE: 1095 mm Hg at 20°C

ELECTRICAL EQUIPMENT: Class I, Group B (C)

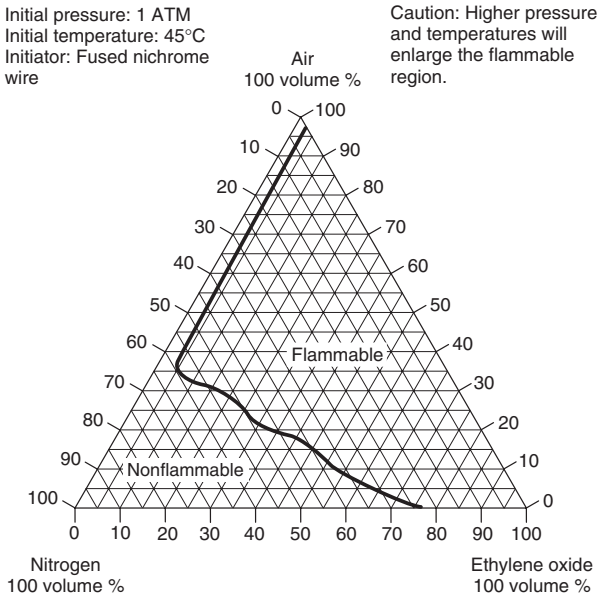
D.2 Nonflammable Mixtures of Ethylene Oxide. Ethylene oxide is often mixed with a second, inert component and shipped as a liquefied gas mixture for use by sterilizer operators. Several of these mixtures are nonflammable. Table D.2 indicates the maximum amount of ethylene oxide that a nonflammable mixture can contain, as well as typical ethylene oxide contents of commercially available nonflammable mixtures. Figure D.2(a) through Figure D.2(c) show how the flammable range for ethylene oxide varies as a function of pressure in nitrogen and air atmospheres.

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Table D.2 Nonflammable Mixtures of Ethylene Oxide

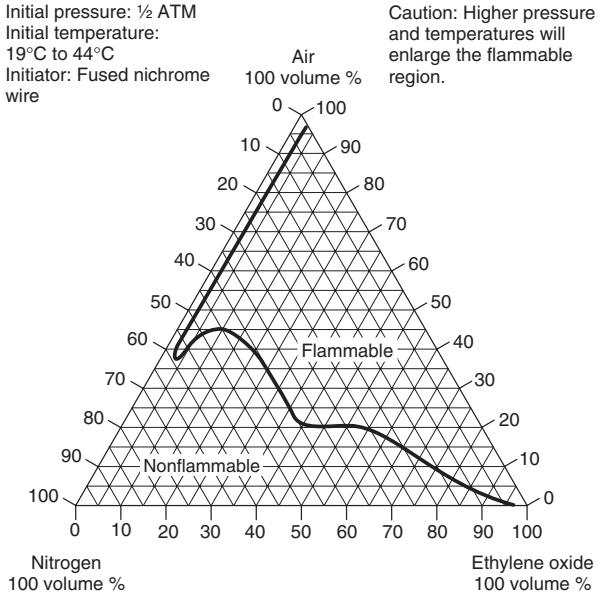
Second Component Chemical Name	Common Name	Chemical Formula	Maximum Ethylene Oxide by Weight (percent)	Typical Ethylene Oxide by Weight (percent)	Maximum Ethylene Oxide by Volume (percent)
Dichloro difluoromethane	CFC-12	CF_2Cl_2	12.5	12.0	28.0
Carbon dioxide	—	CO_2	9.0	8.5	9.0
2 Chloro-2,1,1,1 Tetrafluoroethane	HCFC-124	$CHClF\text{-}CF_3$	9.3	8.6	24.2
2,1,1,1 Tetrafluoroethane	HFC-134a	CH_2FCF_3	6.1	N/A	13.0
2,2,1,1,1 Pentafluoroethane	HFC-125	CHF_2CF_3	8.5	N/A	21.2

Note: Mixtures measured in accordance with ASTM E 681, *Standard Test Method for Concentration Limits of Flammability of Chemicals*, with an ignition energy of 40 J.



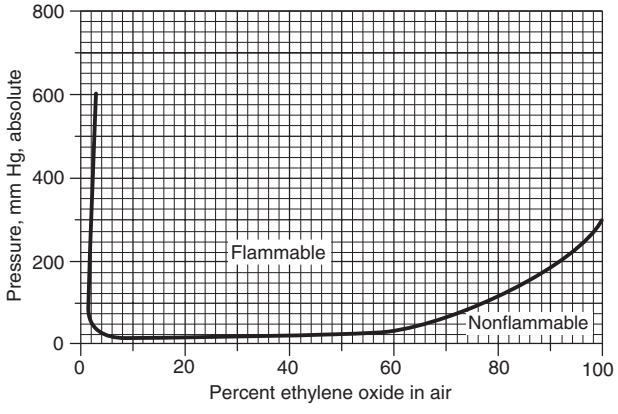
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FIGURE D.2(a) Flammability of Ethylene Oxide–N_2–Air Mixtures at 1 Atmosphere. (45°C = 113°F) (Source: Allied Signal Inc.)



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FIGURE D.2(b) Flammability of Ethylene Oxide–CO_2–Air Mixtures at 1 Atmosphere. (19°C to 44°C = 66°F to 111°F) (Source: Allied Signal Inc.)



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FIGURE D.2(c) Flammability of Ethylene Oxide Mixtures at Subatmospheric Pressures. (Source: Allied Signal Inc.)

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Annex E Determination of Separation Distances for Bulk Gaseous Hydrogen Systems

This annex is not part of the requirements of this NFPA document but is included for informational purposes only.

This annex is a paper by William Houf and Robert Schefer, "Description of Hazard Models Used in the Development of Separation Distance Tables for NFPA 55 and NFPA 2" (Sandia National Laboratories, P.O. Box 969, Livermore, CA 94551-0969).

The informational references found in Section I.2 will assist code users in gaining further understanding of the methodologies used in the development of the separation distance tables for bulk gaseous hydrogen systems. Two key references are the work by LaChance et al., which provides the technical rationale used as the basis in the development of a risk-informed approach to separation distances, and the work of Houf and Schefer, which provides information relative to the determination of the physical effects of an ignited and an unignited release.

E.1 Introduction. Separation distances in NFPA 55 and NFPA 2 are based on the prediction of the characteristics of unignited jets or ignited jet flames from hydrogen leaks. Because the characteristics of hydrogen jets and jet flames depend on the source pressure and effective diameter of the leak the separation distance table for was broken into four pressure ranges. The effective leak diameter for each pressure range was based on a characteristic pipe diameter (I.D. = inside diameter), where the leak flow area was taken to be 3% of the flow area of the pipe (based on I.D. of the pipe). For a round leak the effective diameter of the leak is

$$d_{leak} = (0.03)^{1/2} d_{pipe(I.D.)}$$

where d_{leak} is the effective leak diameter and $d_{pipe(I.D.)}$ is the inside diameter of the pipe. Table E.1(a) lists the pressure ranges for the separation distances table and the associated inside pipe diameter of the characteristic pipe used to determine the leak effective diameter for each pressure range.

When using the separation distance table one must first determine the storage pressure. The storage pressure determines what pressure range in the table is to be used in the determination of separation distances. The storage pressure is defined as the maximum pressure of a storage array with volume greater than 400 scf (standard cubic feet) in the system. If the system has more than one storage array with a volume greater than 400 scf then a storage pressure must be determined for each array. The next parameter that must be determined is the largest diameter (I.D.) of the piping within the system or portion of the system downstream of the stored volume. If the largest pipe diameter associated with the storage pressure is less than the characteristic pipe diameter listed in Table E.1(a) for that pressure range, then the values listed in separation distance table may used, or alternately the formulas at the bottom of the table may be applied using the determined value of largest pipe diameter (I.D.).

If the value of the largest pipe diameter (I.D.) is greater than the characteristic pipe diameter for the storage pressure range of interest then the formulas at the bottom of separation distance table must be used to determine separation distances. These formulas reproduce the numeric values in the separation distance tables for the pipe diameters shown in Table E.1(a).

The formulas are based on performing curve-fits to hazard distance calculations performed over a range of pipe diameters (assuming 3% flow area leak) and pressures using the hazard models discussed in Section E.2. The formulas are simple enough that they can easily be entered into an Excel spreadsheet program or programmable calculator for computation of separation distances for any value of pipe diameter (I.D.). An Excel spreadsheet based on these formulas was developed and distributed to the NFPA Hydrogen Technology Committee members as part of the development of separation distance tables.

If a system contains multiple storage arrays (greater than 400 scf) at different pressures then storage pressures and largest pipe diameters must be determined for each storage array in the system. The separation distance table and formula procedure outlined above is then applied to each storage array in the system and the largest separation distance for each storage array defines the value of the separation distance for the overall system.

A description of the models used to determine the values of the separation distances are discussed in the sections that follow. More detailed descriptions of the models and the experiments used in their development and validation can be found in the publications (Houf and Schefer, 2007, 2008; Schefer et al. 2006, 2007). The models consider either the concentration decay of an unignited high-momentum hydrogen leak or in the case where the mixture ignites, a high-momentum hydrogen jet flame, its visible length, and the radiation heat flux from the flame. Table E.1(b) lists the hazard criteria that were used with the unignited jet and jet flames models to create a risk informed consequence-based separation distance table for NFPA 55 and NFPA 2.

E.2 Description of Engineering Hazard Models: Nomenclature. See Table E.2 for specification of the parameters used in engineering hazard models.

Table E.1(a) Pressure Ranges for Separation Distances Table and the Associated System Characteristic Pipe Diameter

Storage Pressure Range	Characteristic Pipe Diameter (I.D.)
>103 to ≤ 1724 kPa (gauge) (>15 to ≤250 psig)	52.50 mm (2.067 in)
>1724 to ≤ 20684 kPa (gauge) (>250 to ≤3000 psig)	18.97 mm (0.75 in)
>20684 ≤ 51711 kPa (gauge) (>3000 to ≤7500 psig)	7.92 mm (0.312 in)
>51711 ≤ 103421 kPa (gauge) (>7500 to ≤15000 psig)	7.16 mm (0.282 in)

Table E.1(b) Hazard Parameters for Separation Distances Tables

Hydrogen unignited jet	Distance to point where concentration has decayed to 4% mole fraction hydrogen in air
Hydrogen jet flame	Visible flame length
Hydrogen jet flame	Distance to radiation heat flux level of 1577 W/m^2 (500 Btu/hr · ft^2)
Hydrogen jet flame	Distance to radiation heat flux level of 4732 W/m^2 (1500 Btu/hr · ft^2) exposure to employees for a maximum of 3 minutes
Hydrogen jet flame	Distance to combustible heat flux level of 20,000 W/m^2 (6340 Btu/hr · ft^2)
Hydrogen jet flame	Distance to non-combustible equipment heat flux level of 25,237 W/m^2 (8000 Btu/hr · ft^2)

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Table E.2 Parameters Used in Hazard Models

b	Coefficient for hydrogen in the Abel-Nobel equation of state (7.691×10^{-3} m^3/kg)
Btu	British thermal unit
C*	Non-dimensional radiant power
CH_4	Methane
C_2H_2	Acetylene
C_2H_4	Ethylene
C_3H_8	Propane
d_{eff}	The effective diameter, m
d_j	Jet exit diameter, m
d*	Jet momentum diameter, m
D_{rad}	Radiation distance, m
Fr_f	Froude number (dimensionless parameter based on the ratio of momentum effects to buoyancy effects)
f_s	Mass fraction of fuel at stoichiometric conditions
g	Acceleration due to gravity (9.8 m/sec^2)
H_2	Molecular hydrogen
hr	hour
K	The entrainment constant
K_c	The entrainment constant for a round jet
L_{vis}	Visible flame length, m
L*	Non-dimensional flame length
LFL	Lower flammability limit
LFL_{DPF}	Lower flammability limit for a downward propagating flame
LFL_{UPF}	Lower flammability limit for an upward propagating flame
m_{fuel}	Total fuel mass flow rate, kg/sec
$m_{fuel}\Delta H_c$	Total heat released due to chemical reaction, W
p_j	The jet exit pressure, bar
p_{supply}	The pressure in the supply, bar
p_{tank}	The pressure in the tank, bar
p_∞	The ambient pressure, bar
$q_{rad}(x,r)$	The radiant heat flux measured at a particular axial location, x, and radial location, r, W/m^2
r	Radial position, m
R_{H2}	Gas constant for hydrogen (4124.18 J/kg/K)
R_u	Universal gas constant (8314.34 J/kmol/K)
R_{max}	The maximum radial position from the flame centerline for the given heat flux level, m
S_{rad}	The total emitted radiative power, W
T_{ad}	Adiabatic flame temperature of hydrogen in air (2390K)
u_j	Jet exit velocity, m/sec
u_{eff}	The effective velocity at the end of expansion, m/sec
x	Axial position, m
x_o	The virtual origin of the jet, m
$X(R_{max})$	The axial location at which the maximum heat flux level occurs, m
X_{rad}	The radiant fraction or the fraction of the total chemical heat release that is radiated to the surroundings
W_f	Flame width, m
W_{mix}	Mean molecular weight of the products of stoichiometric combustion of hydrogen in air (24.54 kg/kmol)
Z	The compressibility factor [$Z = p/(\rho RT)$]
ΔH_c	Heat of combustion, J/kg
ΔT_f	Peak flame temperature rise due to combustion heat release, K
π	Pi
ρ_f	Flame density, kg/m^3
ρ_{gas}	The density of the exiting gas evaluated at ambient temperature and pressure, kg/m^3
ρ_j	Jet exit density, kg/m^3
(ρ_j/ρ_∞)	Ratio of jet gas density to ambient gas density
ρ_∞	Density of the ambient fluid, kg/m^3
$\bar{\eta}_{cl}$	Volume fraction (mole fraction) along the centerline of the jet
τ_f	Global flame residence time, sec

The development of an infrastructure for hydrogen utilization requires safety codes and standards that establish guidelines for building the components of this infrastructure. Based on a recent workshop on unintended hydrogen releases, one release case of interest involves leaks from pressurized hydrogen-handling equipment (Schefer et al., 2004). These leaks range from small-diameter, slow-release leaks originating from holes in delivery pipes to larger, high-volume releases resulting from accidental breaks in the tubing from high-pressure storage tanks. In all cases, the resulting hydrogen jet represents a potential fire hazard, and the buildup of a combustible cloud poses a hazard if ignited downstream of the leak.

