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Hydrogen Technologies Code

2023

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NFPA® 2

Hydrogen Technologies Code

2023 Edition

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NFPA® 2

Hydrogen Technologies Code

2023 Edition

This edition of NFPA 2, *Hydrogen Technologies Code,* was prepared by the Technical Committee on Hydrogen Technology. It was issued by the Standards Council on November 29, 2022, with an effective date of December 19, 2022, and supersedes all previous editions.

This edition of NFPA 2 was approved as an American National Standard on December 19, 2022.

Origin and Development of NFPA 2

With the increased interest in hydrogen being used as a fuel source, the National Fire Protection Association was petitioned to develop an all-encompassing document that establishes the necessary requirements for hydrogen technologies. In 2006, the Technical Committee on Hydrogen Technology was formed and tasked to develop a document that addresses all aspects of hydrogen storage, use, and handling; that draws from existing NFPA codes and standards; and that identifies and fills technical gaps for a complete functional set of requirements for code users and enforcers. This document is also structured so that it works seamlessly with building and fire codes.

This code is largely extracted from other NFPA codes and standards (e.g., NFPA 52, NFPA 55, and NFPA 853) and is organized in a fashion that is specific for hydrogen. Paragraphs that have been extracted from other documents are shown with the extract reference brackets at the end of the paragraph. In some cases, modifications have been made to the extracted text to use terminology appropriate for this code, such as the terms GH_2 instead of *compressed gas* and LH_2 instead of *cryogenic fluid*. In those instances, brackets encase the modifying words. Similarly, where language was deleted to adhere to requirements based exclusively on hydrogen and no other changes were made to the paragraph, brackets that encompass a hyphen [-] are inserted into the paragraph to denote a change to the original material while retaining the extract to the source document. In short, added or modified text is shown with brackets around the differing language and pure deletions of text are shown with [-].

The 2016 edition of NFPA 2 was more closely aligned with the requirements in NFPA 55 for gaseous and liquefied hydrogen systems. Both documents were in the same revision cycle, which allowed the technical committees to work more closely together on revisions to the joint content. The requirements for hydrogen generation systems in NFPA 2 (Chapter 13) were no longer extracted from NFPA 55, and the requirements for hydrogen fueling systems (Chapters 10 and 11) were no longer extracted from NFPA 52. The Technical Committee on Hydrogen Technology had primary responsibility for those requirements.

The 2016 edition had the following changes:

(1) Significant revisions to Chapter 10, Gaseous Vehicle Fueling Facilities, that reflected significant efforts by the technical committee in improving this chapter
(2) Clarification and organization of the requirements for gaseous hydrogen systems into three tiers based on the quantity of hydrogen stored: less than or equal to the maximum allowable quantity (MAQ), greater than the MAQ but less than the bulk quantity, and bulk systems
(3) Changes to the requirements in Chapter 7 for emergency isolation consistent with the changes made to NFPA 55
(4) New requirements for hydrogen equipment enclosures to address the growing use of these systems in a variety of field applications
(5) New chapters for parking garages and repair garages for hydrogen fuel cell vehicles

For the 2020 edition of NFPA 2, several updates were made to both Chapter 10, GH_2 Vehicle Fueling Facilities, and Chapter 18, Repair Garage. Changes made to Chapter 10 focused on addressing fueling protocols, authorized fueling, signage, and vehicle to station communication protocols. With the inclusion of these updates, Chapter 10 was restructured to maintain clarity for the user. Chapter 18 was revised to be limited to only apply to LH_2 applications. The changes made

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to Chapter 18 enhance the ease of repair garages to accept hydrogen as an alternative motor fuel while properly addressing the additional hazards the repair and servicing of these vehicles can present without reducing the level of protection currently required.

For the 2023 edition, the word “permitted” has been changed to “allowed” throughout the code to avoid misinterpreting the code to require a permit be acquired to align with code requirements. Any language originally extracted from NFPA 55 that has been maintained in the code has had the NFPA 55 extract citation removed, since the scope of this code has primacy for the development of gaseous and liquid hydrogen requirements.

Where mechanical ventilation is being used to reduce the area classification as prescribed in Chapter 6, new requirements have been developed that mandate detection of loss of ventilation be provided.

Chapter 7 has added a new section for GH_2-filled meteorological and piloted balloons, as well as a new section that identifies minimum design features for courts and enclosed courts that contain bulk gaseous hydrogen gas systems.

Using risk-informed leak size and conservative model assumptions, the separation distances for liquified hydrogen systems in Chapter 8 have been revised. Annex N has been created that explains the methodology utilized to develop these liquid hydrogen separation distances.

In Chapter 10, the vehicle fueling connection nozzle must now be rated to the same or lower pressure class as the fuel supply containers being fueled in order to prevent serious equipment damage. New Section 10.7 addresses compact hydrogen fueling systems (cHFS). These changes require cHFSs to be listed or approved, and a clear delineation has been made between larger hydrogen systems and the smaller cHFS. Additionally, cHFS enclosures must be designed to allow access, inspection, service, repair, and replacement of hardware and cannot be categorized as gas cabinets or gas rooms.

Also in Chapter 10, requirements for the design and construction as it applies to the piping and hoses, vent systems, and buffer capacity for outdoor nonpublic home fueling appliances (HFAs) have been developed. This also includes new requirements for the appliance access and installation of HFAs.

Revisions have been provided in Chapter 10 to clarify the difference between on-demand mobile fueling and outdoor nonpublic mobile fleet fueling. Definitions for *mobile fueling vehicle* and *mobile fueling trailer* have been added to Chapter 3 to add clarity to those revisions.

To provide further guidance for the delivery of hydrogen to fuel stations, additional cargo transport unloading requirements have been added to Chapters 10 and 11.

A new Chapter 19 for hydrogen-powered industrial trucks (HPITs) has been created that applies to the design, construction, and use of HPITs.

Annexes E and I have been consolidated to avoid confusion for NFPA 2 historical references. A new annex, Annex M, has been added that provides guidelines and practices for repairing leaks in hydrogen systems.

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

Committee Scope: This committee shall have primary responsibility for documents on the storage, transfer, production, and use of hydrogen. The use of hydrogen would include stationary, portable, and vehicular applications. This Committee shall be referred to by the Technical Committee on Industrial and Medical Gases for any material on gaseous and liquid hydrogen storage and use.

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Hydrogen Technologies Code

2023 Edition

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1 Scope. This code shall apply to the production, storage, transfer, and use of hydrogen.

1.2 Purpose. The purpose of this code shall be to provide fundamental safeguards for the generation, installation, storage, piping, use, and handling of hydrogen in compressed gas (GH_2) form or cryogenic liquid (LH_2) form.

1.3* Application.

1.3.1 The use of hydrogen shall include stationary, portable, and vehicular infrastructure applications.

1.3.2 The fundamental requirements of Chapters 1 and 4 through 8 shall apply in addition to the use-specific requirements provided in Chapters 9 through 18, as applicable.

Δ **1.3.3 Exemptions.** This code shall not apply to the following:

(1) Design or components related to the transport of hydrogen or propulsion of hydrogen motor vehicles, including onboard hydrogen storage systems
(2) Mixtures of GH_2 and other gases with a hydrogen concentration of less than 95 percent by volume when in accordance with NFPA 55
(3) The storage, handling, use, or processing of metal hydride materials outside of metal hydride storage systems defined in Chapter 3

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1.4 Retroactivity. The provisions of this code reflect a consensus of the criteria 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 (AHJ) determines that the existing situation presents an unacceptable degree of risk, the AHJ 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 would be impractical in the judgment of the AHJ, and only where it is evident that a reasonable degree of safety is provided.

1.5 Equivalency.

1.5.1 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.

1.5.2 Technical documentation shall be submitted to the AHJ to demonstrate equivalency.

1.5.3 The system, method, or device shall be approved for the intended purpose by the AHJ.

1.6 Units and Formulas.

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

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

1.6.6 If a value for measurement given in this code is followed by an equivalent value in other units, the first stated shall be regarded as the requirement. The given equivalent value shall be considered to be approximate.

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

1.7 Enforcement.

1.7.1* This code shall be administered and enforced by the AHJ designated by the governing authority under the administrative provisions of the adopted building or fire prevention code. (*See Annex C for sample wording for enabling legislation.*)

1.7.2 The administrative provisions of Annex B shall be allowed to be used where specifically adopted.

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,* 2021 edition.
NFPA 10, *Standard for Portable Fire Extinguishers,* 2022 edition.
NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2020 edition.
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2022 edition.
NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2022 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2022 edition.
NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2019 edition.
NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2022 edition.
NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2021 edition.
NFPA 17A, *Standard for Wet Chemical Extinguishing Systems,* 2021 edition.
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2023 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2021 edition.
NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages,* 2021 edition.
NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2020 edition.
NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 2019 edition.
NFPA 54, *National Fuel Gas Code,* 2021 edition.
NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2023 edition.
NFPA 58, *Liquefied Petroleum Gas Code,* 2023 edition.
NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2018 edition.
NFPA 69, *Standard on Explosion Prevention Systems,* 2019 edition.
NFPA 70®, National Electrical Code®, 2023 edition.
NFPA 72®, National Fire Alarm and Signaling Code®, 2022 edition.
NFPA 77, *Recommended Practice on Static Electricity,* 2019 edition.
NFPA 79, *Electrical Standard for Industrial Machinery,* 2021 edition.
NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2022 edition.
NFPA 86, *Standard for Ovens and Furnaces,* 2023 edition.
NFPA 88A, *Standard for Parking Structures,* 2023 edition.
NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2021 edition.
NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids,* 2020 edition.
NFPA *101®, Life Safety Code®,* 2021 edition.
NFPA 110, *Standard for Emergency and Standby Power Systems,* 2022 edition.
NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems,* 2022 edition.
NFPA 259, *Standard Test Method for Potential Heat of Building Materials,* 2018 edition.
NFPA 400, *Hazardous Materials Code,* 2022 edition.
NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2021 edition.
NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations,* 2018 edition.
NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2022 edition.
NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2023 edition.
NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems,* 2020 edition.
NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2022 edition.

2.3 Other Publications.

2.3.1 AIHA Publications. American Industrial Hygiene Association, 3141 Fairview Park Dr., Suite 777, Falls Church, VA 22042.

ANSI/AIHA Z9.5, *Laboratory Ventilation*, 2012.

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

ANSI/IEEE C2, *National Electrical Safety Code*, 2017.

ANSI Z535.1, *Safety Colors*, 2017.

ANSI Z535.2, *Environmental and Facility Safety Signs*, 2011 (reaffirmed 2017).

ANSI Z535.3, *Criteria for Safety Symbols*, 2011 (reaffirmed 2017).

ANSI Z535.4, *Product Safety Signs and Labels*, 2011 (reaffirmed 2017).

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

ASME A13.1, *Scheme for the Identification of Piping Systems*, 2015.

ASME B31, *Code for Pressure Piping*, 2018.

ASME B31.3, *Process Piping*, 2018.

ASME B31.12, *Hydrogen Piping and Pipelines*, 2019.

ASME *Boiler and Pressure Vessel Code*, "Rules for the Construction of Unfired Pressure Vessels," Section VIII, Division 1, 2019.

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

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2021a.

ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, 2019a.

ASTM E1529, *Determining Effects of Large Hydrocarbon Pool Fire on Structural Members and Assemblies*, 2016e1.

ASTM E1591, *Standard Guide for Data for Fire Models*, 2020.

ASTM E2652, *Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*, 2018.

ASTM E2965, *Standard Test Method for Determination of Low Levels of Heat Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter*, 2017.

2.3.5 CGA Publications. Compressed Gas Association, 8484 Westpark Drive, Suite 220, McLean, VA 22102.

CGA C-7, *Guide to Classification and Labeling of Compressed Gas*, 2020.

CGA G-5.5, *Hydrogen Vent Systems*, 2014.

CGA P-1, *Safe Handling of Compressed Gases in Containers*, 2015.

CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases*, 2019.

CGA S-1.2, *Pressure Relief Device Standards — Part 2 — Cargo and Portable Tanks for Compressed Gases*, 2019.

CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Stationary Storage Containers for Compressed Gases*, 2020.

Δ **2.3.6 CSA Group Publications.** CSA Group, 178 Rexdale Boulevard, Toronto, ON M9W 1R3, Canada.

ANSI/CSA FC 1, *Fuel Cell Technologies — Part 3-100: Stationary fuel cell power systems — Safety*, 2014 (reaffirmed 2018).

ANSI/CSA America FC 3, *Portable Fuel Cell Power Systems*, 2004 (reaffirmed 2017).

CSA/ANSI HGV 4.3, *Test Methods for Hydrogen Fueling Parameter Evaluation*, 2019.

2.3.7* CTC Publications. Canadian Transportation Agency, 15 Eddy Street, Gatineau, Quebec J8X 4B3.

Transportation of Dangerous Goods Regulations.

2.3.8 ICC Publications. International Code Council, 500 New Jersey Avenue, NW, 6th Floor, Washington, DC 20001.

International Fire Code (IFC), 2021.