A case in which a high-pressure leak of hydrogen is ignited at the source is best described as a classic turbulent-jet flame, shown schematically in Figure E.2. The distances of impor-

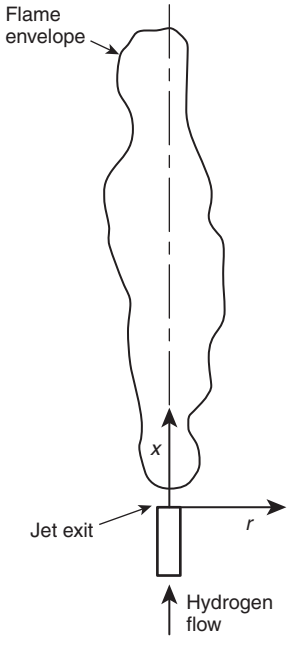


FIGURE E.2 Coordinate System for Turbulent Jet Flame and Unignited Jet.

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tance are the radial distance from the geometrical flame centerline, r, and the distance downstream of the jet exit, x. Other variables of interest are the jet exit diameter, d_j, and the jet exit velocity and density, u_j and ρ_j, respectively. Schefer et al. (2006, 2007) reported experimental measurements of large-scale hydrogen jet flames and verified that measurements of flame length, flame width, radiative heat flux, and radiant fraction are in agreement with non-dimensional flame correlations reported in the literature. This work verifies that such correlations can be used to predict the radiative heat flux from a wide variety of hydrogen flames. The present analysis builds upon this work by incorporating the experimentally verified correlations into an engineering model that predicts flame length, flame width, and the radiative heat flux at an axial position, x, and radial distance, r. The engineering model is then used to predict radiative heat fluxes for hydrogen flames.

For cases where the high-pressure leak of hydrogen is unignited, a classic high-momentum turbulent jet is formed that can be described using the same coordinate system shown in Figure E.2. The hydrogen concentration within the jet varies with axial and radial position due to entrainment and turbulent mixing with the ambient air. The concentration contour beyond which the hydrogen-air mixture is no longer ignitable is of importance to hydrogen ignition studies. The present study develops an engineering model for the concentration decay of a high-momentum turbulent jet based on experimentally-measured entrainment rates and similarity scaling laws for turbulent jets. The model is then verified by comparing simulations for high-pressure natural gas leaks with the experimental data of Birch (1984) for the concentration decay of high-pressure natural gas jets. The engineering model is then applied to hydrogen and used to predict unignited jet mean (time-averaged over turbulent fluctuations) concentration contours for high-pressure hydrogen leaks.

E.2.1 Flame Radiation Heat Flux and Flame Length Model. Gaseous flame radiation is the primary heat transfer mechanism from hydrogen flames. The flame radiation heat flux model follows the approach of Sivathanu and Gore (1993) where the flame properties of importance are the visible flame length, L_{vis}, total radiative power emitted from the flame, S_{rad}, and total heat released due to chemical reaction, $m_{fuel}\Delta H_c$ where m_{fuel} and ΔH_c are the total fuel mass flow rate and the heat of combustion, respectively. The radiant fraction, X_{rad}, is defined as the fraction of the total chemical heat release that is radiated to the surroundings and is given by an expression of the form

$$X_{rad} = S_{rad}/m_{fuel}\Delta H_c \qquad \textbf{(E.2.1a)}$$

For turbulent-jet flames, the radiative heat flux at an axial position x and radial position r can be expressed in terms of the non-dimensional radiant power, C*, and, S_{rad}, the total emitted radiative power. The radiative heat flux is given by an expression of the form (Sivathanu and Gore, 1993)

$$q_{rad}(x, r) = C^*(x/L_{vis})S_{rad}/4\pi r^2 \qquad \textbf{(E.2.1b)}$$

where $q_{rad}(x, r)$ is the radiant heat flux measured at a particular axial location, x, and radial location, r. Experimental data further show that C* may be expressed in non-dimensionalized form as a function of burner diameter, flow rate and fuel type and, for turbulent-jet flames, is dependent only on the normalized axial distance. Figure E.2.1(a) shows typical profiles of C*

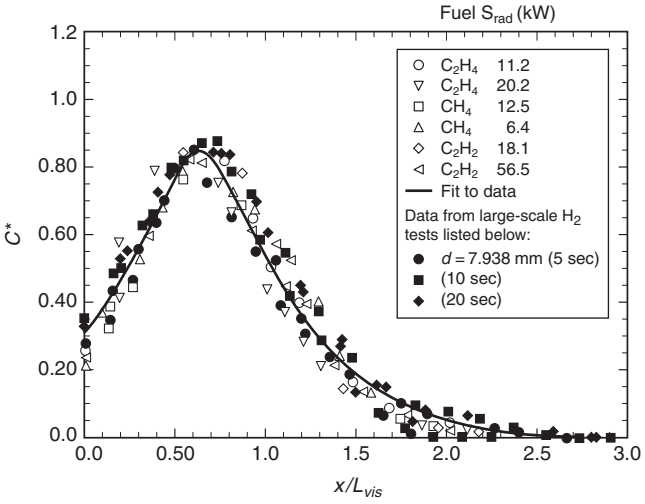


FIGURE E.2.1(a) Axial Variation of Normalized Radiative Heat Flux.

measured in six different turbulent-jet flames using CH_4, C_2H_2 and C_2H_4 as the fuel (Sivanthanu and Gore, 1993) as well as the measurements of Schefer *et al.* (2006, 2007) for large-scale H_2 jet flames.

The use of Equation E.2.1b to calculate flame radiation heat flux levels requires knowledge of the flame radiant fraction. Turns and Myhr (1991) measured the radiant fraction from turbulent jet flames using four hydrocarbon fuels with a wide variety of sooting tendencies. These fuels included methane, ethylene, propane, and a 57% CO/43% H_2 mixture. A plot of the radiant fraction data from Turns and Myhr (1991) along with the radiant fraction data for large-scale H_2 flames is shown in Figure E.2.1(b). The radiant fraction data, X_{rad}, is plotted versus the global flame residence time where the residence time is given by an expression of the form

$$\tau_f = \left(\rho_f W_f^2 L_{vis} f_s\right)/\left(3\rho_j d_j^2 u_j\right) \qquad \textbf{(E.2.1c)}$$

where ρ_f, W_f, and L_{vis} are the flame density, width, and length, and f_s is the mass fraction of hydrogen in a stoichiometric mixture of hydrogen and air. For turbulent-jet flames, the flame width, W_f, is approximately equal to 0.17 L_{vis} (Schefer *et al.*, 2006). This definition of residence time takes into account the actual flame density and models the flame as a cone. The flame density, ρ_f, is calculated from the expression $\rho_f = p_\infty W_{mix}/(R_u T_{ad})$, where p_∞ is the ambient pressure, W_{mix} is the mean molecular weight of the stoichiometric products of hydrogen combustion in air, R_u is the universal gas constant, and T_{ad} is the adiabatic flame temperature for hydrogen. The figure suggests that for flames with a lower sooting tendency, there is a well-defined relationship between radiant fraction and global flame residence time. Both methane and the CO/H_2 mixture show a well-behaved dependence on residence time and nearly collapse onto the same curve over the range of conditions studied. Values for the large-scale hydrogen jet flames are approximately a factor of two lower than the hydrocarbon flames for the same flame residence time.

The visible flame length, L_{vis}, is required for computing the global flame residence time, τ_f, to determine the flame radiant fraction. Based on an analysis of the transition from momentum-controlled to buoyancy-controlled turbulent jet flame dynamics,

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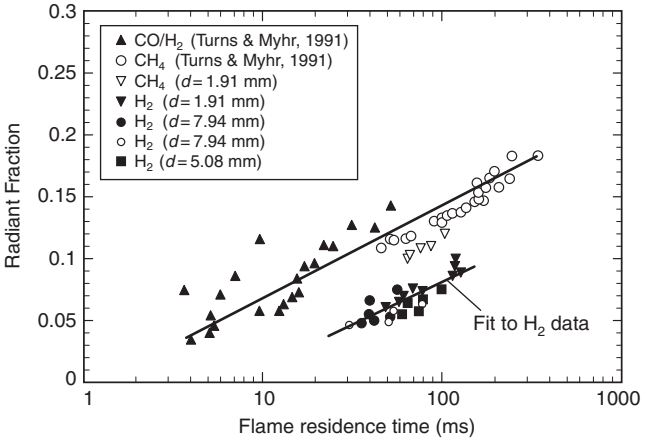


FIGURE E.2.1(b) Radiant Fraction as a Function of Flame Residence Time (lab H_2 flame data for diameters of 1.905 and 3.75 mm, large-scale H_2 flame test data at diameter of 7.94 mm).

Delichatsios (1993) developed a useful correlation for turbulent flame lengths. The correlation is based on a non-dimensional Froude number that measures the ratio of buoyancy to momentum forces in jet flames. Using the nomenclature of Turns (2000) the Froude number is defined as:

$$Fr_f = \frac{u_j f_s^{3/2}}{\left(\rho_j/\rho_\infty\right)^{1/4}\left[\frac{\Delta T_f}{T_\infty} g d_j\right]^{1/2}} \qquad \textbf{(E.2.1d)}$$

where u_j is the jet exit velocity, f_s is the mass fraction of fuel at stoichiometric conditions, (ρ_j/ρ_∞) is the ratio of jet gas density to ambient gas density, d_j is the jet exit diameter, and ΔT_f is the peak flame temperature rise due to combustion heat release. Small values of Fr_f correspond to buoyancy-dominated flames while large values of Fr_f correspond to momentum-dominated flames. Note that the parameters known to control turbulent flame length such as jet diameter, flow rate, stoichiometry, and (ρ_j/ρ_∞) are included in Fr_f. Further, a non-dimensional flame length, L*, can be defined as

$$L^* = \frac{L_{vis} f_s}{d_j\left(\rho_j/\rho_\infty\right)^{1/2}} = \frac{L_{vis} f_s}{d^*} \qquad \textbf{(E.2.1e)}$$

where L_{vis} is the visible flame length and d* is the jet momentum diameter. Figure E.2.1(c) shows the resulting correlation of flame length data for a range of fuels (H_2, C_3H_8 and CH_4) and inlet flow conditions. In the buoyancy-dominated regime, L* is correlated by the expression

$$L^* = \frac{13.5 Fr_f^{2/5}}{\left(1 + 0.07 Fr_f^2\right)^{1/5}} \text{ for } Fr_f < 5 \qquad \textbf{(E.2.1f)}$$

and in the momentum-dominated regime by the expression

$$L^* = 23 \text{ for } Fr_f > 5 \qquad \textbf{(E.2.1g)}$$

The flame length data of Schefer *et al.* (2006, 2007) for large-scale hydrogen flames is shown on the plot and is found to be in good agreement with the L* correlations given by Eqs. (E.2.1f) and (E.2.1g). For choked flow conditions the concept of a notional expansion and effective source diameter (see next section) was used to reduce the hydrogen flame length measurements for plotting in terms of L* in Figure E.2.1(c). The simulation also uses this same effective diameter approach to recover the visible flame length, L_{vis}, from the values of L* computed from Eqs. (E.2.1f) and (E.2.1g).

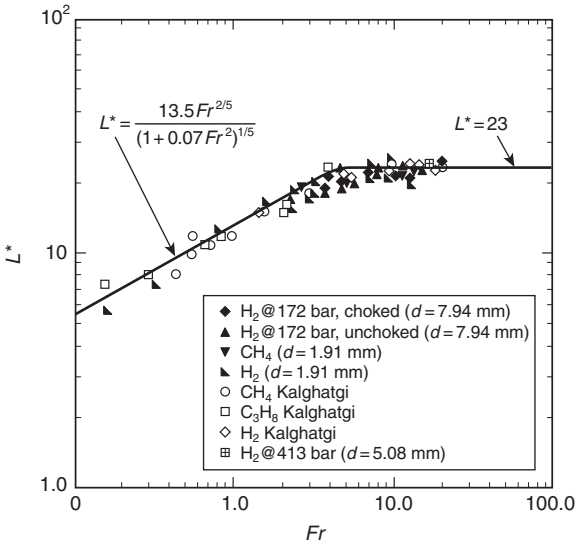


FIGURE E.2.1(c) Variation of Dimensionless Visible Flame Length with Flame Froude Number.

If the jet exit velocity and density of a hydrogen flame are known, then Eq. (E.2.1d) can be used to calculate the flame Froude number and Eq. (E.2.1e) and both Eq. (E.2.1f) and Eq. (E.2.1g) can then be used to compute the visible length of the flame, L_{vis}. The flame width, W_f, can be computed from the expression $W_f = 0.17 L_{vis}$ and used in Eq. (E.2.1c) to compute the global flame residence time, τ_f. Knowing the flame residence time, a curve-fit to the hydrogen radiant fraction data in Figure E.2.1(b) can be used to determine the radiant fraction of the hydrogen flame. Knowing the radiant fraction and using a curve-fit to the C* curve shown in Figure E.2.1(a), Eq. E.2.1b can be used to compute the radiant heat flux from the hydrogen flame at any axial position, x, and radial position r.

E.2.2 Unignited Jet Concentration Decay Model. For cases where the high-pressure leak of hydrogen is unignited, a classic high-momentum turbulent jet is formed that can be described using the same coordinate system shown in Figure E.2.

The hydrogen concentration within the jet varies with axial position, x, and radial position, r, due to entrainment and turbulent mixing with the ambient air.

The nature of the concentration field of subsonic, momentum-dominated incompressible turbulent free jets is well documented in the literature (Chen and Rodi, 1980). The decay of the mean volume fraction, $\bar{\eta}_{cl}$, (or mean mole fraction) along the centerline of the jet is given by an expression of the form

$$\eta_{cl}(x) = \frac{K d_j}{x + x_o}\left(\frac{\rho_\infty}{\rho_{gas}}\right)^{1/2} \qquad \textbf{(E.2.2a)}$$

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where K is the entrainment constant, ρ_∞ is the density of the ambient fluid, ρ_{gas}, is the density of the exiting gas evaluated at ambient temperature and pressure, and x_o is the virtual origin of the jet (Chen and Rodi, 1980).

For high-pressure leaks of hydrogen, the exit flow chokes at the sonic velocity if the pressure ratio across the leak is greater than the critical pressure ratio (approximately 1.9 for hydrogen). At pressure ratios higher than the critical value, the exit velocity remains locally sonic. For these supercritical releases, the flow leaves the exit to form an underexpanded jet that quickly expands to ambient pressure through a complex flow structure involving one or more shocks. As a result, the concentration field behaves as if it were produced by a larger source than the actual exit diameter and the diameter of this effective source is referred to as the effective diameter, d_{eff}. The work of Birch (1984, 1987) for natural gas jets indicates that the classical laws for concentration decay for turbulent jets in pressure equilibrium [i.e., Eq. (E.2.2a)] can be applied to underexpanded jets resulting from supercritical releases provided that the jet exit diameter, d_j, is replaced by the effective diameter d_{eff}. The reports of Britter (1994, 1995) discuss various approaches for computing effective diameter source models for underexpanded jets.

The effective source diameter model used in this work is formulated by considering a notional expansion (Birch, 1987) that conserves both mass and momentum while retaining the assumption that the pressure is reduced to ambient pressure at the end of the expansion. Based on the work of Birch (1987), the equation for the effective source diameter is

$$d_{eff} = \left(\frac{\rho_j u_j}{\rho_{gas} u_{eff}} \right)^{1/2} d_j \qquad \textbf{(E.2.2b)}$$

where ρ_j is the jet exit density, u_j is the jet exit velocity, ρ_{gas} is the density of the exiting gas evaluated at ambient pressure and temperature, d_j is the jet exit diameter, and u_{eff} is the velocity at the end of the expansion. The effective velocity at the end of the expansion is given by an expression of the form_1

$$u_{eff} = u_j + \left(P_j - P_\infty \right) / \left(\rho_j u_j \right) \qquad \textbf{(E.2.2c)}$$

where p_j is the jet exit pressure and p_∞ is the ambient pressure. Equations (E.2.2b) and (E.2.2c) can be used to compute the effective source diameter for supercritical releases and are valid for real gas as well as ideal gas models as long as the jet exit conditions are computed properly. For hydrogen at 200 bar and 300K the compressibility factor Z (where $Z = p/(\rho RT)$ is approximately 1.12; at a pressure of 800 bar and the same temperature the compressibility factor is approximately 1.51. For an ideal gas, Z is equal to unity.

For supercritical releases the effective source diameter replaces the jet diameter in Eq. (E.2.2a) and centerline concentration decay equation becomes

$$\eta_{cl}(x) = \frac{K d_{eff}}{x + x_o} \left(\frac{\rho_\infty}{\rho_{gas}} \right)^{1/2} \qquad \textbf{(E.2.2d)}$$

At each axial position, x, the radial variation of the concentration is computed from the expression

$$\eta(x,r) = \eta_{cl}(x) e^{-K_c (r/x+x_o)^2} \qquad \textbf{(E.2.2e)}$$

where the value of $K_c = 57$ for a round jet (Chen and Rodi, 1980). Equations (E.2.2b), (E.2.2c), (E.2.2d), and (E.2.2e) can be used to compute the concentration field from a high-momentum turbulent jet resulting from the supercritical release of hydrogen. For the studies performed in this paper, a value of the entrainment coefficient equal to K=5.40 (Birch, 1987) was used for the simulations. The value of the virtual origin, x_o, is typically a small multiple (less than 5) of the jet exit diameter and was set to zero for these studies in accordance with the work of Birch (1987).

E.3 Comparison of Models with Experimental Data.

E.3.1 Flame Radiation Heat Flux and Flame Length Model. The hydrogen flame radiation and flame length models were compared against the large-scale hydrogen jet flame experiments of Schefer *et al.* (2006, 2007). In these experiments, hydrogen gas was released from a "six-pack" of high-pressure cylinders, each connected to a central manifold with a common outlet. Typical pressure in the full cylinders was 137.9 bar (2000 psia) to 172.3 bar (2500 psia).

To obtain jet exit conditions, a network flow model of the piping and high-pressure cylinders used in the experiment was developed using the Sandia developed Topaz code (Winters, 1984). The network flow model considers the non-ideal gas behavior of hydrogen through an Abel-Nobel equation of state (Chenoweth, 1983) of the form

$$p = \frac{\rho R_{H_2} T}{(1 - b\rho)} \qquad \textbf{(E.3.1)}$$

where the values of R_{H_2} = 4,124.18 J/kg-K and b = 7.691 $\times 10^{-3}$ m^3/kg were used for hydrogen. The model can also be used with an ideal-gas equation of state by setting the value b equal to zero.

The tank blow-down and network flow model was used to predict the flow and pressure drop through the piping leading to the jet exit. These jet exit conditions were then used with the flame length and radiant fraction correlations described in the previous section to predict the hydrogen jet flame characteristics. Comparisons of the measured and predicted pressure history curves in the high-pressure cylinders were used to validate the tank blow-down network flow model (Schefer *et al.*, 2006). Simulations with the network flow model indicated that significant pressure drop occurred in the piping of the experiment with the total pressure at the jet exit being approximately 16.4 bar (226 psig) or a static pressure of approximately 13.6 bar (182 psig) at 0.1 second into the blow-down.

Figure E.3.1(a) shows a comparison of the flame length predictions from the model with the large-scale hydrogen jet flame length data. Because an approximate ±10% scatter occurs in the data around the L* correlation *[see Figure E.2.1(c)]* used in the model, an uncertainty analysis was performed where the L* correlation was increased and then decreased by 10% from its nominal value. Calculations are shown in Figure E.3.1(a) for the nominal L* correlation, and an increase in L* of 10% and a decrease in L* of –10%. Predictions from the model are found to be in good agreement with the measured hydrogen flame lengths.

Figure E.3.1(b) shows a comparison of simulations and measured radiation heat flux data along the axis of a hydrogen jet flame at a radial distance of 1.82 m (6 ft) from the flame centerline at a time 5 seconds into the blow-down of the high-pressure hydrogen cylinders. An approximate ±10% scatter occurs in the

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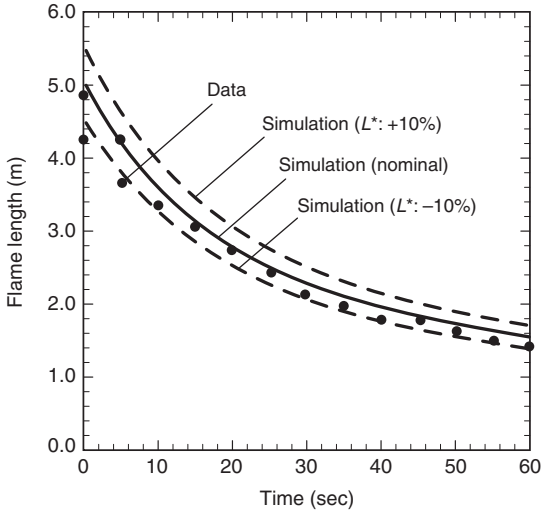


FIGURE E.3.1(a) Comparison of Simulation of Hydrogen Visible Flame Length with the Hydrogen Jet Flame Data of Schefer et al. (2006).

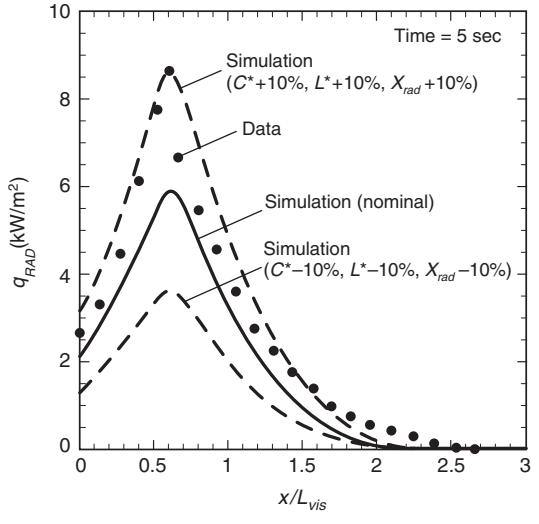


FIGURE E.3.1(b) Comparison of Simulation of Radiative Heat Flux from a Hydrogen Flame at a Radial Position of r=1.83 m with the Data at 5 Seconds into the Blow-Down.

data around the L* correlation *[see Figure E.2.1(c)]*, the C* correlation *[see Figure E.2.1(a)]*, and the radiant fraction correlation *[see Figure E.2.1(b)]*, X_{rad}. Hence, an uncertainty analysis was performed where model calculations were performed with the nominal values of these correlations, and an increase of 10% to each of the 3 correlations (upper bound on radiative heat flux), and a decrease of –10% to each of the correlations (lower bound on radiative heat flux). The results of these calculations are shown in Figure E.3.1(b). An additional comparison with data using the same approach is shown in Figure E.3.1(c) at a time of 10 seconds into the blow-down. The range of the calculations with either an increase of 10% or decrease of 10% in each of the correlations for L*, C*, and X_{rad} are able to bound the range of experimental data adequately at both times.

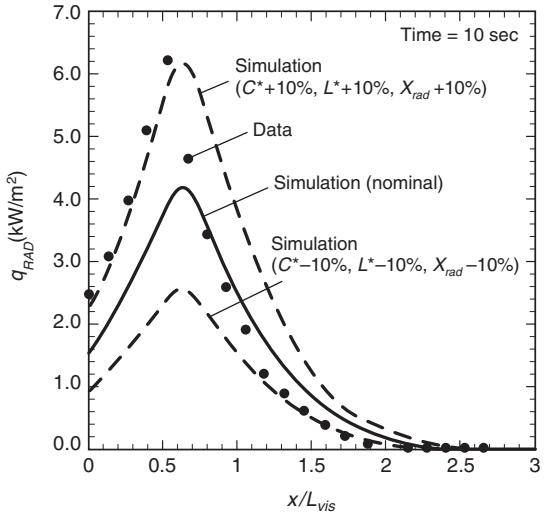


FIGURE E.3.1(c) Comparison of Simulation of Radiative Heat Flux from a Hydrogen Flame at a Radial Position of r=1.83 m with the Data at 10 Seconds into the Blow-Down.

E.3.2 Unignited Jet Concentration Decay Model. There appears to be a lack of data in the literature for the concentration decay of momentum-dominated, choked flow, unignited turbulent hydrogen jets resulting from supercritical releases. Hence the unignited jet model was compared with the jet concentration decay data of Birch (1984) for supercritical releases of natural gas. Birch measured the concentration decay of natural gas into air for a 2.7 mm diameter round nozzle connected to a regulated high-pressure natural gas supply. The method of concentration measurement in the experiment integrated the turbulent concentration fluctuations in the flow and resulted in a time-averaged concentration measurement at each axial location. Measurements of the mean concentration level at different axial positions along the jet centerline were made for supply pressures ranging from 3.5 to 71 bar. Birch found if the mean concentration decay along centerline was plotted in terms of the non-dimensional coordinate $x/(d_j(p_{supply}/p_\infty)^{0.5})$, then the data collapsed onto a single curve.