International Fuel Gas Code (IFGC), 2021.

Δ **2.3.9 IEC Publications.** International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres,* 2020.

N **2.3.10 ISO Publications.** International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

ISO 16110-1,*Hydrogen generators using fuel processing technologies – Part1: Safety,* 2016.

ISO 17268, *Gaseous hydrogen land vehicle refuelling connection devices,* 2020.

2.3.11 SAE Publications. SAE International, Society of Automotive Engineers, 901 15th Street, NW, Suite 520, Washington, DC 20005, www.SAE.org.

SAE J2579 201806, *Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles*, 2018.

SAE J2600, *Compressed Hydrogen Surface Refueling Connection Devices*, 2015.

SAE J2601-3, *Fueling Protocol for gaseous Hydrogen Powered Industrial Trucks,* 2013.

Δ **2.3.12 UL Publications.** Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 263, *Fire Tests of Building Construction and Materials*, 2019.

UL 723, *Tests for Surface Burning Characteristics of Building Materials*, 2018.

UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements,* 2019.

2.3.13 US Government Publications. US Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

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

Title 49, Code of Federal Regulations, Parts 100–199, "Pipeline and Hazardous Materials Safety Administration, Department of Transportation."

Title 49, Code of Federal Regulations, Part 571.108, "Lamps, Reflective Devices, and Associated Equipment."

2.3.14 Other Publications.

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

UN Global Technical Regulation No. 13, *Global technical regulation on hydrogen and fuel cell vehicles*, 2013.

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

NFPA 1, *Fire Code,* 2021 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2022 edition.
NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes,* 2022 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2021 edition.
NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages,* 2021 edition.
NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 2019 edition.

NFPA 52, *Vehicular Natural Gas Fuel Systems Code,* 2023 edition.

NFPA 54, *National Fuel Gas Code,* 2021 edition.

NFPA 56, *Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems,* 2020 edition.

NFPA 58, *Liquefied Petroleum Gas Code,* 2020 edition.

NFPA 70®, *National Electrical Code*®, 2020 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2022 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2023 edition.

NFPA 88A, *Standard for Parking Structures,* 2023 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids,* 2020 edition.

NFPA *101*®, *Life Safety Code*®, 2021 edition.

NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities,* 2022 edition.

NFPA 400, *Hazardous Materials Code,* 2022 edition.

NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials,* 2020 edition.

NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities,* 2020 edition.

NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Systems,* 2020 edition.

NFPA 921, *Guide for Fire and Explosion Investigations,* 2021 edition.

NFPA 5000®, *Building Construction and Safety Code*®, 2021 edition.

Chapter 3 Definitions

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

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

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

3.2.3* Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

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

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

3.2.6 Shall. Indicates a mandatory requirement.

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

3.3 General Definitions.

3.3.1 Aboveground Storage Tank. See 3.3.238.4.1.

3.3.2 Aboveground Tank. See 3.3.238.1.

3.3.3 Absolute Pressure. See 3.3.197.1.

3.3.4 Air.

3.3.4.1 *Auxiliary Air.* Supply or supplemental air delivered near the outside face of a chemical fume hood to reduce room air consumption. [**45,** 2019]

Δ **3.3.4.2 *Exhaust Air.*** Air removed from a space and not reused.

Δ **3.3.4.3 *Ventilation Air.*** The portion of supply air, the source of which is the outside/outdoors, plus any recirculated air that has been treated and is acceptable for use that can be used for circulation, dilution, and/or primary air applications.

3.3.5 Apparatus. Furniture, chemical fume hoods, centrifuges, refrigerators, and commercial or made-on-site equipment used in a laboratory. [**45,** 2019]

3.3.6 Attendant. An employee or authorized person who oversees a motor fuel dispensing facility.

3.3.7 Area.

Δ **3.3.7.1 *Control Area.*** A building or portion of a building or outdoor area within which hazardous materials are allowed to be stored, dispensed, used, or handled in quantities not exceeding the MAQ. [**400,** 2022]

Δ **3.3.7.2 *Indoor Area.*** An area that is within a building or structure having overhead cover, other than a structure qualifying as "weather protection." *(See also 3.3.7.5, Outdoor Area.)*

3.3.7.3 *Laboratory Work Area.* A room or space [regulated by Chapter 16 used] for testing, analysis, research, instruction, or similar activities that involve the use of chemicals. [**45,** 2019]

3.3.7.4 *Nonlaboratory Area.* Any space within a [laboratory] building not included in a laboratory unit. *(See also 3.3.14.2 and 3.3.245.1.)* [**45,** 2019]

Δ **3.3.7.5 *Outdoor Area.*** An area that is not an indoor area.

Δ **3.3.7.6* *Use Area.*** A location inside or outside of a building or structure where the material placed into use is situated.

3.3.8 ASME. American Society of Mechanical Engineers. [**58,** 2020]

3.3.9 ASTM. American Society for Testing and Materials.

3.3.10 Automatic Emergency Shutoff Valve. See 3.3.252.1.1.

3.3.11 Automatic Fire Detection System. See 3.3.237.1.

3.3.12 Auxiliary Air. See 3.3.4.1.

3.3.13 Baffle. An object placed in an appliance to change the direction of or to retard the flow of air, air–gas mixtures, or flue gases. [**54,** 2021]

3.3.14 Building. Any structure used or intended for supporting or sheltering any use or occupancy. [***101,*** 2021]

Δ **3.3.14.1** ***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.

3.3.14.2 ***Laboratory Building.*** A structure consisting wholly or principally of one or more laboratory units. *(See also 3.3.245.1, Laboratory Unit.)* [**45,** 2019]

3.3.15 Building Code. See 3.3.40.1.

3.3.16 Bulk Hydrogen Compressed Gas System. See 3.3.237.2.

3.3.17 Bulk Liquefied Hydrogen Gas System. See 3.3.237.3, Bulk Liquefied Hydrogen (LH_2) System.

3.3.18 Bulk Oxygen System. See 3.3.237.4.

3.3.19 Burner. A device or group of devices used for the introduction of fuel, air, oxygen, or oxygen-enriched air into a furnace at the required velocities, turbulence, and concentration to maintain ignition and combustion of fuel. [**86,** 2023]

3.3.20 Burn-In. The procedure used in starting up a special atmosphere furnace to replace air within the heating chamber(s) and vestibule(s) with flammable special atmosphere. [**86,** 2023]

3.3.21 Burn-Out. The procedure used in shutting down or idling a special atmosphere to replace flammable atmosphere within the heating chamber(s) and vestibule(s) with nonflammable atmosphere. [**86,** 2023]

3.3.22 Bypass [Laboratory Hoods]. An airflow-compensating opening that maintains a relatively constant volume exhaust through a chemical fume hood regardless of sash position, serving to limit the maximum face velocity as the sash is lowered. [**45,** 2019]

3.3.23 Cabinet.

Δ **3.3.23.1*** ***Gas Cabinet.*** A fully enclosed, noncombustible enclosure used to provide an isolated environment for compressed gas cylinders in storage or use.

3.3.23.2 ***Laminar Flow Cabinet.*** A ventilated, partially enclosed cabinet primarily intended to provide filtered airflow over the work surface by use of laminar airflow methods. [**45,** 2019]

3.3.24 Canopy. A permanent structure or architectural projection of rigid construction over which a covering is attached that provides weather protection, identity, or decoration.

3.3.25 Canopy Hood. See 3.3.120.1.

3.3.26 Capacity [Vehicular Fuel Container]. The water volume of a container in gallons (liters). [**52,** 2023]

3.3.27 Cargo Transport Vehicle. A mobile unit designed to transport GH_2 or LH_2.

3.3.28 Cathodic Protection. See 3.3.203.1.

Δ **3.3.29 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.

3.3.30 Ceiling Limit. See 3.3.144.1.

3.3.31 CFR. The Code of Federal Regulations of the United States Government. [**1,** 2021]

3.3.32 CGA. Compressed Gas Association. [**1,** 2021]

3.3.33* Chemical. A substance with one or more of the following hazard ratings as defined in NFPA 704: Health — 2, 3, or 4; Flammability — 2, 3, or 4; Instability — 2, 3, or 4. *(See also Section B.2.)*

3.3.34 Chemical Fume Hood. See 3.3.120.2.

3.3.35 Class 2 Unstable Reactive Gas. See 3.3.106.12.1.

3.3.36 Class 3 Unstable Reactive Gas. See 3.3.106.12.2.

3.3.37 Class 4 Unstable Reactive Gas. See 3.3.106.12.3.

3.3.38* Class C Furnace. An oven or furnace that has a potential hazard due to a flammable or other special atmosphere being used for treatment of material in process. [**86,** 2023]

N **3.3.39* Closed Piping System.** An assembly that is made up of either a fully welded construction, continuous tubing, or of unwelded connections that have been tested in accordance with ASME B31.3, *Process Piping*, and proven to, under normal operating conditions, contain all H_2 within its control boundary without transferring H_2 to the atmosphere.

3.3.40 Code.

Δ **3.3.40.1** ***Building Code.*** The building or construction code adopted by the jurisdiction.

Δ **3.3.40.2** ***Fire Code.*** The fire prevention code adopted by the jurisdiction.

Δ **3.3.40.3** ***Mechanical Code.*** The mechanical or mechanical construction code adopted by the jurisdiction.

3.3.41 Combustible. Capable of undergoing combustion. [**853,** 2020]

3.3.41.1 ***Limited-Combustible Material.*** See 4.15.2.

3.3.42 Combustible Liquid. See 3.3.147.1.

3.3.43 Combustion Safeguard. A safety device or system that responds to the presence or absence of flame properties using one or more flame detectors and provides safe start-up, safe operation, and safe shutdown of a burner under normal and abnormal conditions. [**86,** 2023]

3.3.44 Compact Hydrogen Fueling System (cHFS). A self-contained package or factory-matched package which generates, compresses, stores, and dispenses gaseous hydrogen for public and nonpublic fueling.

3.3.45 Compressed Gas. See 3.3.106.1.

Δ **3.3.46 Compressed Gas Container.** See 3.3.50.1

3.3.47 Compressed Gas System. See 3.3.237.5.

3.3.48 Compression Discharge Pressure. See 3.3.197.2.

Δ **3.3.49 Compressor.** A mechanical device used to increase the pressure and the resultant density of a gas through the act of compression.

Δ **3.3.50 Container.** A vessel, such as a cylinder, portable tank, or stationary tank, that varies in shape, size, and material of construction.

Δ **3.3.50.1** ***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.

3.3.50.2 ***Fuel Supply Container.*** A container mounted on a vehicle to store LH_2 or GH_2 as the fuel supply to the vehicle.

3.3.51 Control.

Δ **3.3.51.1** ***Excess Flow Control.*** A fail-safe system or approved means designed to shut off flow due to a rupture in pressurized piping systems.

Δ **3.3.51.2*** ***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.

Δ **3.3.51.3** ***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.

3.3.52 Control Area. See 3.3.7.1.

3.3.53 Controller.

3.3.53.1 ***Excess Temperature Limit Controller.*** A device designed to cut off the source of heat if the operating temperature exceeds a predetermined temperature set point.

3.3.53.2 ***Temperature Controller.*** A device that measures the temperature and automatically controls the input of heat into the furnace. [**86,** 2023]

Δ **3.3.54 Corrosion Expert.** A person who, by reason of knowledge of the physical sciences and the principles of engineering acquired through professional education and related practical experience, is qualified to engage in the practice of corrosion control of container systems.

3.3.55 Corrosion Protection. See 3.3.203.2.

3.3.56 Corrosive Gas. See 3.3.106.2.

Δ **3.3.57 Court.** An open, uncovered, unoccupied space, unobstructed to the sky, bounded on three sides by walls.

3.3.57.1 ***Enclosed Court.*** A court bounded on all sides by walls.

Δ **3.3.58 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).

Δ **3.3.58.1** ***Flammable Cryogenic Fluid.*** A cryogenic fluid that forms flammable mixtures in air when in its vapor state.

Δ **3.3.59 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.

Δ **3.3.60* 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.

3.3.61* Defueling. The controlled discharge of hydrogen from vehicle fuel storage tank systems according to the vehicle manufacturer's instructions, utilizing a nozzle or port supplied by the vehicle or test system manufacturer and equipment that has been listed and labeled, or approved for the intended use.

3.3.62 Detached Building. See 3.3.14.1.

3.3.63 Device.

Δ **3.3.63.1** ***Emergency Shutdown Device (ESD) [Vehicle Fueling].*** A device that brings all operations to a fail-safe condition within the fueling facility from either local or remote locations.

Δ **3.3.63.2** ***Pressure Relief Device.*** A device designed to open to prevent a rise of internal pressure in excess of a specified value.

3.3.63.3 ***Safety Device [Furnaces].*** An instrument, a control, or other equipment that acts, or initiates action, to cause the furnace to revert to a safe condition in the event of equipment failure or other hazardous event. [**86,** 2023]

3.3.64* Distributed Integrated Controls (DIC). Systems or integrated controls used to monitor and control the functions of equipment, systems, or plants. [**853,** 2020]

Δ **3.3.65 Distributor.** A business engaged in the sale or resale, or both, of compressed gases or cryogenic fluids, or both.

3.3.66 DOT. U.S. Department of Transportation. [**52,** 2023]

3.3.67 Duct System. See 3.3.237.6.

3.3.68 Dwelling. Any detached building, or any part of a townhouse, back-to-back townhouse, or stacked townhouse structure that is separated from the remainder of the townhouse structure with fire-resistance-rated assemblies in accordance with local building code, that contains no more than two dwelling units intended to be used, rented, leased, let, or hired out to be occupied or that are occupied for habitation purposes. [**13D,** 2022]

3.3.69 Emergency Shutdown Device (ESD). See 3.3.63.1.

3.3.70 Emergency Shutoff Valve. See 3.3.252.1.

3.3.71 Enclosed Court. See 3.3.57.1.

3.3.72 Enclosed Parking Structure. See 3.3.186.1.

3.3.73 Engineered and Field-Constructed Fuel Cell Power System. See 3.3.237.7.

3.3.74 Evaluation.

3.3.74.1* ***Fire Risk Evaluation.*** A detailed engineering review of a plant's construction features and operating process conducted to ensure that applicable fire prevention and fire protection requirements for safeguarding life and physical property are met. [**853,** 2020]

3.3.75 Excess Flow Control. See 3.3.51.1.

3.3.76 Excess Temperature Limit Controller. See 3.3.53.1.

3.3.77 Exhaust Air. See 3.3.4.2.

3.3.78 Exhaust System. See 3.3.237.8.

Δ **3.3.79* 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.

3.3.80 Exit Access. That portion of a means of egress that leads to an exit. [***101,*** 2021]

3.3.81 Explosion Control. See 3.3.51.2.

3.3.82 Face Velocity. The rate of flow or velocity of air moving into the chemical fume hood entrance or face, as measured at the plane of the chemical fume hood face. [**45,** 2019]

3.3.83 Facility.

3.3.83.1 ***Incidental Testing Facility.*** An area within a production facility set aside for the purpose of conducting in-process control tests that are related to the production process. [**45,** 2019]

3.3.83.2 ***Motor Fuel Dispensing Facility.*** That portion of a property where motor fuels are stored and dispensed from fixed equipment into the fuel tanks of motor vehicles or marine craft or into approved containers, including all equipment used in connection therewith. [**30A,** 2021]

3.3.83.2.1 ***Attended Self-Service Motor Fuel Dispensing Facility.*** A motor fuel dispensing facility that has an attendant or employee on duty whenever the facility is open for business. The attendant or employee on duty does not typically dispense motor fuels into fuel tanks or containers. The customer or vehicle operator usually conducts the dispensing. [**30A,** 2021]

3.3.83.2.2 ***Fleet Vehicle Motor Fuel Dispensing Facility.*** A motor fuel dispensing facility at a commercial, industrial, governmental, or manufacturing property where motor fuels are dispensed into the fuel tanks of motor vehicles that are used in connection with the business or operation of that property by persons within the employ of such business or operation. [**30A,** 2021]

3.3.83.2.3 ***Full-Service Motor Fuel Dispensing Facility.*** A motor fuel dispensing facility that has one or more attendants or supervisors on duty to dispense motor fuels into fuel tanks or containers whenever the facility is open for business. [**30A,** 2021]

3.3.83.2.4* ***Motor Fuel Dispensing Facility Located Inside a Building.*** That portion of a motor fuel dispensing facility located within the perimeter of a building or building structure that also contains other occupancies. [**30A,** 2021]

3.3.83.2.5 ***Unattended Self-Service Motor Fuel Dispensing Facility.*** A motor fuel dispensing facility that has no attendant or employee on duty. The customer or vehicle operator conducts the dispensing operation. This includes coin, currency, membership card, and credit card dispensing operations. [**30A,** 2021]

• *N* **3.3.83.3*** ***Home Fueling Appliance (HFA).*** A self-contained package or factory-matched package of integrated systems or hardware that provides fueling of hydrogen-powered vehicles in residential dwellings with a nominal voltage not exceeding 240 volts ac.

3.3.84* 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.

3.3.85 Fire Damper. A device, installed in an air-distribution system, that is designed to close automatically upon detection of heat to interrupt migratory airflow and to restrict the passage of flame. [**5000,** 2021]

3.3.86 Fire Prevention. Measures directed toward avoiding the inception of fire. [**801,** 2020]

3.3.87 Fire Protection. See 3.3.203.3.

3.3.88 Fire Risk Evaluation. See 3.3.74.1.

3.3.89 Flammable Cryogenic Fluid. See 3.3.58.1.

3.3.90 Flammable Gas. See 3.3.106.3.

3.3.91 Flammable Liquefied Gas. See 3.3.106.4.

3.3.92 Flammable Liquid. See 3.3.147.2, Flammable Liquid (Class I).

3.3.93 Flammable Special Atmosphere. See 3.3.227.1.

3.3.94 Flash Point. The minimum temperature at which a liquid or a solid emits vapor sufficient to form an ignitable mixture with air near the surface of the liquid or the solid. [**853,** 2020]

3.3.95 Fleet Vehicle Motor Fuel Dispensing Facility. See 3.3.83.2.2.

3.3.96 Flow Switch. A switch that is activated by the flow of a fluid in a duct or piping system. [**86,** 2023]

3.3.97 Fuel Cell Cartridge. A removable article that contains and supplies fuel to the micro fuel cell power unit or internal reservoir.

3.3.98 Fuel Cell Power System (FCPS). See 3.3.237.9.

3.3.99 Fuel Gas. See 3.3.106.5.

3.3.100 Fuel Line. The pipe, tubing, or hose on a vehicle, including all related fittings, through which hydrogen passes during normal vehicle fueling or operation.

3.3.101 Fuel Supply Container. See 3.3.50.2.

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

3.3.103 **Fueling Protocol.**

3.3.103.1* ***Nonstandard Automotive Fueling Protocol.*** A fueling protocol that has not been described in a published standard.

3.3.103.2 ***Standard Automotive Fueling Protocol.*** A fueling protocol published by a standards developing organization that has been accepted by the automotive fuel supply industries to ensure all hydrogen vehicles can use the protocol without exceeding operating parameters.

3.3.104* **Full Trycock.** A valve connected to a line inserted into the inner tank of a cryogenic fluid tank and positioned such that liquid just begins to flow from the valve when opened.

3.3.105 **Gallon, U.S. Standard.** 1 U.S. gal = 0.833 Imperial gal = 231 in.^{3} = 3.785 L. [**58,** 2020]

3.3.106 **Gas.**

Δ 3.3.106.1* ***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).

Δ 3.3.106.2 ***Corrosive Gas.*** A gas that causes visible destruction of or irreversible alterations in living tissue by chemical action at the site of contact.

Δ 3.3.106.3* ***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.

Δ 3.3.106.4 ***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.

3.3.106.5 ***Fuel Gas.*** A gas used as a fuel source, including natural gas, manufactured gas, sludge gas, liquefied petroleum gas–air mixtures, liquefied petroleum gas in the vapor phase, and mixtures of these gases. [**820,** 2020]

Δ 3.3.106.6* ***Inert Gas.*** A nonreactive, nonflammable, noncorrosive gas such as argon, helium, krypton, neon, nitrogen, and xenon.

Δ 3.3.106.7 ***Nonflammable Gas.*** A gas that does not meet the definition of a flammable gas.

Δ 3.3.106.8* ***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.

Δ 3.3.106.9 ***Oxidizing Gas.*** A gas that can support and accelerate combustion of other materials more than air does.

Δ 3.3.106.10 ***Pyrophoric Gas.*** A gas with an autoignition temperature in air at or below 130°F (54.4°C).

Δ 3.3.106.11 ***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.

Δ 3.3.106.11.1 ***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 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.

Δ 3.3.106.12* ***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.

Δ 3.3.106.12.1 ***Class 2 Unstable Reactive Gas.*** Materials that readily undergo violent chemical change at elevated temperatures and pressures.

Δ 3.3.106.12.2 ***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.

Δ 3.3.106.12.3 ***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.

3.3.107 **Gas Analyzer.** A device that measures concentrations, directly or indirectly, of some or all components in a gas or mixture. [**86,** 2023]

3.3.108 **Gas Cabinet.** See 3.3.23.1.

3.3.109 **Gas Detection System.** See 3.3.237.10.

Δ 3.3.110 **Gas Manufacturer/Producer.** A business that produces compressed gases or cryogenic fluids, or both, or fills portable or stationary gas cylinders, containers, or tanks.

Δ 3.3.111 **Gas Room.** A separately ventilated, fully enclosed room in which only compressed gases, cryogenic fluids, associated equipment, and supplies are stored or used.

3.3.112 **Gaseous Hydrogen (GH_2) System.** See 3.3.237.11.

Δ 3.3.113 **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.

N 3.3.114 **Gasifier Hazard Area.** An area around a gasifier containing hazards such as flammable gases, toxic materials, hot surfaces, and so on.

3.3.115 **GH_2.** Hydrogen in the gas phase.

Δ 3.3.116* **Handling.** The deliberate movement of material in containers by any means to a point of storage or use.

Δ **3.3.117* Hazard Rating.** The numerical rating of the health, flammability, self-reactivity, and other hazards of the material, including its reaction with water.

3.3.118 Hazardous Material (Chemical). See 3.3.149.1, Hazardous Material.

3.3.119 Health Hazard Material. A chemical or substance classified as a toxic, highly toxic, or corrosive material in accordance with definitions set forth in this code. [**400,** 2022]

3.3.120 Hood.

3.3.120.1* ***Canopy Hood.*** A suspended ventilating device used only to exhaust heat, water vapor, odors, and other nonhazardous materials. [**45,** 2019]

3.3.120.2* ***Chemical Fume Hood.*** A ventilated enclosure designed to contain and exhaust fumes, gases, vapors, mists, and particulate matter generated within the hood interior. [**45,** 2019]

3.3.121 Hood Interior. The volume enclosed by the side, back, and top enclosure panels, the work surface, the access opening (called the face), the sash or sashes, and the exhaust plenum, including the baffle system for airflow distribution. [**45,** 2019]

3.3.122* Hydrogen Equipment Enclosure (HEE). A prefabricated area designed to protect hydrogen equipment that is confined by at least three walls and a roof not routinely occupied, and has a total area less than 450 ft^2 (41.8 m^2).

3.3.123 Hydrogen Generation System. See 3.3.237.12.

3.3.124 Hydrogen Generator. A packaged or factory- matched hydrogen gas generation device that (1) uses electrochemical reactions to electrolyze water to produce hydrogen and oxygen gas (electrolyzer) or (2) converts hydrocarbon fuel to a hydrogen-rich stream of composition and conditions suitable for the type of device (e.g., fuel cells) using the hydrogen (reformer).

N **3.3.125 Hydrogen-Powered Industrial Truck (HPIT).** Hydrogen-powered vehicles including lift trucks, motorized hand trucks, and other specialized industrial trucks.

3.3.126 Incidental Testing Facility. See 3.3.83.1.

3.3.127 Indoor Area. See 3.3.7.2.

3.3.128* Indoor Installation. See 3.3.130.1.

3.3.129 Inert Gas. See 3.3.106.6.

Δ **3.3.130 Installation (Fuel Cell Power System).** The location where a fuel cell power system other than a portable micro fuel cell power system is sited as a unit or built as an assembly.

3.3.130.1 ***Indoor Installation (Fuel Cell Power System).*** A fuel cell power system other than a portable or micro fuel cell power system completely surrounded and enclosed by walls, a roof, and a floor.

3.3.130.2 ***Outside or Outdoor Installation [Fuel Cell Power System].*** A power system installation (other than a portable or micro fuel cell power system) that is not located inside a building or that has only partial weather protection (maximum coverage of a roof and up to 25 percent enclosing walls).

Δ **3.3.130.3** ***Portable Fuel Cell Power System Installation.*** A fuel cell power system generator other than a micro fuel cell power system of electricity that is not fixed in place. A portable appliance utilizes a cord and plug connection to a grid-isolated load and has an integral fuel supply.

3.3.130.4 ***Rooftop Installation.*** A power system installation located on the roof of a building. [**853,** 2020]

3.3.131 Instructional Laboratory Unit. See 3.3.245.1.1.

3.3.132 Interactive System. See 3.3.237.15.

3.3.133 Interlock.

3.3.133.1 ***1400°F (760°C) Bypass Interlock.*** A device designed to permit specific permitted logic when the combustion chamber is proved to be above 1400°F (760°C). [**86,** 2023]

3.3.133.2 ***Excess Temperature Limit Interlock.*** A device designed to cut off the source of heat if the operating temperature exceeds a predetermined temperature set point. [**86,** 2023]

3.3.133.3 ***Safety Interlock.*** A device required to ensure safe startup and safe operation and to cause safe equipment shutdown. [**86,** 2023]

Δ **3.3.134* ISO Module.** An assembly of tanks or tubular cylinders permanently mounted in a frame conforming to International Organization for Standardization (ISO) requirements.