Calculations with the unignited jet model discussed in the previous section were performed using natural gas properties and generating jet exit conditions for a large high-pressure supply attached to a short round nozzle. The Topaz network flow code with an ideal gas equation of state for natural gas was used to generate jet exit conditions for this geometry. Calculations were performed at pressures of 18.25 bar (250 psig) and 207.85 bar (3000 psig) for jet exit diameters of 0.794 mm and 1.158 mm. The axial variation of the reciprocal of the mean concentration $(1/\overline{\eta}_{ct})$ on jet centerline was plotted in terms of the non-dimensional axial coordinate, $x/(d_j(p_{supply}/p_\infty)^{0.5})$, where d_j is the jet exit diameter, p_{supply} is the pressure in high-pressure supply, p_∞ is the ambient pressure. Comparison of the calculations from the model with the data of Birch (1984) using the nominal value of the turbulent entrainment constant (K = 5.40) is shown in Figure E.3.2. Based on data reported by Birch (1984, 1987) there appears to be approximately ±10% variation in the value of the turbulent entrainment constant, K. Hence, in addition to using the nominal value of K, calculations were performed for the 207.85 bar 1.158 diameter nozzle by varying K ±10% from the nominal value. Results of the calculations using the nominal value of K are in excellent agreement with the data

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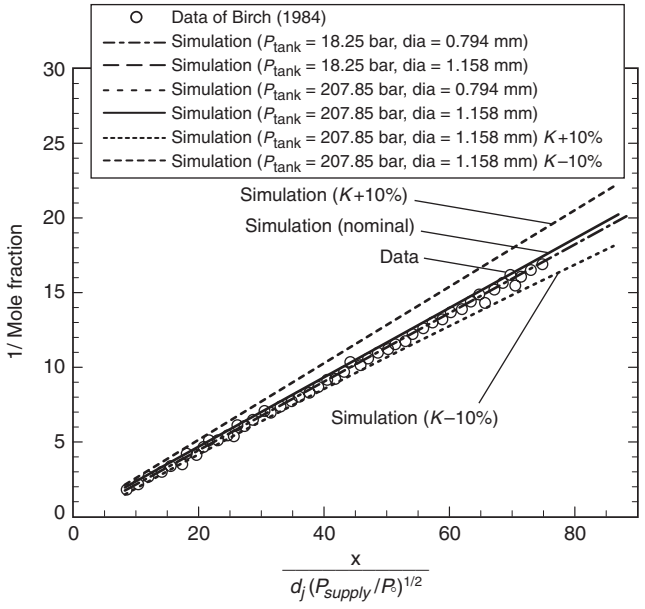


FIGURE E.3.2 Comparison of Simulation of Centerline Concentration Decay for Gas Unignited Jets with the Data of Birch [3].

of Birch. Moreover the calculations at 207.8 bar, which are well beyond the maximum pressure of 71 bar used in Birch's experiments, are found to be in excellent agreement with the collapsed data curve plotted in terms of $x/(d_j(p_{supply}/p_\infty)^{0.5})$. The work of Ruffin *et al.* (1996) also appears to confirm the notional expansion concentration decay model of Birch for supercritical jets of methane and hydrogen at a pressure of 40 bar.

E.4 Simulation of Unintended Releases.

E.4.1 Hydrogen Jet Flame Radiation and Unignited Jet Concentration Decay. Simulations for unintended releases of hydrogen were performed by considering a break in the tubing directly connected to a large hydrogen storage container. Based on a survey of a panel of experts (ICC, 2003) familiar with current and intended uses of hydrogen, pressures in the range from 18.25 bar (250 psig) to 1,035.21 bar (15,000 psig) and leak diameters in the range from 9.525 mm (⅜ inch) to 0.25 mm were suggested for analysis.

For the simulations reported in this section a storage tank volume of 29.7 m^3 was used based on the recommendation of the expert panel. Calculations are reported for pressures of 18.25 bar (250 psig), 207.85 bar (3000 psig), 518.11 bar (7500 psig), and 1,035.21 bar (15,000 psig) and leak diameters ranging between 1.587 mm (1/16 inch) and 6.35 mm (¼ inch). Jet exit conditions were computed using the Topaz network flow code with an Abel-Nobel equation of state for hydrogen to simulate a large tank of hydrogen connected to a short length of tubing (3.175 mm) with a diameter equal to the diameter of the leak under consideration. The tank temperature was assumed to be initially at ambient temperature (294K) with the end of the tubing exiting to the ambient environment (1.0133 bar, 294K). Calculations were performed for hydrogen jet flames and unignited jets with the results for radiative heat flux and concentration decay being reported at 1 second into the tank blow-down for each case. At 1 second, the tank pressure has not changed significantly from its initial value and the radiative and concentration length scales are at their largest values.

For the hydrogen jet flames, radiative heat flux contours were recorded for heat flux levels of 1577 W/m^2 (500 Btu/hr-ft^2), 4732 W/m^2 (1500 Btu/hr-ft^2), and 25237 W/m^2 (8000 Btu/hr-ft^2). These heat flux levels corresponding to values listed in the 2003 International Fire Code (2002) for exposure at property line, exposure for employees for a maximum of 3 minutes, and exposure for noncombustible equipment, respectively. Figure E.4.1(a) shows results for the radiative heat flux from a hydrogen jet flame with a tank pressure of 207.85 bar (3000 psig) and a leak diameter of 3.175 mm (⅛ inch). Important safety related information recorded from the simulations includes the maximum radial position from the flame centerline for the given heat flux level, R_{max}, the axial location at which the maximum occurs, $X(R_{max})$, the combination of these two distances, $D_{rad}=(R_{max}+X(R_{max}))$, and the visible flame length, L_{vis}. Figure E.4.1(b) shows a plot of D_{rad} and the visible flame length for various leak diameters for a tank pressure of 207.85 bar. Also included on the plot are the upper and lower bounds for D_{rad} and L_{vis} assuming an uncertainty of ±10% in each of the values of C*, L*, and X_{rad}. Figure E.4.1(c) shows a plot of R_{max} and $X(R_{max})$ for various leak diameters for a tank pressure of 207.85 bar, including the upper and lower bounds for R_{max} and $X(R_{max})$ assuming ±10% uncertainty in each of the values of C*, L*, and X_{rad}. At this pressure the value of D_{rad} can be computed to approximately ±14% to ±18% depending on the jet diameter, while the flame length can be computed to approximately ±10%.

Figure E.4.1(d) shows mole fraction contours for the simulation of the concentration decay of an unignited jet of hydrogen for a tank pressure of 207.85 bar (3000 psig) and a leak diameter of 3.175 mm (⅛ inch). Important safety information recorded from the simulations is the distance from the jet exit to where the mean concentration decays to a given concentration level on the jet centerline. Although the generally accepted value for the upward-propagating lower flammability limit of hydrogen in air is 0.04 mole fraction, experimental data in the literature indicate that the limit may be as high as 0.072 mole fraction for horizontal-propagating flames and 0.095 mole fraction for downward-propagating flames (Zebetakis, 1965, Coward and Jones, 1952). For the unignited hydrogen jet simulations, distances from the origin to jet centerline concentration levels of 0.08, 0.06, 0.04, and 0.02 mole fraction were recorded, and these distances are referred to as

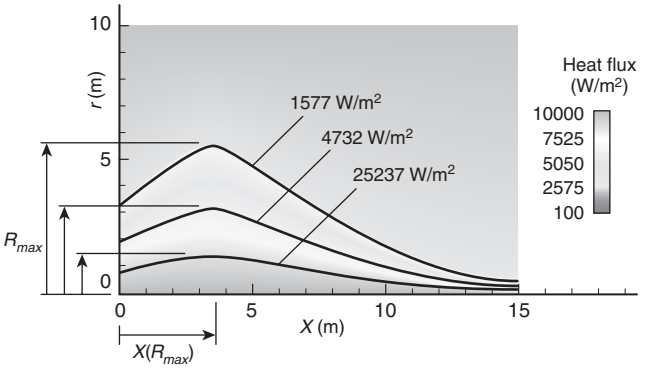


FIGURE E.4.1(a) Simulation of Radiation Heat Flux from a Hydrogen Jet Flame with a Leak Diameter of 3.175 mm and a Tank Pressure of 207.85 bar (3000 psig).

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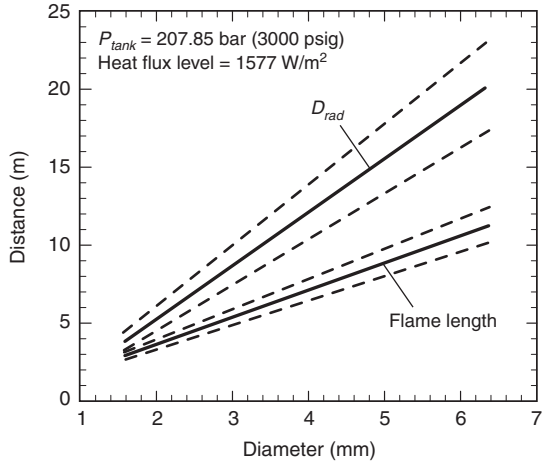


FIGURE E.4.1(b) Simulations of Hydrogen Jet Flame Radiation from a Tank at Pressure 207.85 bar (3000 psig) for Various Diameter Leaks. Results showing radiation distance, D_{rad} = ($X(R_{max}) + R_{max}$), for a heat flux level of 1577 W/m^2 and the visible flame length. Solid lines show distances using nominal values of C*, L*, and X_{rad}. Dashed lines show upper and lower bounds for D_{rad} and visible flame length with ±10% uncertainty in each of the values of C*, L*, and X_{rad}.

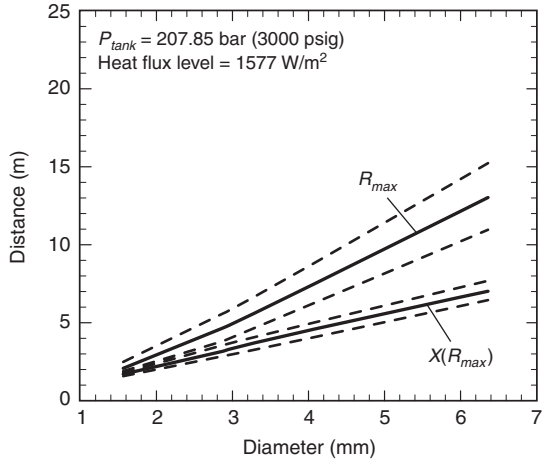


FIGURE E.4.1(c) Simulations of Hydrogen Jet Flame Radiation from a Tank at Pressure 207.85 bar (3000 psig) for Various Diameter Leaks. Results showing maximum radial distance from the flame centerline, R_{max}, for a heat flux level of 1577 W/m^2 and the axial location on centerline, $X(R_{max})$, where the maximum occurs. Solid lines show distances using nominal values of C*, L*, and X_{rad}. Dashed lines show upper and lower bounds for R_{max} and $X(R_{max})$ with ±10% uncertainty in each of the values of C*, L*, and X_{rad}.

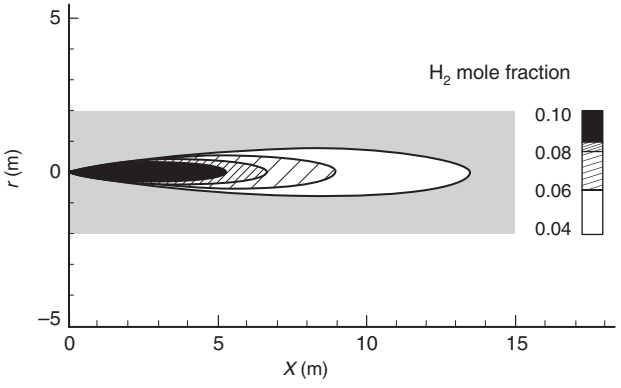


FIGURE E.4.1(d) Simulations of Concentration Decay of an Unignited Hydrogen Jet with a Diameter of 3.175 mm (⅛ inch) and a Tank Pressure of 207.85 bar (3000 psig). Contour lines correspond to mole fraction levels shown in the color legend.