3.3.135 Laboratory. A facility as regulated by Chapter 16 that provides controlled conditions in which scientific research, experiments, or measurements are performed.

3.3.136 Laboratory Building. See 3.3.14.2.

3.3.137 Laboratory Equipment. See 3.3.5, Apparatus.

3.3.138 Laboratory Unit. See 3.3.245.1.

3.3.139* Laboratory Work Area. See 3.3.7.3.

3.3.140 Laminar Flow Cabinet. See 3.3.23.2.

3.3.141 Lecture Bottle. A small compressed gas cylinder up to a size of approximately 2 in. × 13 in. (5 cm × 33 cm). [**45,** 2019]

3.3.142* LH_2**.** Hydrogen in the liquid phase.

3.3.143 LH_2 **System.** An assembly of equipment designed to contain, distribute, or transport LH_2.

3.3.144 Limit.

3.3.144.1* ***Ceiling Limit.*** The maximum concentration of an airborne contaminant to which one can be exposed. [**5000,** 2021]

3.3.144.2 ***Exposure Limit.***

Δ **3.3.144.2.1*** ***Permissible Exposure Limit (PEL).*** The maximum permitted 8-hour, time-weighted average concentration of an airborne contaminant.

Δ **3.3.144.2.2*** ***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).

3.3.144.3 ***Lower Flammability Limit (LFL).*** That concentration of a combustible material in air below which ignition will not occur. [**52,** 2023]

3.3.145 Limited Combustible. See 3.3.41.1, Limited-Combustible Material.

3.3.146 Liquefied Hydrogen System. See 3.3.237.16, Liquefied Hydrogen (LH_2) System.

3.3.147 Liquid.

Δ 3.3.147.1* ***Combustible Liquid.*** An ignitible liquid that is classified as a Class I or Class III liquid. *(See 4.2.2 and 4.2.3 in NFPA 30.)* [**30,** 2021]

Δ 3.3.147.2* ***Flammable Liquid (Class I).*** Any liquid having a closed-cup flash point not exceeding 100°F (37.8°C).

3.3.148 Lower Flammability Limit (LFL). See 3.3.144.3.

3.3.149 Material.

3.3.149.1* ***Hazardous Material.*** A chemical or substance that is classified as a physical hazard material or a health hazard material, whether the chemical or substance is in usable or waste condition. *(See also 3.3.119, Health Hazard Material, and 3.3.188, Physical Hazard Material.)* [**400,** 2022]

3.3.149.2 ***Noncombustible Material.*** See 4.15.1.

Δ **3.3.150 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.

3.3.151 Maximum Allowable Working Pressure (MAWP). See 3.3.197.3.

3.3.152* Maximum Operating Pressure. See 3.3.197.5.1.

3.3.153 Mechanical Code. See 3.3.40.3.

3.3.154 Mechanical Connection. A non-welded or brazed connection.

3.3.155 Mechanical Ventilation. See 3.3.256.2.

Δ **3.3.156 Metal Hydride.** A generic name for compounds composed of metallic element(s) and hydrogen.

3.3.157 Metal Hydride Storage System. See 3.3.237.17.

3.3.158 Metallic Hose. A hose whose strength depends primarily on the strength of its metallic parts; it can have metallic liners or covers, or both. [**52,** 2023]

3.3.159 Micro Fuel Cell. A fuel cell that is wearable or easily carried by hand providing a direct current output that does not exceed 60 VDC and power output that does not exceed 240 VA.

3.3.160* Mobile [Fueling]. The dispensing of hydrogen from a mobile fueling vehicle or mobile fueling trailer directly into a hydrogen motor vehicle.

N 3.3.160.1 ***On-Demand Mobile Fueling.*** The dispensing of hydrogen into a parked hydrogen motor vehicle from a mobile fueling vehicle or mobile fueling trailer that is driven to the parked vehicle.

N **3.3.161 Mobile Fueling Trailer.** A DOT-approved trailer used for mobile fueling with the fueling equipment and containers mounted directly to the trailer and towed by a motor vehicle.

N **3.3.162 Mobile Fueling Vehicle.** A DOT-approved vehicle used for mobile fueling with the fueling equipment and containers mounted directly to the vehicle.

3.3.163 Mobile Supply Unit. See 3.3.245.2.

3.3.164 Motor Fuel Dispensing Facility. See 3.3.83.2.

3.3.165 Motor Fuel Dispensing Facility Located Inside a Building. See 3.3.83.2.4.

3.3.166 Motor Vehicle. Any self-propelled car, bus, truck, tractor, semitrailer, truck-trailer combination, or other vehicle used for the transportation of passengers or freight for use on public streets, roads, and highways.

3.3.166.1 ***Hydrogen Vehicle.*** A vehicle that uses hydrogen as a fuel for propulsion.

3.3.166.2* ***Light-Duty Hydrogen Motor Vehicle.*** A hydrogen vehicle that has a gross vehicle weight less than 8,500 lb, as defined by the United States Environmental Protection Agency.

N 3.3.166.3* ***Heavy-Duty Hydrogen Motor Vehicle.*** A hydrogen motor vehicle that has a gross vehicle weight rating greater than 26,001 lbs (11,794 kg) as defined by the United States Department of Transportation Federal Highway Administration.

3.3.167 Natural Ventilation. See 3.3.256.3.

Δ **3.3.168 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).

3.3.169* Non-Bulk Hydrogen Compressed Gas. Gaseous hydrogen (GH_2) packaged in cylinders, containers, or tanks with a contained volume not exceeding 5000 scf (141.6 Nm^3) each at NTP that are either not interconnected by manifolds or piping systems or that when interconnected have an aggregate contained volume of less than 5000 scf (141.6 Nm^3).

3.3.170 Noncombustible. Not capable of igniting and burning when subjected to a fire. [**80,** 2022]

3.3.171 Noncombustible Material. See 3.3.149.2.

3.3.172 Nonflammable Gas. See 3.3.106.7.

3.3.173 Nonlaboratory Area. See 3.3.7.4.

Δ **3.3.174 Normal Cubic Meter (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).

3.3.175 Normal Temperature and Pressure (NTP). See 3.3.197.4.

3.3.176 Open Parking Structure. See 3.3.186.2.

3.3.177 Operating Pressure. See 3.3.197.5.

3.3.178 Operator [Furnace]. An individual trained and responsible for the start-up, operation, shutdown, and emergency handling of the furnace and associated equipment. [**86,** 2023]

Δ **3.3.179 OSHA.** The Occupational Safety and Health Administration of the U.S. Department of Labor.

3.3.180 Other Gas. See 3.3.106.8.

3.3.181 Outdoor Area. See 3.3.7.5.

3.3.182 Outside or Outdoor Installation. See 3.3.130.2.

3.3.183 Oven. See 3.3.38, Class C Furnace.

3.3.184 Overpressure. See 3.3.197.6.

3.3.185 Oxidizing Gas. See 3.3.106.9.

3.3.186* Parking Structure. A building, structure, or portion thereof used for the parking, storage, or both, of motor vehicles. [**88A,** 2023]

3.3.186.1 ***Enclosed Parking Structure.*** Any parking structure that is not an open parking structure. [**88A,** 2023]

3.3.186.2 ***Open Parking Structure.*** A parking structure that meets the requirements of Section 5.6 of NFPA 88A. [**88A,** 2023]

3.3.187 Permissible Exposure Limit (PEL). See 3.3.144.2.1.

3.3.188 Physical Hazard Material. A chemical or substance classified as an explosive, flammable cryogen, flammable gas, flammable solid, ignitable (flammable or combustible) liquid, organic peroxide, oxidizer, oxidizing cryogen, pyrophoric, unstable (reactive), or water-reactive material. [**400,** 2022]

3.3.189 Pilot. A flame that is used to light the main burner. [**86,** 2023]

3.3.190 Pilot Plant. An experimental assembly of equipment for exploring process variables or for producing semicommercial quantities of materials. [**45,** 2019]

3.3.191 Piping System. See 3.3.237.20.

3.3.192 Point of Transfer. The location where connections and disconnections are made. [**52,** 2023]

3.3.193 Portable Fuel Cell [Power System] Installation. See 3.3.130.3.

3.3.194 Portable Tank. See 3.3.238.2.

3.3.195 Pre-engineered and Matched Modular Components Fuel Cell Power System. See 3.3.237.21.

3.3.196 Prepackaged, Self-Contained Fuel Cell Power System. See 3.3.237.22.

3.3.197 Pressure.

Δ **3.3.197.1*** ***Absolute Pressure.*** Pressure based on a zero reference point, the perfect vacuum.

3.3.197.2 ***Compression Discharge Pressure.*** The varying pressure at the point of discharge from the compressor. [**52,** 2023]

3.3.197.3 ***Maximum Allowable Working Pressure (MAWP) [GH_2 Fueling Facilities].*** The maximum pressure to which a component is designed to be subjected when handling fluid or gas over the range of design temperature. [**52,** 2023]

Δ **3.3.197.4*** ***Normal Temperature and Pressure (NTP).*** A temperature of 70°F (21°C) at an absolute pressure of 14.7 psi (101.3 kPa).

3.3.197.5 ***Operating Pressure.*** The varying pressure in a fuel system component during normal use. [**52,** 2023]

3.3.197.5.1 ***Maximum Operating Pressure [GH_2 Vehicular Fueling].*** The steady-state gauge pressure at which a part or system normally operates. This value is 1.25 × the pressure.

3.3.197.6 ***Overpressure.*** Exceeding the MAWP or a pressure that can cause damage or rupture to a component or container.

Δ **3.3.197.7** ***Service Pressure.*** The settled pressure of the fuel container at a uniform gas temperature of 70°F (21°C) and full gas content and for which the container, under normal conditions, has been constructed.

3.3.197.8 ***Set Pressure.*** The start-to-discharge pressure for which a relief valve is set and marked. [**52,** 2023]

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

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

3.3.198* Pressure Class. The designation of the service pressure of a fuel supply container. The pressure class is denoted by the letter H followed by the service pressure in MPa.

3.3.199 Pressure Regulator. See 3.3.212.1.

3.3.200 Pressure Relief Device. See 3.3.63.2.

3.3.201 Pressure Relief Device Channels. The passage or passages beyond the operating parts of the pressure relief device through which fluid passes to reach the atmosphere. [**52,** 2023]

3.3.202 Pressure Vessel. A container or other component designed in accordance with the ASME *Boiler and Pressure Vessel Code.* [**52,** 2023]

3.3.203 Protection.

Δ **3.3.203.1*** ***Cathodic Protection.*** A technique to resist the corrosion of a metal surface by making the surface the cathode of an electrochemical cell.

Δ **3.3.203.2** ***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.

3.3.203.3 ***Fire Protection.*** Methods of providing for fire control or fire extinguishment. [**801,** 2020]

Δ **3.3.204* 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.

3.3.205* Purge [Special Atmosphere Applications]. The replacement of a flammable, indeterminate, or high-oxygen-bearing atmosphere with another gas that, when complete, results in a nonflammable final state. [**86,** 2023]

Δ **3.3.206 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.

3.3.207 Pyrophoric Gas. See 3.3.106.10.

Δ **3.3.208 Qualified Individual.** An individual knowledgeable in the hazards of compressed gases and cryogenic fluids through training and work experience.

3.3.209 Qualified Person. A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems relating to a particular subject matter, work, or project. [**45,** 2019]

3.3.210 Ramp-Type Parking Structure. See 3.3.186, Parking Structure.

Δ **3.3.211 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.

3.3.212 Regulator.

3.3.212.1 ***Pressure Regulator.*** A device, either adjustable or nonadjustable, for controlling and maintaining, within acceptable limits, a uniform outlet pressure. [**52,** 2023]

3.3.213 Remotely Located, Manually Activated Shutdown Control. See 3.3.51.3.

3.3.214 Repair Garages.

Δ **3.3.214.1** ***Major Repair Garage (Hydrogen Vehicle).*** A building or portions of a building for major repairs, such as work on the hydrogen storage system, the fuel system, repairs that require defueling of the hydrogen vehicle, and maintenance or repairs that require open-flame cutting or welding.

3.3.214.2* ***Minor Repair Garage (Hydrogen Vehicle).*** A building or portions of a building used for lubrication, inspection, and minor automotive maintenance work, such as engine tune-ups, replacement of parts, fluid changes (e.g., brake fluid, air conditioning refrigerants), brake system repairs, tire rotation, and similar routine maintenance work.

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3.3.215 Rooftop Installation. See 3.3.130.4.

3.3.216* Safety Data Sheet (SDS). The document that describes composition of a material, hazardous properties and hazard mitigation, and disposal information. [**400,** 2022]

3.3.217* Safety Device. See 3.3.63.3.