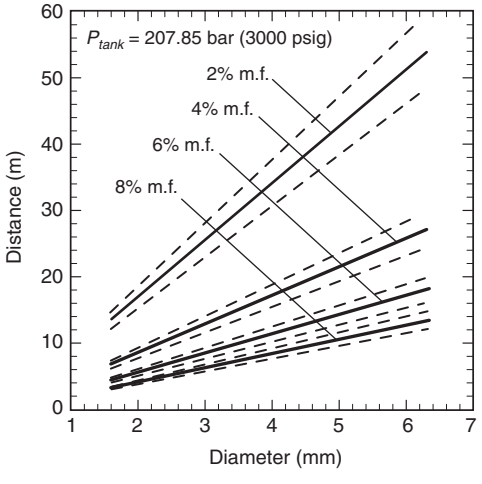


FIGURE E.4.1(e) Simulations of Concentration Decay for a Turbulent High-Momentum Supercritical Unignited Hydrogen Jet from a Tank at Pressure 207.85 bar (3000 psig) for Various Diameter Leaks. Results showing axial distance from jet origin to the point where jet concentration reaches 2.0%, 4.0%, 6.0%, and 8.0% mole fraction on jet centerline. Solid lines show distances using the nominal value of the turbulent jet entrainment constant, K = 5.40. Dashed lines show upper and lower bounds for distances with ±10% uncertainty in the value of K.

x8%, x6%, x4%, and x2% respectively. Figure E.4.1(e) shows a plot of unignited jet concentration decay distances for a tank pressure of 207.85 bar (3000 psig) for various leak diameters. Upper and lower bounds for the concentration decay distances are also shown on the plot assuming a ±10% uncertainty in the turbulent jet entrainment constant K.

Table E.4.1(a) shows a summary of radiation distances recorded from hydrogen jet flame simulations for 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) for selected leak diameters using the nominal values of C*, L*, and X_{rad}. Table E.4.1(b) shows a summary of concentration

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decay distances for unignited hydrogen jets for the same tank pressures and selected leak diameters using the nominal value of the entrainment constant K. Detailed plots of radiation and concentration decay distances for the range of parameters considered are presented in E.7.

Figure E.4.1(f) shows a comparison of hydrogen jet flame radiation hazard distances with unignited jet concentration decay distances for a range of tank pressures and leak diameters. Results are shown for the visible flame length and the radiation hazard distance, D_{rad}, for heat flux levels of 1577 W/m^2 and 4732 W/m^2. These radiation hazard distances are compared with unignited jet concentration decay distances from origin to jet centerline mean concentration levels of 0.08, 0.06, 0.04 mole fractions. For the range of pressures studied, the unignited jet concentration decay distance to the generally accepted lower flammability limit of hydrogen in air (0.04 mole fraction) is greater than the radiation jet flame hazard distance (D_{rad}) for exposure at property line (1577 W/m^2).

E.5 Summary and Conclusions. The previous sections presented methods by which the radiant heat flux from hydrogen jet flames and the concentration decay of supercritical high-momentum unignited hydrogen jets may be computed. If the jet exit conditions can be computed at the leak (Chernicoff *et al.*, 2005), then these methods can be used to compute hydrogen jet flame radiation and unignited jet concentration decay based on the models.

Table E.4.1(a) Hydrogen Jet Flame Radiation Distances for Selected Leak Diameters and Tank Pressures (Note: Assuming worst case of no pressure loss in tubing).

P_{tank} (bar)	d_j (mm)	$X(R_{max})$ (m)	R_{max} (m)	D_{rad} (m)	L_{vis} (m)	Heat Flux (W/m^2)
18.25	1.00	0.35	0.10	0.45	0.55	1577
18.25	1.00	0.35	0.059	0.41	0.55	4732
18.25	1.00	0.35	0.026	0.38	0.55	25237
18.25	2.3810	0.84	0.52	1.36	1.32	1577
18.25	2.3810	0.84	0.30	1.14	1.32	4732
18.25	2.3810	0.84	0.13	0.97	1.32	25237
18.25	4.2333	1.49	1.59	3.09	2.35	1577
18.25	4.2333	1.49	0.92	2.41	2.35	4732
18.25	4.2333	1.49	0.39	1.89	2.35	25237
18.25	6.35	2.24	2.90	5.14	3.52	1577
18.25	6.35	2.24	1.67	3.91	3.52	4732
18.25	6.35	2.24	0.72	2.96	3.52	25237
207.85	1.00	1.13	0.96	2.08	1.77	1577
207.85	1.00	1.13	0.55	1.68	1.77	4732
207.85	1.00	1.13	0.24	1.36	1.77	25237
207.85	2.3810	2.68	3.75	6.43	4.22	1577
207.85	2.3810	2.68	2.16	4.84	4.22	4732
207.85	2.3810	2.68	0.93	3.61	4.22	25237
207.85	4.2333	4.76	7.94	12.71	7.50	1577
207.85	4.2333	4.76	4.58	9.35	7.50	4732
207.85	4.2333	4.76	1.98	6.75	7.50	25237
207.85	6.35	7.14	13.09	20.23	11.25	1577
207.85	6.35	7.14	7.55	14.70	11.25	4732
207.85	6.35	7.14	3.27	10.42	11.25	25237
518.11	1.00	1.68	1.91	3.60	2.65	1577
518.11	1.00	1.68	1.10	2.79	2.65	4732
518.11	1.00	1.68	0.48	2.16	2.65	25237
518.11	2.3810	4.01	6.46	10.47	6.31	1577
518.11	2.3810	4.01	3.73	7.74	6.31	4732
518.11	2.3810	4.01	1.61	5.62	6.31	25237
518.11	4.2333	7.13	13.27	20.40	11.23	1577
518.11	4.2333	7.13	7.66	14.79	11.23	4732
518.11	4.2333	7.13	3.31	10.45	11.23	25237
518.11	6.35	10.69	21.58	32.28	16.84	1577
518.11	6.35	10.69	12.46	23.16	16.84	4732
518.11	6.35	10.69	5.39	16.09	16.84	25237
1035.21	1.00	2.21	2.89	5.10	3.48	1577
1035.21	1.00	2.21	1.67	3.88	3.48	4732
1035.21	1.00	2.21	0.72	2.93	3.48	25237
1035.21	2.3810	5.26	9.30	14.56	8.29	1577
1035.21	2.3810	5.26	5.37	10.63	8.29	4732
1035.21	2.3810	5.26	2.32	7.59	8.29	25237

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Table E.4.1(b) Unignited Hydrogen Jet Concentration Decay Distances on Jet Centerline for Selected Leak Diameters, Tank Pressures, and Mole Fractions (ie. X2% indicates the distance from jet origin to the point where the centerline concentration has decayed to a mean concentration of 2% mole fraction).

P_{tank} (bar)	d_j (mm)	X 2% (m)	X 4% (m)	X 6% (m)	X 8% (m)
18.25	0.25	0.67	0.33	0.22	0.16
18.25	0.50	1.34	0.67	0.44	0.33
18.25	1.00	2.67	1.34	0.89	0.67
18.25	2.3810	6.36	3.18	2.12	1.59
18.25	4.2333	11.31	5.65	3.77	2.82
18.25	6.35	16.97	8.48	5.65	4.24
207.85	0.25	2.13	1.07	0.71	0.53
207.85	0.50	4.26	2.13	1.42	1.07
207.85	1.00	8.53	4.26	2.84	2.13
207.85	2.3810	20.30	10.15	6.76	5.07
207.85	4.2333	36.10	18.05	12.03	9.02
207.85	6.35	54.13	27.06	18.04	13.53
518.11	0.25	3.19	1.59	1.06	0.80
518.11	0.50	6.38	3.19	2.13	1.60
518.11	1.00	12.77	6.38	4.25	3.19
518.11	2.3810	30.39	15.19	10.13	7.598
518.11	4.2333	54.03	27.01	18.01	13.50
518.11	6.35	81.03	40.51	27.01	20.25
1035.21	0.25	4.18	2.09	1.39	1.05
1035.21	0.50	8.37	4.18	2.79	2.09
1035.21	1.00	16.74	8.37	5.58	4.18
1035.21	2.3810	39.86	19.93	13.29	9.96
1035.21	4.2333	70.85	35.42	23.62	17.71
1035.21	6.35	106.24	53.12	35.41	26.56

An uncertainty analysis of the hydrogen jet flame radiation model (207.85 bar case) using an uncertainty of ±10% in each of the three experimentally measured correlations (C*, L*, X_{rad}), indicates that the radiation distance, D_{rad}, can be computed to approximately ±14% to ±18% for the jet diameters studied. The flame length can be computed to approximately ±10%. Assuming a ±10% uncertainty in the experimentally measured turbulent jet entrainment constant, K, an uncertainty analysis of the unignited jet concentration decay model indicates that concentration decay distances can be computed to ±10%. Figure E.7(a) through Figure E.7(e) in the appendix of this paper give detailed plots of the hydrogen jet flame radiation hazard distances [D_{rad}, $X(R_{max})$, R_{max}] and unignited jet concentration decay distances (including upper and lower bounds) for 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 from 0.25 mm to 6.35 mm.

E.6 Acknowledgements. This work was supported by the U. S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Hydrogen, Fuel Cells and Infrastructure Technologies Program.

E.7 Appendix. Figure E.7(a) shows simulation results of unignited hydrogen jet concentration decay distances and their uncertainty for the range of leak diameters and tank pressures studied. Figure E.7(b) through Figure E.7(e) show simulation results of hydrogen jet flame radiation distances and their uncertainty for the range of leak diameters and tank pressures studied.

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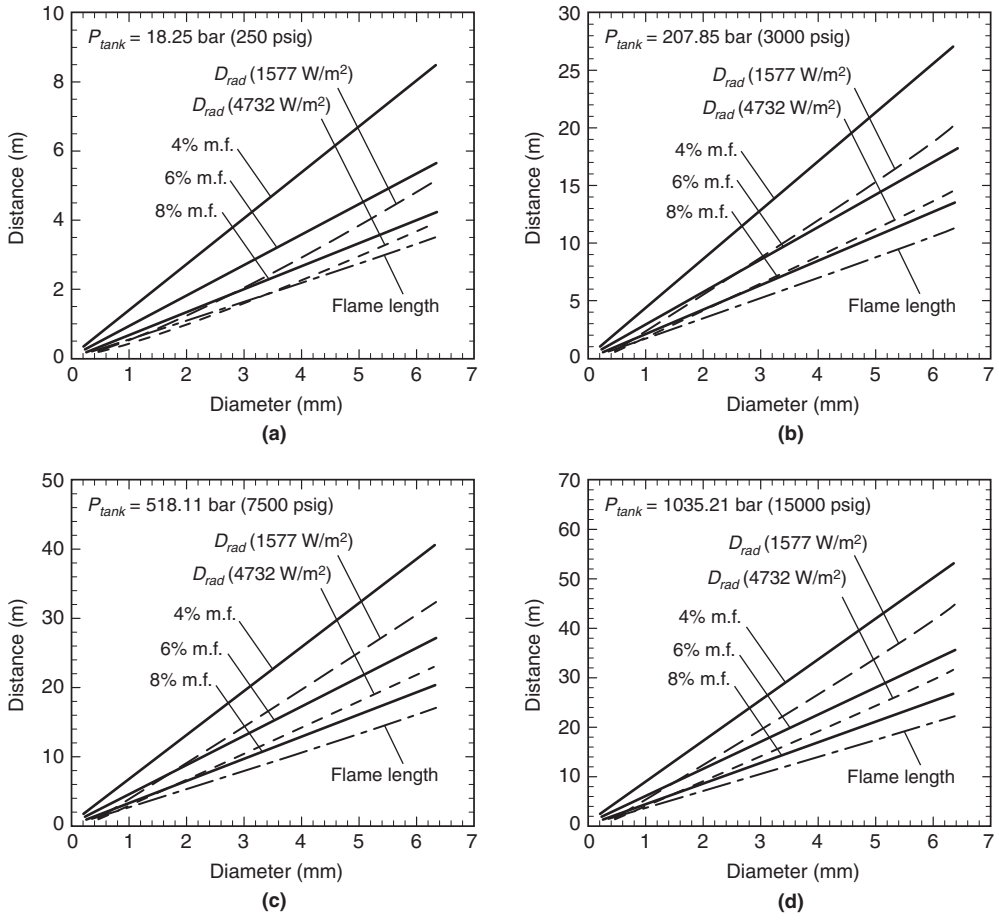


FIGURE E.4.1(f) Comparison of Simulations of Hydrogen Jet Flame Radiation Hazard Distances with Unignited Hydrogen Jet Centerline Concentration Decay Distances for Various Tank Pressures [18.25 bar (250 psig), 207.85 bar (3000 psig), 518.11 bar (7500 psig), 1035.21 bar (15000 psig)] and Leak Diameters. Dashed lines show the radiation hazard distance, $D_{rad} = (X(R_{max}) + R_{max})$, for radiation heat flux levels of 1577 W/m² and 4732 W/m² and the visible flame length. Solid lines show unignited jet concentration decay distances along jet centerline for concentration levels of 4%, 6%, and 8% mole fraction.