3.3.218 Safety Interlock. A device required to ensure safe startup and safe operation and to cause safe equipment shutdown. [**86,** 2023]

3.3.219 Safety Shutoff Valve. See 3.3.252.2.1.

3.3.220 Sash. A movable panel or panels set in the hood entrance. [**45,** 2019]

3.3.221* Self-Service Motor Fuel Dispensing Facility. A property where liquids or gases used as motor fuels are stored and dispensed from fixed, approved dispensing equipment into the fuel tanks of motor vehicles by persons other than the facility attendant.

3.3.222 Service Pressure. See 3.3.197.7.

3.3.223 Set Pressure. See 3.3.197.8.

3.3.224 Settled Pressure. See 3.3.197.9.

3.3.225 Short-Term Exposure Limit (STEL). See 3.3.144.2.2.

3.3.226 Source Valve. See 3.3.252.3.

3.3.227* Special Atmosphere. A prepared gas or a gas mixture that is introduced into the heating chamber of a furnace to replace air, generally to protect or intentionally change the surface of the material undergoing heat processing (heat treatment). [**86,** 2023]

3.3.227.1 ***Flammable Special Atmosphere.*** A special atmosphere in which gases are known to be flammable and predictably ignitible where mixed with air. [**86,** 2023]

3.3.227.2 ***Synthetic Special Atmosphere.*** A special atmosphere such as those of anhydrous ammonia, hydrogen, nitrogen, or inert gases obtained from compressed gas cylinders or bulk storage tanks and those derived by chemical dissociation or mixing of hydrocarbon fluids, including mixtures of synthetic and generated atmospheres. [**86,** 2023]

Δ **3.3.228 Special Provisions.** Controls required when the maximum allowable quantity in the control area is exceeded.

3.3.229 Sprinkler System. See 3.3.237.23.

Δ **3.3.230 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).

3.3.231 Stationary. Permanently connected and fixed in place. [**853,** 2020]

3.3.232 Stationary Tank. See 3.3.238.3.

Δ **3.3.233 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.

3.3.234 Storage Pressure. See 3.3.197.10.

3.3.235 Storage Tank. See 3.3.238.4.

3.3.236 Synthetic Special Atmosphere. See 3.3.227.2.

3.3.237 System.

Δ **3.3.237.1** ***Automatic Fire Detection System.*** A fire detection system that senses the presence of fire, smoke, or heat and activates a fire suppression system and/or an automatic alarm system. [**853,** 2022]

Δ **3.3.237.2*** ***Bulk Hydrogen Compressed Gas System.*** A gaseous hydrogen (GH_2) system with a storage capacity of more than 5000 scf (141.6 Nm^3) of compressed hydrogen gas.

Δ **3.3.237.3*** ***Bulk Liquefied Hydrogen (LH_2) System.*** A liquefied hydrogen (LH_2) system with a storage capacity of more than 39.7 gal (150 L) of liquefied hydrogen.

Δ **3.3.237.4*** ***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.

3.3.237.5 ***Compressed Gas System.*** An assembly of equipment designed to contain, distribute, or transport compressed gases. [**318,** 2022]

3.3.237.6 ***Duct System.*** A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, fans, and accessory air-managing equipment and appliances. [**853,** 2020]

3.3.237.7* ***Engineered and Field-Constructed Fuel Cell Power System.*** A fuel cell power system that is not preassembled or does not have factory-matched components. [**853,** 2020]

3.3.237.8 ***Exhaust System.*** An air-conveying system for moving materials from a source to a point of discharge. [**91,** 2020]

3.3.237.9 ***Fuel Cell Power System (FCPS).*** A generator system that converts the chemical energy of reactants (a fuel and oxidant) by an electrochemical process to electric energy (direct current or alternating current electricity) and thermal energy. [**853,** 2020]

Δ **3.3.237.10** ***Gas Detection System.*** One or more sensors capable of detecting hydrogen at specified concentrations and activating alarms and safety systems.

Δ **3.3.237.11*** ***Gaseous Hydrogen (GH_2) System.*** An assembly of equipment that consists of, but is not limited to, storage containers, pressure regulators, pressure relief devices, compressors, manifolds, and piping and that terminates at the source valve.

Δ **3.3.237.12** ***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.

3.3.237.13 ***Hydrogen Storage System.*** That portion of a closed system used for retention of hydrogen gas or liquid upstream of the source valve.

3.3.237.14 ***Hydrogen Use System.*** Placing hydrogen into action through the use of piping, pressure or control systems downstream of the source valve.

Δ **3.3.237.15** ***Interactive System.*** A fuel cell power system that operates in parallel with and may deliver power to an electrical production and distribution network. For the purpose of this definition, an energy storage subsystem of a fuel cell power system, such as a battery, is not another electrical production source.

Δ **3.3.237.16*** ***Liquefied Hydrogen (LH_2) System.*** An assembly of equipment that consists of, but is not limited to, storage containers, pressure regulators, pressure relief devices, compressors, manifolds, and piping and that terminates at the source valve.

Δ **3.3.237.17** ***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.

3.3.237.18 ***Micro Fuel Cell Power System.*** A micro fuel cell power unit and associated fuel cartridges that is wearable or that is easily carried by hand.

Δ **3.3.237.19*** ***Non-Bulk Flammable Gas System.*** A system consisting of cylinders or other storage systems, with each individual cylinder and each individual set of connected cylinders having less than 5000 scf (141.6 Nm^3).

Δ **3.3.237.20*** ***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.

Δ **3.3.237.21*** ***Pre-engineered and Matched Modular Components Fuel Cell Power System.*** A fuel cell power system that has components that are assembled in a factory in separate modules, such as the fuel cell power system stack, reformer, and inverter.

3.3.237.22 ***Prepackaged, Self-Contained Fuel Cell Power System.*** A fuel cell power system that is designed as one unit, assembled in a factory, and shipped to site. [**853,** 2020]

Δ **3.3.237.23** ***Sprinkler System.*** A system, commonly activated by heat from a fire and discharges water over the fire area, that consists of an integrated network of piping designed in accordance with fire protection engineering standards that includes a water supply source, a control valve, a waterflow alarm, and a drain. The portion of the sprinkler system above ground is a network of specially sized or hydraulically designed piping installed in a building, structure, or area, generally overhead, and to which sprinklers are attached in a systematic pattern. [**13,** 2022]

Δ **3.3.237.24** ***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.

3.3.238 Tank (Flammable or Combustible Liquid).

3.3.238.1 ***Aboveground Tank.*** A storage tank that is installed above grade, at grade, or below grade without backfill. [**30,** 2021]

Δ **3.3.238.2** ***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.

Δ **3.3.238.3*** ***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.

3.3.238.4 ***Storage Tank.*** Any vessel having a liquid capacity that exceeds 60 gal (230 L), is intended for fixed installation, and is not used for processing. [**30,** 2021]

3.3.238.4.1 ***Aboveground Storage Tank [Flammable or Combustible Liquids].*** A horizontal or vertical tank that is listed and intended for fixed installation, without backfill, above or below grade and is used within the scope of its approval or listing. [**30A,** 2021]

3.3.239 Temperature Controller. See 3.3.53.2.

3.3.240* Thermal Spraying. A coating process in which melted (or heated) materials are sprayed onto a surface. The "feedstock" (coating precursor) is heated by electrical (plasma or arc) or chemical means (combustion flame).

3.3.241 Toxic Gas. See 3.3.106.11.

3.3.242 TC. Transport Canada.

3.3.243 Treatment System. See 3.3.237.24.

Δ **3.3.244* 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.

3.3.245 Unit.

3.3.245.1* ***Laboratory Unit.*** An enclosed space [within a laboratory building] used for experiments or tests. [**45,** 2019]

3.3.245.1.1 ***Instructional Laboratory Unit.*** A laboratory unit, under the direct supervision of an instructor, that is used for the purposes of instruction for students beyond the twelfth grade. [**45,** 2019]

Δ **3.3.245.2*** ***Mobile Supply Unit.*** Any supply source that is equipped with wheels so it is able to be moved around.

Δ **3.3.246 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.

3.3.247 Unstable Reactive Gas. See 3.3.106.12.

Δ **3.3.248 Use.** To place a material into action, including solids, liquids, and gases.

3.3.249 User (Dispenser). A person who uses a dispenser to fuel a motor vehicle who might or might not be trained.

3.3.250* Vacuum Jacket. A double-walled pressure vessel consisting of an inner and outer vessel that has been constructed in a manner similar to a thermos bottle where the atmosphere between the inner and outer vessels has been removed by mechanical means.

3.3.251 Vacuum Pump. A compressor for exhausting air and noncondensable gases from a space that is to be maintained at subatmospheric pressure. [**86,** 2023]

3.3.252 Valve.

Δ **3.3.252.1** ***Emergency Shutoff Valve.*** A designated valve designed to shut off the flow of gases or liquids.

Δ **3.3.252.1.1** ***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.

3.3.252.2 ***Shutoff Valve.***

3.3.252.2.1* ***Safety Shutoff Valve.*** A normally closed valve installed in the piping that closes automatically to shut off the fuel, atmosphere gas, or oxygen in the event of abnormal conditions or during shutdown. [**86,** 2023]

Δ **3.3.252.3*** ***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.

3.3.253* Vaporizer. A heat exchanger that transfers heat from an outside source to a liquid, typically a cryogenic fluid contained within a closed piping system, in order to transform the fluid from its liquid phase to the gaseous phase.

3.3.254 Vehicle. A device or structure for transporting persons or things; a conveyance (e.g., automobiles, trucks, marine vessels, railroad trains). [**52,** 2023]

N **3.3.255* Vent System.** A system that provides a means of depressurizing or relieving excess gas pressure and directing the venting gas to a safe location.

3.3.256 Ventilation.

Δ **3.3.256.1** ***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.

3.3.256.2 ***Mechanical Ventilation.*** The flow of air or gas created by a fan, blower, or other mechanical means that will push or induce the gas stream through a ventilation system. [**853,** 2020]

3.3.256.3 ***Natural Ventilation.*** The flow of air or gases created by the difference in the pressures or gas densities between the outside and inside of a vent, room, or space. [**853,** 2020]

3.3.257 Ventilation Air. See 3.3.4.3.

3.4 Definitions for Performance-Based Designs.

3.4.1 Alternative Calculation Procedure. A calculation procedure that differs from the procedure originally employed by the design team but that provides predictions for the same variables of interest. [***101,*** 2021]

3.4.2 Analysis.

3.4.2.1 ***Sensitivity Analysis.*** An analysis performed to determine the degree to which a predicted output will vary given a specified change in an input parameter, usually in relation to models. [**5000,** 2021]

3.4.2.2 ***Uncertainty Analysis.*** An analysis performed to determine the degree to which a predicted value will vary. [**5000,** 2021]

3.4.3 Data Conversion. The process of developing the input data set for the assessment method of choice. [***101,*** 2021]

3.4.4 Design Fire Scenario. See 3.4.9.1.

3.4.5 Design Specification. See 3.4.20.1.

3.4.6 Design Team. A group of stakeholders including, but not limited to, representatives of the architect, client, and any pertinent engineers and other designers. [***101,*** 2021]

3.4.7* Exposure Fire. A fire that starts at a location that is remote from the area being protected and grows to expose that which is being protected. [***101***, 2021]

3.4.8* Fire Model. A structured approach to predicting one or more effects of a fire. [***101***, 2021]

3.4.9* Fire Scenario. A set of conditions that defines the development of fire, the spread of combustion products throughout a building or portion of a building, the reactions of people to fire, and the effects of combustion products. [***101***, 2021]

3.4.9.1 ***Design Fire Scenario.*** A fire scenario selected for evaluation of a proposed design. [***101***, 2021]

3.4.10 Fuel Load. The total quantity of combustible contents of a building, space, or fire area, including interior finish and trim, expressed in heat units or the equivalent weight in wood. [**921**, 2021]

3.4.11 Incapacitation. A condition under which humans do not function adequately and become unable to escape untenable conditions. [***101***, 2021]

3.4.12 Input Data Specification. See 3.4.20.2.

3.4.13 Occupant Characteristics. The abilities or behaviors of people before and during a fire. [***101***, 2021]

3.4.14* Performance Criteria. Threshold values on measurement scales that are based on quantified performance objectives. [***101***, 2021]

3.4.15* Proposed Design. A design developed by a design team and submitted to the authority having jurisdiction for approval. [***101***, 2021]

3.4.16 Safe Location. A location remote or separated from the effects of a fire so that such effects no longer pose a threat. [***101***, 2021]

3.4.17 Safety Factor. A factor applied to a predicted value to ensure that a sufficient safety margin is maintained. [***101***, 2021]

3.4.18 Safety Margin. The difference between a predicted value and the actual value where a fault condition is expected. [***101***, 2021]

3.4.19 Sensitivity Analysis. See 3.4.2.1.

3.4.20 Specification.

3.4.20.1* ***Design Specification.*** A building characteristic and other conditions that are under the control of the design team. [**5000,** 2021]

3.4.20.2 ***Input Data Specification.*** Information required by the verification method. [***101***, 2021]

3.4.21 Stakeholder. An individual, or representative of same, having an interest in the successful completion of a project. [***101***, 2021]

3.4.22 Uncertainty Analysis. See 3.4.2.2.

3.4.23 Verification Method. A procedure or process used to demonstrate or confirm that the proposed design meets the specified criteria. [***101***, 2021]

Chapter 4 General Fire Safety Requirements

4.1 Application. Sections 4.1 and 4.2 shall establish the minimum goals and objectives commensurate with public safety to be considered in the application of this code.