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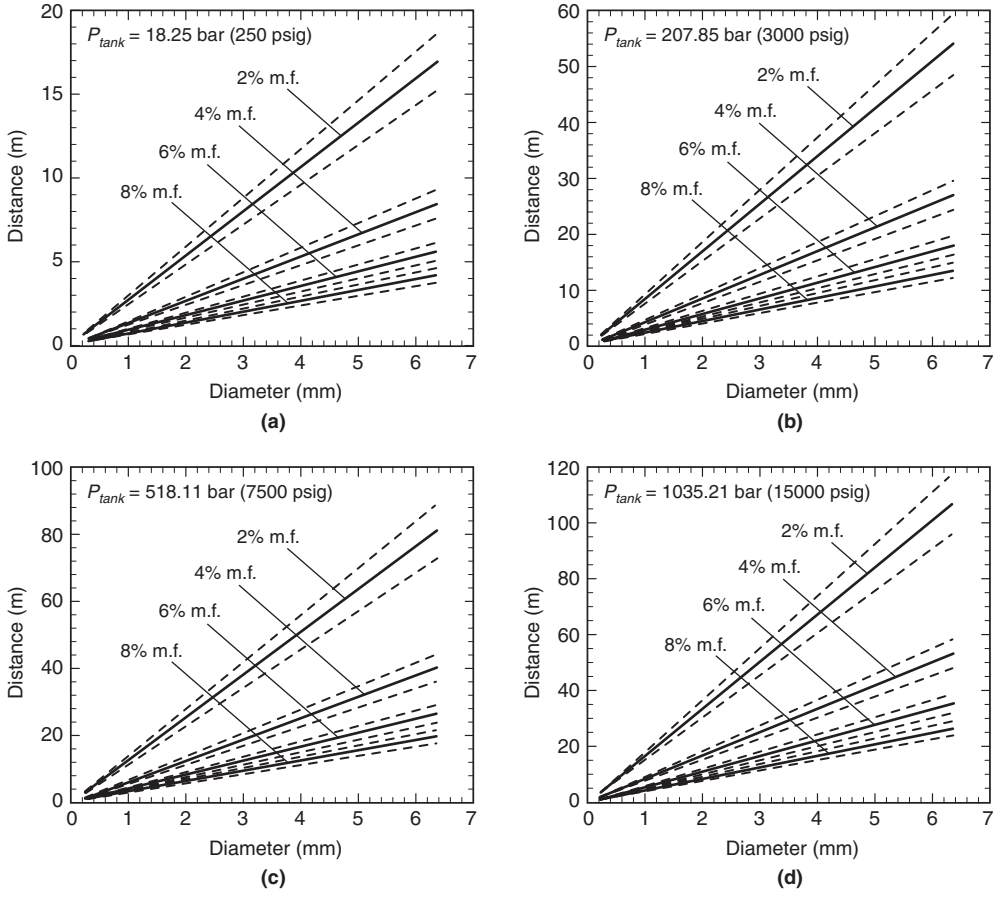


FIGURE E.7(a) Simulations of Concentration Decay for Turbulent High-Momentum Supercritical Unignited Hydrogen Jets from Tanks at Pressures from 18.25 bar (250 psig) to 1035.21 bar (15000 psig) for Various Diameter Leaks. Results showing axial distance from jet origin to the point where jet concentration reaches 2.0%, 4.0%, 6.0%, and 8.0% mole fraction on jet centerline. Solid lines show distances using the nominal value of the turbulent jet entrainment constant, K = 5.40. Dashed lines show upper and lower bounds for distances with ±10% uncertainty in the value of K.

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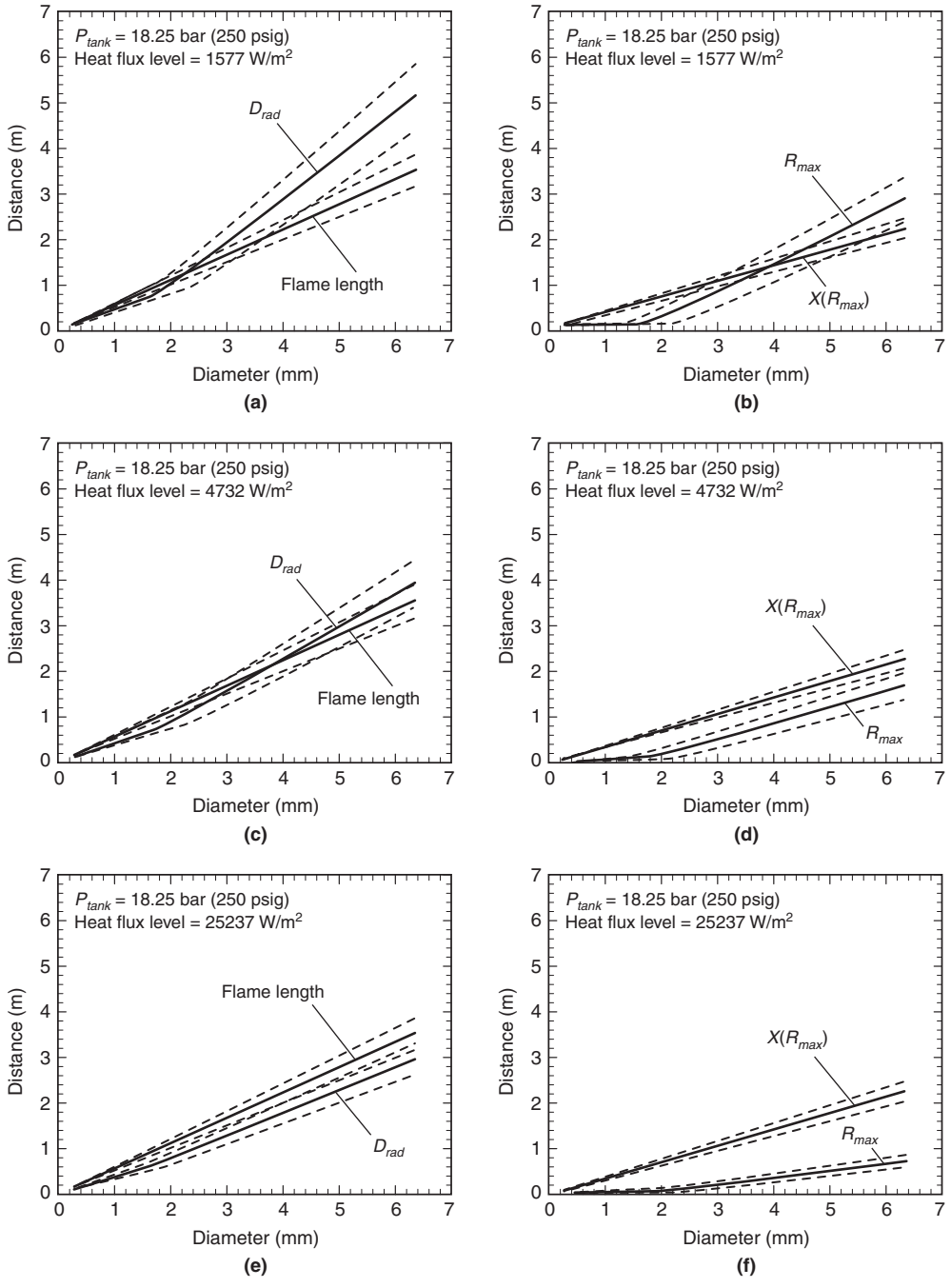


FIGURE E.7(b) Simulations of Hydrogen Jet Flame Radiation from a Tank at Pressure 18.25 bar (250 psig) for Various Diameter Leaks. Results showing maximum radial distance from the flame centerline, R_{max}, for a heat flux levels of 1577, 4732, and 25237 W/m^2 and the axial location on centerline, $X(R_{max})$, where the maximum occurs. Solid lines show distances using nominal values of C*, L*, and X_{rad}. Dashed lines show upper and lower bounds for R_{max} and $X(R_{max})$ with ±10% uncertainty in each of the values of C*, L*, and X_{rad}.

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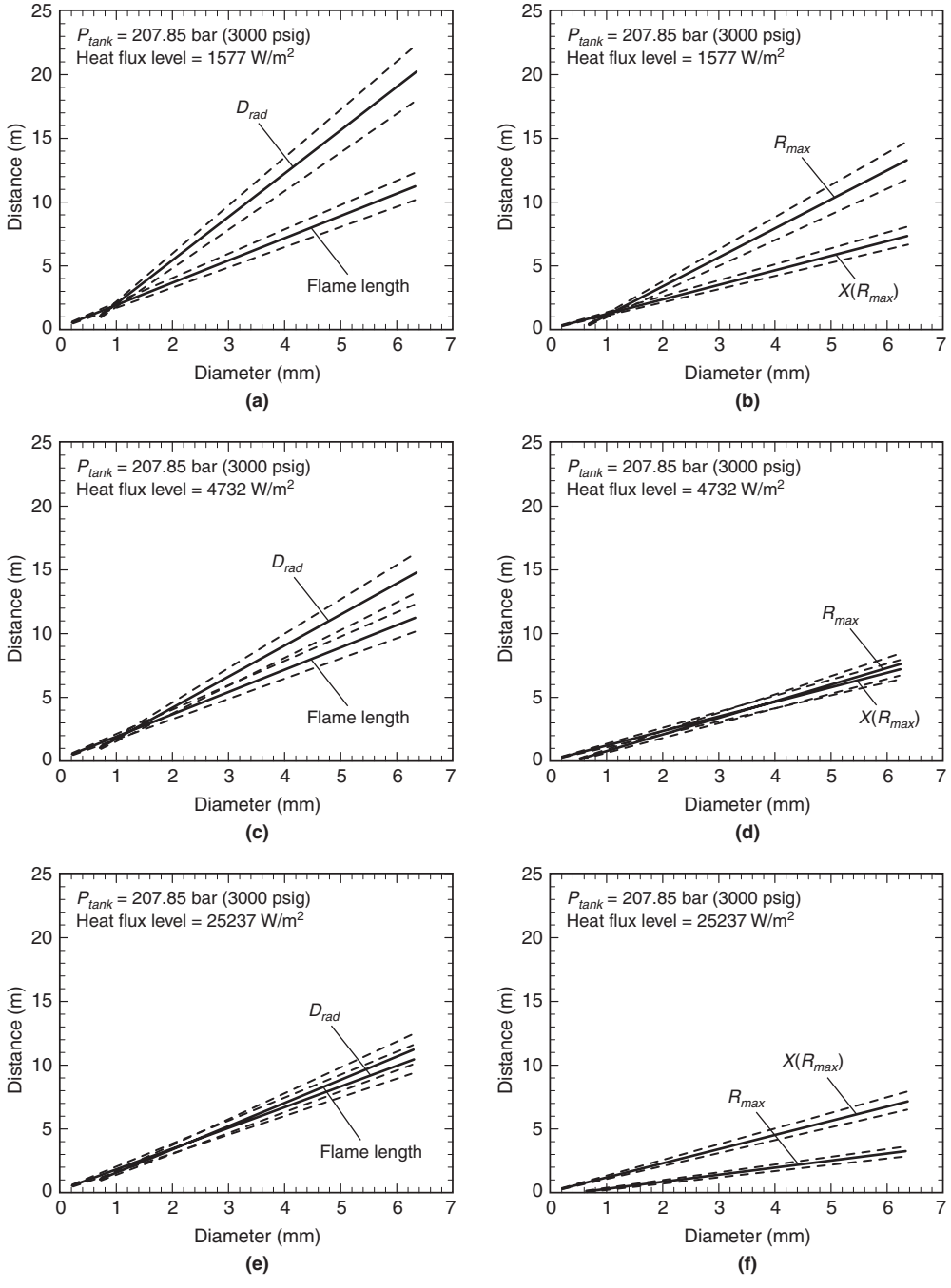


FIGURE E.7(c) Simulations of Hydrogen Jet Flame Radiation from a Tank at Pressure 207.85 bar (3000 psig) for Various Diameter Leaks. Results showing maximum radial distance from the flame centerline, R_{max}, for a heat flux levels of 1577, 4732, and 25237 W/m^2 and the axial location on centerline, $X(R_{max})$, where the maximum occurs. Solid lines show distances using nominal values of C*, L*, and X_{rad}. Dashed lines show upper and lower bounds for R_{max} and $X(R_{max})$ with ±10% uncertainty in each of the values of C*, L*, and X_{rad}.