4.1.1 For applications where buildings or structures are to be provided, this code and the building code adopted by the jurisdiction shall be used to regulate matters of construction, including requirements for life safety in the building or structure in which hydrogen is stored, handled, or used.

4.1.2* For applications in facilities located outdoors, the proximity of hydrogen storage systems and systems that use or produce hydrogen shall be regulated by this code in addition to the requirements of building or local zoning regulations that address matters of location, quantity restrictions, or matters that are the subject of local, state, or federal regulations.

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

4.1.4 Subsection 4.4.1 shall be the default design option applicable to facilities where hydrogen is stored, handled, used, or produced.

4.1.4.1 The use of 4.4.2 shall be permitted at the option of the permittee with the approval of the authority having jurisdiction (AHJ).

4.1.4.2 Performance-based designs shall be in accordance with the requirements of Chapter 5.

4.2* Goals and Objectives. *(Also see Section 4.3.)*

Δ **4.2.1* Goals.** The goals of this *Code* shall be to provide a reasonable level of safety, property protection, and public welfare from the hazards created by fire, explosion, and other hazardous conditions. [**1:**4.1.1]

Δ **4.2.2* Objectives.** To achieve the goals stated in 4.2.1, the goals and objectives of 4.2.3 through 4.2.5 shall be used to determine the intent of this *Code*. [**1:**4.1.2]

Δ **4.2.3* Safety.** This *Code* shall provide for life safety by reducing the probability of injury or death from fire, explosions, or events involving [GH_2 or LH_2]. [**1:**4.1.3]

4.2.3.1 Safety from Fire.

Δ **4.2.3.1.1* Safety-from-Fire Goals.** The fire safety goals of this *Code* shall be as follows:

(1) To provide an environment for the occupants in a building or facility and for the public near a building or facility that is reasonably safe from fire and similar emergencies
(2) To protect fire fighters and emergency responders

[**1:**4.1.3.1.1]

4.2.3.1.2 Safety-from-Fire Objectives.

4.2.3.1.2.1 Buildings and facilities shall be designed, constructed, and maintained to protect occupants who are not intimate with the initial fire development for the amount of time needed to evacuate, relocate, or defend in place. [**1:**4.1.3.1.2.1]

4.2.3.1.2.2* Buildings shall be designed and constructed to provide reasonable safety for fire fighters and emergency responders during search and rescue operations. [**1:**4.1.3.1.2.2]

4.2.3.1.2.3 Buildings shall be designed, located, and constructed to reasonably protect adjacent persons from injury or death as a result of a fire. [**1:**4.1.3.1.2.3]

4.2.3.1.2.4 Buildings shall be designed, located, and constructed to provide reasonable access to the building for emergency responders. [**1:**4.1.3.1.2.4]

4.2.3.1.2.5* Operations shall be conducted at facilities in a safe manner that minimizes, reduces, controls, or mitigates the risk of fire injury or death for the operators, while protecting the occupants not intimate with initial fire development for the amount of time needed to evacuate, relocate, or defend in place. [**1:**4.1.3.1.2.5]

4.2.3.2 Safety During Building Use.

Δ **4.2.3.2.1* Safety-During-Building-Use Goal.** The safety-during-building-use goal of this *Code* shall be to provide an environment for the occupants of the building that is reasonably safe during the normal use of the building. [**1:**4.1.3.2.1]

4.2.3.2.2 Safety-During-Building-Use Objectives. Performance-based building design shall be in accordance with the requirements of the adopted building code.

4.2.3.3* Safety from Hydrogen Hazards.

4.2.3.3.1 Safety-from-Hydrogen-Hazards Goal. The safety-from- [hydrogen-hazards] goal of this code shall be to provide an environment for the occupants in a building or facility and to those adjacent to a building or facility that is reasonably safe from exposures to adverse effects from [hydrogen hazards] present therein. [**1:**4.1.3.3.1]

4.2.3.3.2 Safety-from-Hydrogen-Hazards Objectives.

4.2.3.3.2.1 The storage, use, or handling of [hydrogen] in a building or facility shall be accomplished in a manner that provides a reasonable level of safety for occupants and for those adjacent to a building or facility from health hazards, illness, injury, or death during normal storage, use, or handling operations and conditions. [**1:**4.1.3.3.2.1]

4.2.3.3.2.2* The storage, use, or handling of [hydrogen] in a building or facility shall be accomplished in a manner that provides a reasonable level of safety for occupants and for those adjacent to a building or facility from illness, injury, or death due to the following conditions:

(1) An unplanned release of [hydrogen]
(2) A fire impinging upon the [hydrogen piping or containment system] or the involvement of [hydrogen] in a fire
(3) The application of an external force on the [hydrogen piping or containment system] that is likely to result in an unsafe condition

[**1:**4.1.3.3.2.2]

4.2.4 Property Protection.

Δ **4.2.4.1 Property Protection Goal.** The property protection goal of this *Code* shall be to limit damage created by a fire, explosion, or event associated with [GH_2 or LH_2] to a reasonable level to the building or facility and adjacent property. [**1:**4.1.4.1]

4.2.4.2 Property Protection Objectives.

4.2.4.2.1* Prevention of Ignition. The facility shall be designed, constructed, and maintained, and operations associated with the facility shall be conducted, to prevent unintentional explosions and fires that result in failure of or damage to adjacent compartments, emergency life safety systems, adjacent properties, adjacent outside storage, and the facility's structural elements. [**1:**4.1.4.2.1]

4.2.4.2.2* Fire Spread and Explosions. In the event that a fire or explosion occurs, the building or facility shall be sited, designed, constructed, or maintained, and operations associated with the facility shall be conducted and protected, to reasonably reduce the impact of unwanted fires and explosions on the adjacent compartments, emergency life safety systems, adjacent properties, adjacent outside storage, and the facility's structural elements. [**1:**4.1.4.2.2]

4.2.4.2.3 Structural Integrity. The facility shall be designed, constructed, protected, and maintained, and operations associated with the facility shall be conducted, to provide a reasonable level of protection for the facility, its contents, and adjacent properties from building collapse due to a loss of structural integrity resulting from a fire. [**1:**4.1.4.2.3]

4.2.4.2.4 Hydrogen Hazards. The facility shall be designed, constructed, and maintained, and operations associated with the facility shall be conducted, to provide reasonable property protection from damage resulting from fires, explosions, and other unsafe conditions associated with the storage, use, and handling of [hydrogen] therein. [**1:**4.1.4.2.4]

4.2.5 Public Welfare.

Δ **4.2.5.1* Public Welfare Goal.** The public welfare goal of this *Code* shall be to maintain a high probability that buildings and facilities that provide a public welfare role for a community continue to perform the function for their intended purpose following a fire, explosion, or hazardous materials event. [**1:**4.1.5.1]

4.2.5.2* Public Welfare Objective. Buildings and facilities that provide a public welfare role for a community shall be designed, constructed, maintained, and operated to provide reasonable assurance of continued function following a fire, explosion, or hazardous materials event. [**1:**4.1.5.2]

4.3 Assumptions.

4.3.1* Single Fire Source.

Δ **4.3.1.1** The fire protection methods of this *Code* shall assume that multiple simultaneous fire incidents will not occur. [**1:**4.2.1.1]

4.3.1.2 The single fire source assumption shall not preclude the evaluation of multiple design fire scenarios as required by Section 5.4. [**1:**4.2.1.2]

4.3.2* Single Hazardous Material Release.

Δ **4.3.2.1** The protection methods of this *Code* shall assume that multiple simultaneous unauthorized releases of hazardous materials from different locations will not occur. [**1:**4.2.2.1]

4.3.2.2 The single hazardous material release assumption shall not preclude the evaluation of multiple design scenarios as required by Section 5.4. [**1:**4.2.2.2]

Δ **4.3.3* Incidents Impinging on Hazardous Materials.** The protection methods of this *Code* shall assume that a fire, explosion, hazardous materials release, or external force that creates a dangerous condition has the potential to impinge on hazardous materials being stored, handled, or used in the building or facility under normal conditions. (*See Section 5.4 for performance-based design scenarios.*) [**1:**4.2.3]

Δ **4.4 Compliance Options.** Compliance with the goals and objectives of Section 4.2 shall be provided in accordance with either of the following:

(1) The prescriptive-based provisions per 4.4.1
(2) The performance-based provisions per 4.4.2

[**1:**4.3]

4.4.1 Prescriptive-Based Option.

4.4.1.1 A prescriptive-based option shall be in accordance with Chapters 1 through 4 and Chapters 6 through 18 of this code as applicable.

4.4.2 Performance-Based Option.

Δ **4.4.2.1** A performance-based option shall be in accordance with Chapter 1 through Chapter 5 of this *Code*. [**1:**4.3.2.1]

Δ **4.4.2.2** Prescriptive requirements shall be permitted to be used as part of the performance approach, if they, in conjunction with the performance features, meet the overall goals and objectives of this *Code*. [**1:**4.3.2.2]

4.4.3 Where any of the requirements of either compliance method requires records to be kept, they shall comply with all of the following:

(1) Records shall be maintained on the premises or other approved location.
(2) Retention of records shall be for not less than three years, or shall comply with the period of time where specified in this code or referenced standards, whichever is longer.
(3) Records shall be made available for inspection by the AHJ and a copy shall be provided to the AHJ upon request.

Δ **4.5 Permits.** Permits shall be obtained in accordance with the requirements of the jurisdiction in which the facility operates.

4.6 Emergency Plan.

Δ **4.6.1** An emergency plan shall be prepared and updated wherever GH_2 or LH_2 are produced, handled, stored, or used in amounts exceeding the maximum allowable quantity (MAQ) per control area or where required by the AHJ.

Δ **4.6.2** The plan shall be available for inspection by the AHJ 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 safety data sheet (SDS) or equivalent for GH_2 or LH_2 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
    (b) Identifying the location of the GH_2 and LH_2 stored or used
    (c) Accessing SDSs
    (d) Knowing the site emergency procedures
(7) A list of the types and quantities of GH_2 and LH_2 found within the facility

4.7 Facility Closure.

4.7.1 Where required by the AHJ, no facility storing hazardous materials listed in 1.1.1 of NFPA 400 shall close or abandon an entire storage facility without notifying the AHJ at least 30 days prior to the scheduled closing. [**400:**1.9.1]

4.7.2 The AHJ shall be permitted to reduce the 30-day period specified in 4.7.1 where there are special circumstances requiring such reduction. [**400:**1.9.2]

4.7.3 Facilities Out of Service.

4.7.3.1 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]

4.7.3.2 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 4.7.4.1 through 4.7.4.2. [**400:**1.9.3.2]

4.7.4 Closure Plan.

4.7.4.1 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 [GH_2 or LH_2] at least 30 days prior to facility closure. [**400:**1.9.4.1]

4.7.4.2 The plan shall demonstrate that [GH_2 or LH_2] that was stored, dispensed, handled, or used in the facility has 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]

Δ **4.7.4.3** The plan shall be submitted with a permit application for facility closure in accordance with Section 4.5.

Δ **4.8* 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 7.1.7.

4.9 Management Plan and Hazardous Materials Documentation.

Δ **4.9.1 Hazardous Materials Management Plan.** Where required by the AHJ, a hazardous materials management plan (HMMP) shall be submitted to the AHJ.

Δ **4.9.1.1** The HMMP shall comply with the requirements of the adopted fire code.

4.9.2* Hazardous Materials Inventory Statement. When required by the AHJ, a hazardous materials inventory statement (HMIS) [addressing the GH_2 or LH_2 present] shall be completed and submitted to the AHJ. [**400:**1.12.1]

4.9.3 Safety Data Sheets. Safety Data Sheets (SDS) shall be available on the premises for [GH_2 or LH_2] regulated by this code. When approved, SDSs shall be permitted to be retrievable by electronic access. [**400:**6.1.2]

4.10 Release of GH_2 or LH_2.

Δ **4.10.1* Prohibited Releases.** [GH_2 or LH_2] 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) Pressure relief devices and vents designed as part of a system

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

4.10.3* Records of Unauthorized Releases. Accurate records of the unauthorized releases of [GH_2 or LH_2] shall be kept by the permittee. [**400:**6.1.3.3]

4.10.4 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]

4.10.5 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]

4.10.6 Responsibility for Cleanup of Unauthorized Releases.

4.10.6.1 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]

4.10.6.2 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]

4.11* Personnel Training. Persons in areas where [GH_2 or LH_2] 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 4.11.1 through 4.11.4.4. [**400:**6.1.4]

4.11.1 Awareness. The training provided for persons designated in Section 4.11 shall include awareness training in accordance with 4.11.1.1 through 4.11.1.3. [**400:**6.1.4.1]

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

4.11.1.2 Hazard Communications. Training shall be provided prior to beginning work in the work area to enable personnel to recognize and identify [GH_2 or LH_2] stored, dispensed, handled, or used on site and where to find hazard safety information pertaining to the hazards of the materials employed. [**400:**6.1.4.1.2]

4.11.1.3 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]

4.11.2 Operations Personnel. Persons engaged in storing, using, or handling [GH_2 or LH_2] shall be designated as operations personnel and shall be trained in accordance with 4.11.1 and 4.11.2.2 through 4.11.2.7. [**400:**6.1.4.2]

4.11.2.1 Fueling. Customers performing public motor fuel dispensing of GH_2 vehicles in accordance with Chapter 10 shall not be designated as operations personnel subject to the requirements of 4.11.2.