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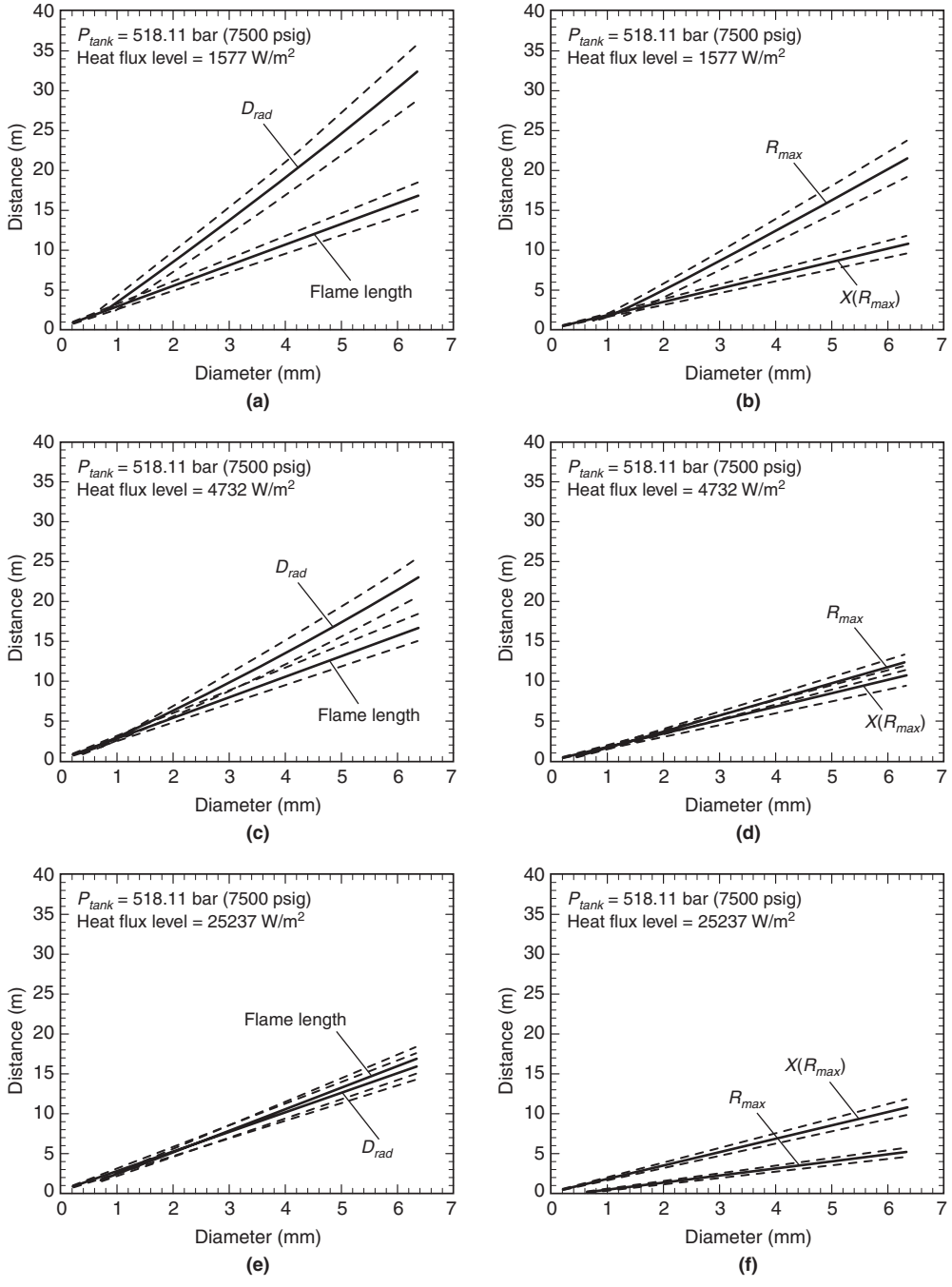


FIGURE E.7(d) Simulations of Hydrogen Jet Flame Radiation from a Tank at Pressure 518.11 bar (7500 psig) for Various Diameter Leaks. Results showing maximum radial distance from the flame centerline, R_{max}, for a heat flux levels of 1577, 4732, and 25237 W/m^2 and the axial location on centerline, $X(R_{max})$, where the maximum occurs. Solid lines show distances using nominal values of C*, L*, and X_{rad}. Dashed lines show upper and lower bounds for R_{max} and $X(R_{max})$ with ±10% uncertainty in each of the values of C*, L*, and X_{rad}.

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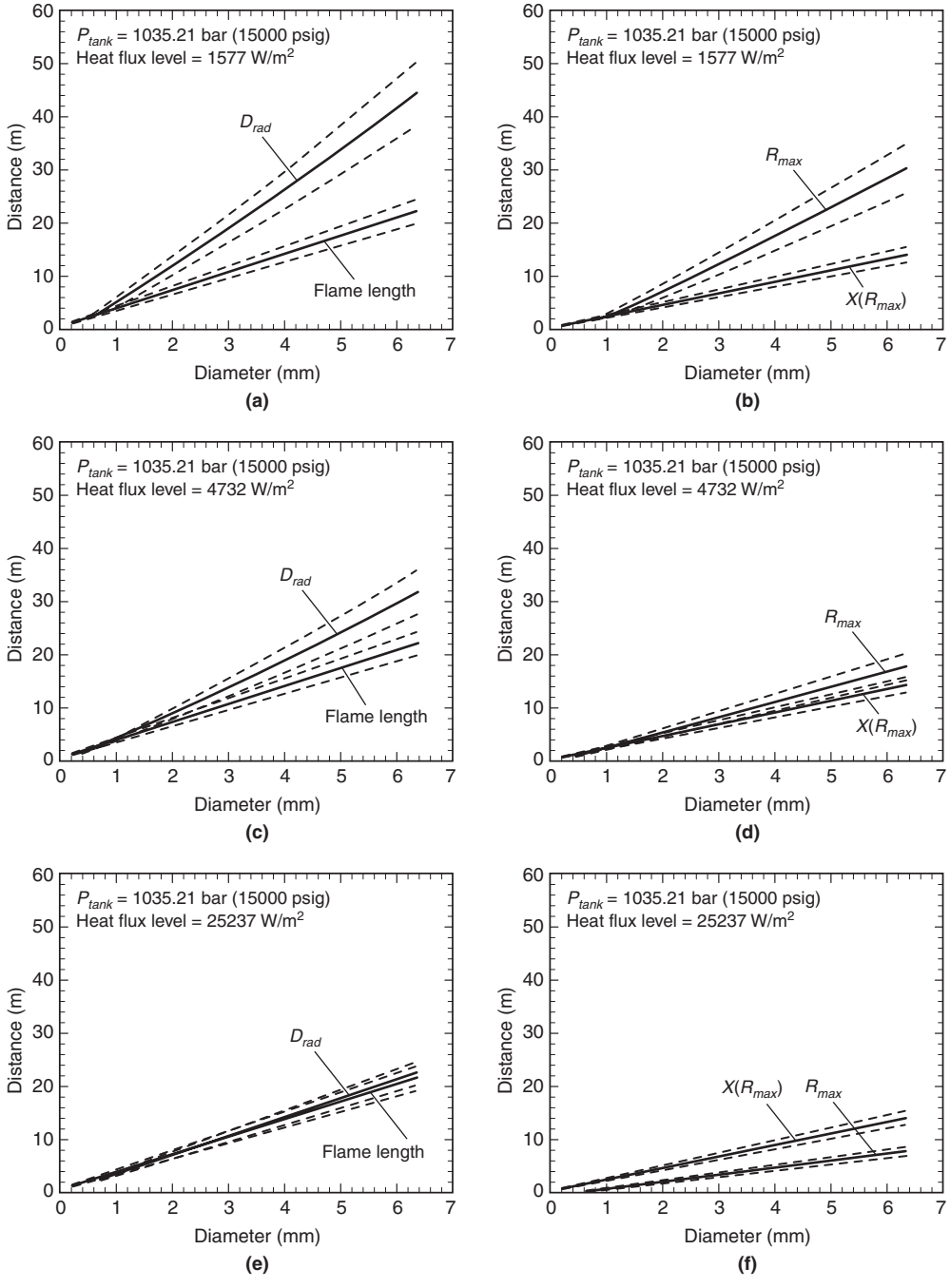


FIGURE E.7(e) Simulations of Hydrogen Jet Flame Radiation from a Tank at Pressure 1035.21 bar (15000 psig) for Various Diameter Leaks. Results showing maximum radial distance from the flame centerline, R_{max}, for a heat flux levels of 1577, 4732, and 25237 W/m^2 and the axial location on centerline, $X(R_{max})$, where the maximum occurs. Solid lines show distances using nominal values of C*, L*, and X_{rad}. Dashed lines show upper and lower bounds for R_{max} and $X(R_{max})$ with ±10% uncertainty in each of the values of C*, L*, and X_{rad}.

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Annex F Sample Ordinance Adopting NFPA 55

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

F.1 The following sample ordinance is provided to assist a jurisdiction in the adoption of this code and is not part of this code.

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; 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 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 G 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.

G.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 G.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

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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.

G.2 OSHA Tables. The OSHA tables [Table G.2(a) and Table G.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.

Table G.2(a) OSHA Table: Minimum Distance from Gaseous Hydrogen Systems to Exposure

	Size of Hydrogen System					
	<3,000 scf (85 Nm^3)		3,000 to 15,000 scf (85 m^3 to 425 Nm^3)		>15,000 scf (425 Nm^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 Nm^3) capacity	10	3.1	25	7.6	25	7.6
In excess of 15,000 scf (425 Nm^3) capacity	25	7.6	50	15.2	50	15.2
7. Oxygen storage						
12,000 scf (340 Nm^3) or less[4]				—		
More than 12,000 scf (340 Nm^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* (1969).

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Table G.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.

Annex H Explanation of Methodology Utilized to Develop Separation Distances Table 10.3.2.2.1(a), Table 10.3.2.2.1(b), and Table 10.3.2.2.1(c)

H.1 Separation Distances Tables Methodology. 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 10.3.2.1(a) and Table 10.3.2.1(b) have been developed to inform the user of the rationale considered for each of the exposures listed in Table H.1(a) and Table H.1(b). Table H.1(a) is cross-referenced to Table 10.3.2.1(a) and Table 10.3.2.1(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 H.1(b). 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

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Table H.1(a) 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 Combustible construction Noncombustible non-fire-rated construction 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) Openable Fire-rated or non fire-rated Unopenable 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 Nonbulk Bulk	2
12	Aboveground vents or exposed piping and components of flammable gas storage systems, including other hydrogen systems below ground Gaseous or cryogenic	6, 7
13	Hazardous materials (other than flammable gases) storage below ground Physical hazard materials or health hazard materials	6, 7
14	Hazardous materials storage (other than flammable gases) above ground 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 H.1(b) for explanation of notes.

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 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 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]

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Table H.1(b) Hazard Scenario Rationale Notes to Table H.1(a)

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]

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Table H.1(b) *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]

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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.3.3.93.2. 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.

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 and informational articles found in I.2. 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 10 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 the parameters given in Sections H.2 through H.5.

H.2 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.

H.3 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.[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

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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 2×10^{-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.

H.4 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]

H.5 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

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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.

H.6 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.

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Formal Interpretation

NFPA 55

Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks

2013 Edition

Reference: Table 10.3.2.2.1
F.I. No.: 55-05-1

Question: Do the requirements of NFPA 55 Table 10.3.2.2.1 relating to building exposures, apply to structures that are unattended, electrical devices housed in unoccupied, pre-fabricated equipment enclosures including cabinets, underground vaults and huts?

Answer: Yes

Issue Edition: 2005
Reference: Table 10.3.2.2.1. (1)
Issue Date: June 21, 2005
Effective Date: July 10, 2005

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Tentative Interim Amendment

NFPA® 55

Compressed Gases and Cryogenic Fluids Code

2013 Edition

Reference: 3.3.x Cleaning Media, Purging, 7.1.19, 8.14.1.5, 9.4.1.9, 10.2.3.2, 11.2.3.9, 12.3.2.8.5.7, 14.4.1.3, 14.4.3.1, 15.4.1.10.1.3, A.3.3.x, A.7.1.19.1.1(c), A.7.1.19.1.1(d), A.7.1.19.1.3, A.7.1.19.1.3.1, A.7.1.19.1.5.3, A.7.1.19.2, A.7.1.19.2.2, A.7.1.19.3, and H.1.2.4
TIA 13-2
(SC 12-10-5/TIA Log #1073)

Pursuant to Section 5 of the NFPA Regulations Governing Committee Projects, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2013 edition. The TIA was processed by the Technical Committee on Industrial and Medical Gases, and was issued by the Standards Council on October 30, 2012, with an effective date of November 19, 2012.

A Tentative Interim Amendment is tentative because it has not been processed through the entire standards-making procedures. It is interim because it is effective only between editions of the standard. A TIA automatically becomes a proposal of the proponent for the next edition of the standard; as such, it then is subject to all of the procedures of the standards-making process.

1. Add the following new definitions to Chapter 3, Definitions:

3.3.xx* Cleaning Media. Materials used to clean piping systems.

A.3.3.xx Cleaning Media. Cleaning methods that incorporate chemical washing techniques can include the use of chemical substances, usually liquid, capable of dissolving or dispersing a foreign substance or contaminants and can include techniques such as rinsing, heating, steaming, or vacuum with such techniques applied either individually or in combination with others. Air, inert gas, steam and water are acceptable cleaning media.

3.3.xx Purging. A method used to free the internal volume of a piping system of unwanted contents that results in the existing contents being removed or replaced.

2. Add the following new sections to Chapter 7, Compressed Gases:

7.1.19 Cleaning and Purging of Gas Piping Systems.

7.1.19.1 General.

7.1.19.1.1 Piping systems shall be cleaned and purged in accordance with the requirements of 7.1.19 when one or more of the following conditions exist:

(a) When the system is installed and prior to being placed into service.

(b) When there is a change in service.

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(c)* When there are alterations or repair of the system involving the replacement of parts or addition to the piping system and prior to returning the system to service.

(d)* Where specified by the design standards or written procedures.

7.1.19.1.2 Cleaning and purging of the internal surfaces of piping systems shall be conducted by qualified individuals trained in cleaning and purging operations and procedures, including the recognition of potential hazards associated with cleaning and purging.

7.1.19.1.3* A written cleaning or purging procedure shall be provided to establish the requirements for the cleaning and purging operations to be conducted.

7.1.19.1.3.1* An independent or third-party review of the written procedure shall be conducted after the procedure has been written and shall:
(1) evaluate hazards, errors, and malfunctions related to each step in the procedure
(2) review the measures prescribed in the procedure for applicability
(3) make recommendations for additional hazard mitigation measures if deemed to be necessary.

7.1.19.1.3.2 The completed written procedure shall be:
(1) maintained on site by the facility owner/operator
(2) provided to operating personnel engaged in cleaning or purging operations
(3) made available to the AHJ upon request.

7.1.19.1.3.3 Where generic cleaning or purging procedures have been established, a job-specific operating procedure shall not be required.

7.1.19.1.3.4 Generic procedures shall be reviewed when originally published or when the procedure or operation is changed.

7.1.19.1.4 Written procedures to manage a change in process materials, technology, equipment, procedures, and facilities shall be established by the facility owner/operator.

7.1.19.1.4.1 The management-of-change procedures shall ensure that the following topics are addressed prior to any change in the configuration or design of the piping system:
(1) The technical basis for the proposed change.
(2) The safety and health implications.
(3) Whether the change is permanent or temporary.
(4) Whether modifications to the cleaning and purging procedures are required as a result of the changes identified.

7.1.19.1.4.2 When modifications to the cleaning and purging procedures are required, the written procedure shall be updated to incorporate any elements identified by the management-of-change procedures.

7.1.19.1.5 Prior to cleaning or purging, piping systems shall be inspected and tested to determine that the installation, including the materials of construction, and method of fabrication, comply with the requirements of the design standard used and the intended application for which the system was designed.

7.1.19.1.5.1 Inspection and testing of piping systems shall not be required to remove a system from service.

7.1.19.1.5.2 Purging of piping systems shall not be required for systems that are utilized for operations designated by written operating procedures when systems are utilized in accordance with the requirements of the cleaning or purging procedure specified in 7.1.19.1.1.

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7.1.19.1.5.3* Personnel in the affected area(s), as determined by the cleaning or purging procedure, shall be informed of the hazards associated with the operational activity and notified prior to the initiation of any such activity.

7.1.19.2* Cleaning. Piping system designs shall be documented to specify the requirements for the internal cleaning of the piping system prior to installation and initial use.

7.1.19.2.1 The internal surfaces of gas piping systems shall be cleaned to ensure that the required standard of cleanliness specified by the design is met prior to placing the gas piping system into service.

7.1.19.2.2* When piping systems are cleaned in stages during installation or assembly, the interior of the cleaned piping shall be protected against the infiltration of unwanted contaminants.

7.1.19.3* Purging. Piping systems used to contain gases with a physical or health hazard in any of the categories specified by Section 5.1 shall be purged prior to being placed into service for initial use.

7.1.19.3.1 Piping systems shall be purged to remove the internal contents preceding the following activities or operations to:
(1) activate or place a piping system into service
(2) deactivate or remove a piping system from service
(3) change the service of a piping system from one gas to another, except when such gas is supplied to a manifold or piping system designed for the purpose of filling or otherwise processing cylinders, containers, or tanks in a process with established procedures
(4) perform service, maintenance or modifications on a system where personnel or designated areas will potentially be exposed to the internal contents of the piping system
(5) perform hot work including but not limited to welding, cutting or brazing on the piping system.

7.1.19.3.2 The termination point for the release of purged gases shall be in accordance with Section 6.15.

7.1.19.3.2.1 The release of purged gases or mixtures containing any quantity of corrosive, toxic, or highly toxic gases shall be through a treatment system in accordance with the applicable requirements of Section 7.5.3.4 or 7.9.3.

7.1.19.3.2.2 The termination point for the release of purged gases resultant from the purging of piping systems out of service, other than those in accordance with Section 7.1.19.3.2.1, shall not be required to be in accordance with Section 6.15 where the contained volume of the piping system when released to indoor areas does not result in a concentration in the room or area that exceeds any of the following limits or that will reduce the oxygen concentration in the room or area below a level of 19.5%:

(1) Ceiling Limit
(2) Permissible Exposure Limit
(3) Short Term Exposure Limit
(4) 25% of the Lower Flammable Limit

A.7.1.19.1.1(c) The replacement of parts in a system to repair leaks, the addition of gaskets, and similar routine maintenance is not intended to establish the need for cleaning of the entire piping system. Conversely, when a piping system is extended, or when the system needs to be rendered safe for maintenance purposes, purging the system before disassembly will likely be required as will internal cleaning if new piping or materials of construction are introduced.

A.7.1.19.1.1(d) Cleaning and purging of piping systems can be conducted as individual functions, i.e., just cleaning or just purging, or in combination as required to satisfy the requirements of the procedures.

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A.7.1.19.1.3 It is not intended that a new written procedure be required each time the activity occurs within a facility.

A.7.1.19.1.3.1 The review of the written procedures should not be performed solely by the same person or persons responsible for developing the procedures. It can be performed by an independent person or group within the company or department or by a third-party consultant.

A.7.1.19.1.5.3 The notification is given to warn personnel that such procedures are about to occur so that they will be out of zones potentially affected by the cleaning or purging procedure. The intended notification is to be commensurate with the operation to be conducted and the timing of the notification should be relevant to the activity conducted so that personnel in the area can respond in a timely manner. Notification could consist of sounding of an audible and/or visible alarm, or it could consist of an announcement over a public address system, private network, radio, or similar and reliable means of electronic transmission.

Verbal notification can be used in operations where the piping system is limited to the area occupied by those that will be conducting the cleaning or purging procedures and related operating personnel. These areas are frequently found in occupancies where the gas used to charge the piping system is supplied from portable containers, as well as those areas where the piping system is primarily located in the occupied work area.

A.7.1.19.2 Cleaning. For additional information on cleaning techniques used for stainless steel parts and equipment, see ASTM A380, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.*

A.7.1.19.2.2 During construction, visual inspection should be performed on sections of pipe as the piping system is assembled to ensure that no gross contamination is left in the pipe. When the standard of cleanliness is high, fabrication techniques should be utilized that do not introduce contamination into the pipe. Examples of these techniques can include, but are not limited to, constant inert gas purging, or assembly in a particulate controlled environment. The use of piping and components with a high quality interior surface finish, and materials of construction-all have an effect on the ability to maintain a high degree of cleanliness.

Cleaning after construction can typically be accomplished by applying one or more of the following methods:

(1) pigging
(2) mechanical scraping
(3) high velocity gas flow
(4) liquid washing
(5) use of cleaning media
(6) application of high vacuum
(7) solvent cleaning
(8) water washing
(9) steam cleaning.

A.7.1.19.3 Purging. Purging can be accomplished by continuous media or gas flow, evacuation or vacuum, or repeated pressurizing and venting cycles commonly referred to as pulse or cycle purging. In some cases purge procedures can involve more than one type of purging technique. Purging can be accomplished by manual or automatic means. The use of automated purge panels or manifold systems operated by a programmable logic controller is common as a means to enhance the results of a purging process where high purity gas delivery systems are employed.

3. Add the following new subsection to Chapter 8, Cryogenic Fluids:

8.14.1.5 Cleaning and Purging of Gas Piping Systems. Cleaning and purging of piping systems shall be in accordance with Section 7.1.19.

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4. Add the following new subsections to Chapter 9, Bulk Oxygen Systems:

9.4.1.9 Cleaning and Purging of Gas Piping Systems. Cleaning and purging of piping systems shall be in accordance with Section 7.1.19.

9.4.1.9.1 Cleaning of oxygen systems used in medical gas service shall be in accordance with NFPA 99, *Health Care Facilities Code.* See also 9.4.3.1.

5. Add the following new subsection to Chapter 10, Gaseous Hydrogen Systems:

10.2.3.2 Cleaning and purging of piping systems shall be in accordance with Section 7.1.19.

6. Add the following new subsection to Chapter 11, Liquid Hydrogen Systems:

11.2.3.9 Cleaning and purging of piping systems shall be in accordance with Section 7.1.19.

7. Revise Chapter 12 Gas Generation Systems as follows:

12.3.2.8.5.7 Process Purging and Venting. Process purging and vents shall conform to the following:
(1) Pressure equipment and piping intended to be purged, pressure regulators, relief valves, and other potential sources of combustible gas shall be vented to the outside of the building in accordance with the applicable requirements of Section 6.15 or 7.1.19.
(2) The vent shall be designed to prevent entry of water or foreign objects.
(3) The vent gas shall be directed so as to not create additional hazards to the building openings, such as windows, doors, or HVAC intakes.

8. *Revise Chapter 14 Storage, Handling, and Use of Ethylene Oxide for Sterilization and Fumigation as follows:*

14.4.1.3 Cleaning and Purging of Gas Piping Systems. Cleaning and purging of piping systems shall be in accordance with Section 7.1.19.

14.4.3.1 Piping and valves that have been used to transport ethylene oxide to or from a sterilizer to the emission control or release point shall be drained and purged in accordance with Section 7.1.19 prior to dismantling.

9. Revise Chapter 15 Acetylene Cylinder Charging Plants as follows:

15.4.1.10.1.3 Cleaning and purging of piping systems shall be in accordance with Section 7.1.19.

10. Add the following to H.1.2.4:

ASTM A380, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.*

Issue Date: October 30, 2012
Reissued: May 24, 2013
Reissued: June 6, 2013

Effective Date: November 19, 2012

(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/codelist)

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Tentative Interim Amendment

NFPA® 55

Compressed Gases and Cryogenic Fluids Code

2013 Edition

Reference: 15.3.9 and A.15.3.9
TIA 13-1
(SC 12-10-4/TIA Log #1071)

Pursuant to Section 5 of the NFPA Regulations Governing Committee Projects, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2013 edition. The TIA was processed by the Technical Committee on Industrial and Medical Gases, and was issued by the Standards Council on October 30, 2012, with an effective date of November 19, 2012.

A Tentative Interim Amendment is tentative because it has not been processed through the entire standards-making procedures. It is interim because it is effective only between editions of the standard. A TIA automatically becomes a proposal of the proponent for the next edition of the standard; as such, it then is subject to all of the procedures of the standards-making process.

1. Revise 15.3.9 as follows:

15.3.9 Fire Protection.

15.3.9.1 MATS. Fire protection requirements for MATS shall apply to charging or discharging stations located indoors or outdoors.

15.3.9.1.1* A deluge or water spray fixed system shall be provided for MATS fire areas used as indoor and outdoor charging and discharging stations.

15.3.9.1.2* Deluge or water spray fixed systems shall provide a minimum design density in accordance with the design documents for the MATS fire area being protected.

15.3.9.1.3 The deluge or water spray fixed system shall be able to be activated automatically by a fast acting fire detection system and also by manual actuator.

15.3.9.1.3.1 Manual activation controls shall be identified and marked with a sign and shall be positioned for use in an emergency.

15.3.9.1.3.2 Fire protection equipment and manual activation controls serving the MATS fire protection system shall not be blocked or obstructed.

15.3.9.1.4 Existing acetylene charging and discharging stations shall be protected by an automatic deluge or water spray fixed system in accordance with 15.3.9.1 not later than January 1, 2015. See also Section 1.4.

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15.3.9.1.4.1 The requirements of 15.3.9.1.1 shall not apply to existing indoor or outdoor facilities, equipment, structures, or other installations where MATS are charged or discharged that existed or were approved for construction or installation prior to the effective date of this code providing the MATS are protected with an automatic sprinkler system with a minimum design density of not less than 0.25 gpm per square foot (10.1 L/min per square meter).

15.3.9.1.5 At least one listed portable fire extinguisher rated in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, at not less than 20 B:C shall be mounted on the mobile acetylene trailer.

15.3.9.2 Indoor Areas. Buildings or portions thereof required to comply with Protection Level controls serving or using containers other than those regulated by 15.3.9.1 shall be protected by an approved automatic sprinkler system in accordance with Section 6.10.

15.3.9.2.1* Automatic sprinkler systems shall be prohibited in rooms or areas used exclusively for:

(1) calcium carbide storage
(2) calcium carbide transfer operations
(3) acetylene generation

15.3.9.2.2 Fire protection equipment shall be identified and located so that it is visible and accessible in an emergency.

A.15.3.9.1.2 For additional information on mobile acetylene trailer systems, see CGA G-1.6, *Standard for Mobile Acetylene Trailer Systems.*

Issue Date: October 30, 2012
Effective Date: November 19, 2012

(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/codelist**)**

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Sequence of Events Leading to Issuance of this 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.

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- ❑ Inspector, Building Official, Fire Marshal (F03)
- ❑ Owner, President, Manager, Administrator (C10)
- ❑ Other (please specify): (G11)_____

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- ❑ Architecture, Engineering, Contracting (A14)
- ❑ Commercial Firm (Office, Retail, Lodging, Restaurant) (G13)
- ❑ Electrical Services, Installation (J11)
- ❑ Fire Service, Public and Private (AA1)
- ❑ Government (C12)
- ❑ Industrial Firm (Factory, Warehouse) (C11)
- ❑ Institutional (Health Care, Education, Detention, Museums) (B11)
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