4.11.2.2 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 safety data sheet (SDS) furnished by the manufacturer or other authoritative sources. [**400:**6.1.4.2.1]

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

4.11.2.4 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]

4.11.2.5 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]

4.11.2.6 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]

4.11.2.7 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 any of the following:

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

[**400:**6.1.4.2.6]

4.11.3 Emergency Response Liaison. [400:6.1.4.3]

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

4.11.3.2 Emergency response liaison personnel shall do the following:

(1) Aid emergency responders in pre-planning responses to emergencies
(2) Identify locations where [GH_2 or LH_2] are located
(3) Have access to safety data sheets
(4) Be knowledgeable in the site emergency response procedures

[**400:**6.1.4.3.2]

4.11.4* 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]

4.11.4.1* 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]

4.11.4.2* Response to Incipient Events. Responses to incidental releases of [GH_2 or LH_2] 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 with the scope of this code. [**400:**6.1.4.4.2]

4.11.4.3* 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]

4.11.4.4 Training Mandated by other Agencies. Training required by federal, state, or local regulations that is required based on the quantity or type of [GH_2 or LH_2] 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]

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

4.12 Ignition Source Controls.

Δ **4.12.1 Smoking.** Smoking shall be prohibited in the following locations:

(1) Within 25 ft (7.6 m) of outdoor storage or areas, dispensing areas, or open use areas.
(2) In rooms or areas where [GH_2 or LH_2] are stored or dispensed or used in open systems in amounts requiring a permit in accordance with Section 4.5

[**400:**6.1.5.1]

4.12.2 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]

4.12.3 Energy-Consuming Equipment. Energy-consuming equipment with the potential to serve as a source of ignition shall be listed or approved for use with [GH_2 or LH_2] stored or used. [**400:**6.1.5.3]

4.12.4 Powered Industrial Trucks. Powered industrial trucks shall be operated and maintained in accordance with NFPA 505. [**1:**10.17]

4.12.5 Laboratories. Equipment in laboratories shall be in accordance with Chapter 16.

4.13 Signs.

4.13.1 General.

4.13.1.1* 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]

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

4.13.1.3 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]

4.13.2 Hazard Identification Signs.

4.13.2.1 Visible hazard identification signs in accordance with NFPA 704 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 4.9.1 and 4.9.2 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]

4.13.2.2 Identification of Containers, Cartons, and Packages. Individual containers, cartons, or packages shall be conspicuously marked or labeled in accordance with nationally recognized codes and standards.

Δ **4.13.2.3 Identification of Gas Rooms and Cabinets.** Rooms or cabinets containing compressed gases shall be conspicuously labeled as follows:

COMPRESSED GAS

4.13.3 No Smoking Signs. Where "no smoking" is not applicable to an entire site or building, signs shall be provided as follows:

(1) In rooms or areas where [GH_2 or LH_2] is stored or dispensed or used in open systems in amounts requiring a permit in accordance with Section 1.8 of NFPA 400
(2) Within 25 ft (7.6 m) of outdoor storage, dispensing, or open-use areas

[**400:**6.1.8.3]

4.14 Protection From Vehicular Damage.

4.14.1 Where required, guard posts in accordance with 4.14.1.2 or other approved means shall be provided to protect against physical damage.

4.14.1.1 Guard posts or other approved means shall be provided to protect the following 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 [GH_2 or LH_2]
(3) Use areas

[**400:**6.1.9.1]

4.14.1.2 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. (380 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 3 ft (0.9 m) from the tank.

[**400:**6.1.9.2]

4.15* Building Construction Materials.

Δ **4.15.1* Noncombustible Material.** The material complies with any of the following shall be considered a noncombustible material:

(1)* The material, in the form in which it is used and under the condition anticipated, will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat.
(2) A material that is reported as passing ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace at 750°C*.
(3) A material that is reported as complying with the pass/fail criteria of ASTM E136 when tested in accordance with the test method and procedure in ASTM E2652, *Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*.

[**5000:**7.1.4.1]

Δ **4.15.2* Limited-Combustible Material.** A material shall be considered a limited-combustible material where one of the following is met:

(1) The conditions of 4.15.2.1 and 4.15.2.2, and the conditions of either 4.15.2.3 or 4.15.2.4, shall be met.
(2) The conditions of 4.15.2.6 shall be met.

[**5000:**7.1.4.2]

Δ **4.15.2.1** The material shall not comply with the requirements for a noncombustible material, in accordance with 4.15.1. [**5000:**7.1.4.2.1]

Δ **4.15.2.2** The material, in the form which it is used, exhibits a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) where tested in accordance with NFPA 259. [**5000:**7.1.4.2.2]

Δ **4.15.2.3** 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 E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials.* [**5000:**7.1.4.2.3]

Δ **4.15.2.4** The material shall be composed of materials that, in the form and thickness used, neither exhibit a flame spread index greater than 25 nor exhibit evidence of continued progressive combustion when tested in accordance with ASTM E84, or ANSI/UL 723, and are of such composition that all surfaces that would be exposed by cutting through the material on any plane would neither exhibit a flame spread index greater than 25 nor exhibit evidence of continued progressive combustion when tested in accordance with ASTM E84 or UL 723. [**5000:**7.1.4.2.4]

Δ **4.15.2.5** Materials shall be considered limited-combustible materials where tested in accordance with ASTM E2965, *Standard Test Method for Determination of Low Levels of Heat Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter*, at an incident heat flux of 75 kW/m^2 for a 20-minute exposure and both of the following conditions are met:

(1) The peak heat release rate shall not exceed 150 kW/m^2 for longer than 10 seconds.
(2) The total heat released shall not exceed 8 MJ/m^2.

[**5000:**7.1.4.2.5]

Δ **4.15.2.6** Where the term *limited-combustible* is used in this *Code*, it shall also include the term *noncombustible*. [**5000:**7.1.4.2.6]

Chapter 5 Performance-Based Option

5.1* General.

5.1.1 Application. The requirements of this chapter shall apply to facilities designed to the performance-based option permitted by Section 4.4. [**1:**5.1.1]

5.1.2 Goals and Objectives. The performance-based design shall meet the goals and objectives of this code in accordance with Section 4.3.

5.1.3* Approved Qualifications. The performance-based design shall be prepared by a person with qualifications acceptable to the AHJ. [**1:**5.1.3]

5.1.4* Plan Submittal Documentation. When a performance-based design is submitted to the AHJ for review and approval, the owner shall document, in an approved format, each performance objective and applicable scenario, including any calculation methods or models used in establishing the proposed design's fire and life safety performance. [**1:**5.1.4]

5.1.5* Independent Review. The AHJ shall be permitted to require an approved, independent third party to review the proposed design and provide an evaluation of the design to the AHJ at the expense of the owner. [**1:**5.1.5]

5.1.6 Sources of Data. Data sources shall be identified and documented for each input data requirement that is required to be met using a source other than a required design scenario, an assumption, or a facility design specification. [**1:**5.1.6]

5.1.6.1 The degree of conservatism reflected in such data shall be specified, and a justification for the source shall be provided. [**1:**5.1.6.1]

5.1.6.2 Copies of all references relied upon by the performance-based design to support assumptions, design features, or any other part of the design shall be made available to the AHJ if requested. [**1:**5.1.6.2]

5.1.7 Final Determination. The AHJ shall make the final determination as to whether the performance objectives have been met. [**1:**5.1.7]

Δ **5.1.8* Operations and Maintenance Manual.** An approved Operations and Maintenance (O&M) Manual shall be provided by the owner to the AHJ and the fire department and shall be maintained at the facility in an approved location. [**1:**5.1.8]

5.1.9* Information Transfer to the Fire Service. Where a performance-based design is approved and used, the designer shall ensure that information regarding the operating procedures of the performance-based designed fire protection system is transferred to the owner and to the local fire service for inclusion in the pre-fire plan. [**1:**5.1.9]

5.1.10* Design Feature Maintenance.

5.1.10.1 The design features required for the facility to meet the performance goals and objectives shall be maintained by the owner and be readily accessible to the AHJ for the life of the facility. [**1:**5.1.10.1]

5.1.10.2 The facility shall be maintained in accordance with all documented assumptions and design specifications. [**1:**5.1.10.2]

5.1.10.2.1 Any proposed changes or variations from the approved design shall be approved by the AHJ prior to the actual change. [**1:**5.1.10.2.1]

5.1.10.2.2 Any approved changes to the original design shall be maintained in the same manner as the original design. [**1:**5.1.10.2.2]

5.1.11* Annual Certification. Where a performance-based design is approved and used, the property owner shall annually certify that the design features and systems have been maintained in accordance with the approved original performance-based design and assumptions and any subsequent approved changes or modifications to the original performance-based design. [**1:**5.1.11]

5.1.12 Hazardous Materials.

5.1.12.1 Performance-based designs for facilities containing high hazard contents shall identify the properties of hazardous materials to be stored, used, or handled and shall provide adequate and reliable safeguards to accomplish the following objectives, considering both normal operations and possible abnormal conditions:

(1) Minimize the potential occurrence of unwanted releases, fire, or other emergency incidents resulting from the storage, use, or handling of hazardous materials
(2) Minimize the potential failure of buildings, equipment, or processes involving hazardous materials by ensuring that such buildings, equipment, or processes are reliably designed and are suitable for the hazards present
(3) Minimize the potential exposure of people or property to unsafe conditions or events involving an unintended reaction or release of hazardous materials
(4) Minimize the potential for an unintentional reaction that results in a fire, explosion, or other dangerous condition
(5) Provide a means to contain, treat, neutralize, or otherwise handle plausible releases of hazardous materials to minimize the potential for adverse impacts to persons or property outside of the immediate area of a release
(6) Provide appropriate safeguards to minimize the risk of and limit damage and injury that could result from an explosion involving hazardous materials that present explosion hazards
(7) Detect hazardous levels of gases or vapors that are dangerous to health and alert appropriate persons or mitigate the hazard when the physiological warning properties for such gases or vapors are inadequate to warn of danger prior to personal injury
(8) Maintain power to provide for continued operation of safeguards and important systems that are relied upon to prevent or control an emergency condition involving hazardous materials
(9) Maintain ventilation where ventilation is relied upon to minimize the risk of emergency conditions involving hazardous materials
(10) Minimize the potential for exposing combustible hazardous materials to unintended sources of ignition and for exposing any hazardous material to fire or physical damage that can lead to endangerment of people or property

[**1:**5.1.12.1]

5.1.12.2 A process hazard analysis and off-site consequence analysis shall be conducted when required by the AHJ to ensure that people and property are satisfactorily protected from potentially dangerous conditions involving hazardous materials. The results of such analyses shall be considered when determining active and passive mitigation measures used in accomplishing the objectives of 4.2.3.3.2 and 4.2.4.2. [**1:**5.1.12.2]

5.1.12.3 Written procedures for pre-start-up safety reviews, normal and emergency operations, management of change, emergency response, and accident investigation shall be developed prior to beginning operations at a facility [-]. Such procedures shall be developed with the participation of employees. [**1:**5.1.12.3]

5.1.13 Special Definitions. A list of special terms used in this chapter shall be as follows:

(1) Design Fire Scenario *(See 3.4.9.1.)*
(2) Design Specification *(See 3.4.20.1.)*
(3) Design Team *(See 3.4.6.)*
(4) Exposure Fire *(See 3.4.7.)*
(5) Fire Model *(See 3.4.8.)*
(6) Fire Scenario *(See 3.4.9.)*
(7) Fuel Load *(See 3.4.10.)*
(8) Input Data Specification *(See 3.4.20.2.)*
(9) Occupant Characteristics *(See 3.4.13.)*
(10) Performance Criteria *(See 3.4.14.)*
(11) Proposed Design *(See 3.4.15.)*
(12) Safety Factor *(See 3.4.17.)*
(13) Safety Margin *(See 3.4.18.)*
(14) Sensitivity Analysis *(See 3.4.2.1.)*
(15) Stakeholder *(See 3.4.21.)*
(16) Uncertainty Analysis *(See 3.4.2.2.)*
(17) Verification Method *(See 3.4.23.)*

[**1:**5.1.13]

5.2 Performance Criteria.

5.2.1 General. A design shall meet the objectives specified in Section 4.2 if, for each required design scenario, assumption, and design specification, the performance criteria of 5.2.2 are met. [**1:**5.2.1]

5.2.2* Specific Performance Criteria.

5.2.2.1* Fire Conditions. No occupant who is not intimate with ignition shall be exposed to instantaneous or cumulative untenable conditions. [**1:**5.2.2.1]

5.2.2.2* 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]

5.2.2.3* 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]

5.2.2.4* 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]

5.2.2.5* Public Welfare. For facilities that serve a public welfare role as defined in 4.2.5, 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]

5.2.2.6 Occupant Protection from Untenable Conditions. Means shall be provided to evacuate, relocate, or defend in place occupants not intimate with ignition for sufficient time so that they are not exposed to instantaneous or cumulative untenable conditions from smoke, heat, or flames. [**1:**5.2.2.6]

5.2.2.7 Emergency Responder Protection. Buildings shall be designed and constructed to reasonably prevent structural failure under fire conditions for sufficient time to enable fire fighters and emergency responders to conduct search and rescue operations. [**1:**5.2.2.7]

5.2.2.8* Occupant Protection from Structural Failure. Buildings shall be designed and constructed to reasonably prevent structural failure under fire conditions for sufficient time to protect the occupants. [**1:**5.2.2.8]

5.3 Retained Prescriptive Requirements.

5.3.1 Systems and Features. All fire protection systems and features of the building shall comply with applicable NFPA standards for those systems and features. [**1:**5.3.1]

5.3.2 Electrical Systems. Electrical systems shall comply with applicable NFPA standards for those systems. [**1:**5.3.2]

5.3.3 General. The design shall comply with the following requirements in addition to the performance criteria of Section 5.2 and the methods of Sections 5.4 through 5.7:

(1) General requirements for precautions against fire from the adopted fire code
(2) Emergency evacuation drill requirements from the adopted fire code
(3) Smoking prohibition requirements of 4.12.1
(4) Fire service feature requirements of the adopted fire code
(5) Requirements for fire safety during construction and demolition from the adopted fire code

5.3.4 Means of Egress. The design shall comply with the adopted building code in addition to the performance criteria of Section 5.2 and the methods of Sections 5.4 through 5.7.

5.3.5 Equivalency. Equivalent designs for the features covered in the retained prescriptive requirements mandated by 5.3.1 through 5.3.4 shall be addressed in accordance with the equivalency provisions of Section 1.5. [**1:**5.3.5]

5.4* Design Scenarios.

5.4.1 General.

5.4.1.1 The proposed design shall be considered to meet the goals and objectives if it achieves the performance criteria for each required design scenario. The AHJ shall approve the parameters involved with required design scenarios. [**1:**5.4.1.1]

5.4.1.2* Design scenarios shall be evaluated for each required scenario using a method acceptable to the AHJ and appropriate for the conditions. Each scenario shall be as challenging and realistic as any that could realistically occur in the building. [**1:**5.4.1.2]

5.4.1.3* Scenarios selected as design scenarios shall include, but not be limited to, those specified in 5.4.2 through 5.4.5. [**1:**5.4.1.3]

5.4.1.3.1 Design fire scenarios demonstrated by the design team to the satisfaction of the AHJ as inappropriate for the building use and conditions shall not be required to be evaluated fully. [**1:**5.4.1.3.1]

5.4.1.4 Each design scenario used in the performance-based design proposal shall be translated into input data specifications, as appropriate for the calculation method or model. [**1:**5.4.1.4]

5.4.1.5 Any design scenario specifications that the design analyses do not explicitly address or incorporate and that are, therefore, omitted from input data specifications shall be identified, and a sensitivity analysis of the consequences of that omission shall be performed. [**1:**5.4.1.5]

5.4.1.6 Any design scenario specifications modified in input data specifications, because of limitations in test methods or other data generation procedures, shall be identified, and a sensitivity analysis of the consequences of the modification shall be performed. [**1:**5.4.1.6]

5.4.2* Required Design Scenarios — Fire. Performance-based building design for life safety affecting the egress system shall be in accordance with this code and the requirements of the adopted building code.

5.4.3 Required Design Scenarios — Explosion.

5.4.3.1 Explosion Design Scenario 1 — Hydrogen Pressure Vessel Burst Scenario. Explosion Design Scenario 1 shall be the prevention or mitigation of a ruptured hydrogen pressure vessel.

5.4.3.1.1 Explosion Design Scenario 1 shall identify the various pressure vessel failure prevention measures in relation to both expected and potential abnormal vessel fill and operating conditions.

5.4.3.1.2 Mitigation measures, if applicable, shall address the safety of individuals at various distances from the pressure vessel.

5.4.3.2 Explosion Design Scenario 2 — Hydrogen Deflagration. Explosion Design Scenario 2 shall be the deflagration of a hydrogen-air or hydrogen-oxidant mixture within an enclosure such as a room or within large process equipment containing hydrogen.

5.4.3.2.1 Explosion Design Scenario 2 shall identify the specific gas mixture formed in relation to both expected and potential abnormal operating conditions and ventilation in the enclosure.

5.4.3.2.2 Mitigation measures, such as deflagration venting, shall address the hazards to any individuals within the enclosure and in the vicinity of the enclosure.

5.4.3.3 Explosion Design Scenario 3 — Hydrogen Detonation. Explosion Design Scenario 3 shall be the detonation of a hydrogen-air or hydrogen-oxidant mixture within an enclosure such as a room or a process vessel or within piping containing hydrogen.

5.4.3.3.1 The specific enclosure selected shall be the enclosure that has the greatest potential for a detonation.

5.4.3.3.2 Explosion Design Scenario 3 shall identify the specific gas mixture formed in relation to both expected and potential abnormal operating conditions and ventilation in the enclosure.

5.4.3.3.3 Mitigation measures, such as detonation containment, shall address the hazards to any individuals in the vicinity of the enclosure.

5.4.4* Required Design Scenarios — Hazardous Materials.

5.4.4.1 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]

5.4.4.2 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]

5.4.4.3 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]

5.4.4.4 Hazardous Materials Design Scenario 4.

5.4.4.4.1 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]

5.4.4.4.2* Hazardous Materials Design Scenario 4 shall not be required to be applied to protection systems or features for which both the level of reliability and the design performance in the absence of the system are acceptable to the AHJ. [**1:**5.4.4.4.2]

5.4.5 Required Design Scenarios — Safety During Building Use.

5.4.5.1* Building Use Design Scenario 1. Building Use Design Scenario 1 involves an event in which the maximum occupant load is in the assembly building and an emergency event occurs blocking the principal exit/entrance to the building. This design scenario shall address the concern of occupants having to take alternative exit routes under crowded conditions. [**1:**5.4.5.1]

5.4.5.2 Building Use Design Scenario 2. Building Use Design Scenario 2 involves a fire in an area of a building undergoing construction or demolition while the remainder of the building is occupied. The normal fire suppression system in the area undergoing construction or demolition has been taken out of service. This design scenario shall address the concern regarding the inoperability of certain building fire safety features during construction and demolition in a partially occupied building. [**1:**5.4.5.2]

5.5 Evaluation of Proposed Designs.

5.5.1 General.

5.5.1.1 A proposed design's performance shall be assessed relative to each performance objective in Section 4.2 and each applicable scenario in Section 5.4, with the assessment conducted through the use of appropriate calculation methods. [**1:**5.5.1.1]

5.5.1.2 The choice of assessment methods shall require the approval of the AHJ. [**1:**5.5.1.2]

5.5.2 Use. The design professional shall use the assessment methods to demonstrate that the proposed design achieves the goals and objectives, as measured by the performance criteria in light of the safety margins and uncertainty analysis, for each scenario, given the assumptions. [**1:**5.5.2]

5.5.3 Input Data.

5.5.3.1 Data.

5.5.3.1.1 Input data for computer fire models shall be obtained in accordance with ASTM E1591, *Standard Guide for Obtaining Data for Fire Growth Models.* [**1:**5.5.3.1.1]

5.5.3.1.2 Data for use in analytical models that are not computer-based fire models shall be obtained using appropriate measurement, recording, and storage techniques to ensure the applicability of the data to the analytical method being used. [**1:**5.5.3.1.2]

5.5.3.2 Data Requirements. A complete listing of input data requirements for all models, engineering methods, and other calculation or verification methods required or proposed as part of the performance-based design shall be provided. [**1:**5.5.3.2]

5.5.3.3 Uncertainty and Conservatism of Data. Uncertainty in input data shall be analyzed and, as determined appropriate by the AHJ, addressed through the use of conservative values. [**1:**5.5.3.3]

5.5.4 Output Data. The assessment methods used shall accurately and appropriately produce the required output data from input data based on the design specifications, assumptions, and scenarios. [**1:**5.5.4]

5.5.5 Validity. Evidence shall be provided confirming that the assessment methods are valid and appropriate for the proposed facility, use, and conditions. [**1:**5.5.5]

5.6* Safety Factors. Approved safety factors shall be included in the design methods and calculations to reflect uncertainty in the assumptions, data, and other factors associated with the performance-based design. [**1:**5.6]

5.7 Documentation Requirements.

5.7.1* General.

5.7.1.1 All aspects of the design, including those described in 5.7.2 through 5.7.14, shall be documented. [**1:**5.7.1.1]

5.7.1.2 The format and content of the documentation shall be acceptable to the AHJ. [**1:**5.7.1.2]

5.7.2* Technical References and Resources.

5.7.2.1 The AHJ shall be provided with sufficient documentation to support the validity, accuracy, relevance, and precision of the proposed methods. [**1:**5.7.2.1]

5.7.2.2 The engineering standards, calculation methods, and other forms of scientific information provided shall be appropriate for the particular application and methodologies used. [**1:**5.7.2.2]

5.7.3 Facility Design Specifications. All details of the proposed facility design that affect the ability of the facility to meet the stated goals and objectives shall be documented. [**1:**5.7.3]

5.7.4 Performance Criteria. Performance criteria, with sources, shall be documented. [**1:**5.7.4]

5.7.5 Occupant Characteristics. Assumptions about occupant characteristics shall be documented. [**1:**5.7.5]

5.7.6 Design Scenarios. Descriptions of design hazard scenarios shall be documented. [**1:**5.7.6]

5.7.7 Input Data. Input data to models and assessment methods, including sensitivity analysis, shall be documented. [**1:**5.7.7]

5.7.8 Output Data. Output data from models and assessment methods, including sensitivity analysis, shall be documented. [**1:**5.7.8]

5.7.9 Safety Factors. Safety factors utilized shall be documented. [**1:**5.7.9]

5.7.10 Prescriptive Requirements. Retained prescriptive requirements shall be documented. [**1:**5.7.10]

5.7.11* Modeling Features.

5.7.11.1 Assumptions made by the model user, and descriptions of models and methods used, including known limitations, shall be documented. [**1:**5.7.11.1]

5.7.11.2 Documentation shall be provided that the assessment methods have been used validly and appropriately to address the design specifications, assumptions, and scenarios. [**1:**5.7.11.2]

5.7.12 Evidence of Modeler Capability. The design team's relevant experience with the models, test methods, databases, and other assessment methods used in the performance-based design proposal shall be documented. [**1:**5.7.12]

5.7.13 Performance Evaluation. The performance evaluation summary shall be documented. [**1:**5.7.13]

5.7.14 Use of Performance-Based Design Option. Design proposals shall include documentation that provides anyone involved in ownership or management of the facility with all of the following notification:

(1) The facility was approved as a performance-based design with certain specified design criteria and assumptions.
(2) Any remodeling, modification, renovation, change in use, or change in the established assumptions requires a re-evaluation and reapproval.

[**1:**5.7.14]

Chapter 6 General Hydrogen Requirements

6.1 General.

6.1.1 Occupancies containing GH_2 or LH_2 shall comply with this chapter in addition to other applicable requirements of this code.

6.1.1.1 Specific Requirements. Where specific requirements are provided in other chapters, those specific requirements shall apply.

6.1.1.2 Conflict Provisions. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.

Δ **6.1.1.3 Occupancy Classification.** The occupancy of a building or structure, or portion of a building or structure, where hydrogen is stored or used, shall be classified in accordance with the adopted building code.

Δ **6.1.1.4 Quantities Less Than or Equal to the MAQ.** Indoor control areas with GH_2 or LH_2 stored or used in quantities less than or equal to those shown in Table 6.4.1.1.1 shall be in accordance with 6.4.1.5 and Sections 6.1, 6.8, 6.9, 6.13, and 6.17.

Δ **6.1.1.5 Quantities Greater Than the MAQ.** Building-related controls in areas with GH_2 or LH_2 stored or used within an indoor area in quantities greater than those shown in Table 6.4.1.1.1 shall be in accordance with the requirements of Chapter 6.

6.2 Design and Construction. Buildings, or portions thereof, shall be designed, located, and constructed in accordance with the adopted building code.

6.3 Control Areas.

6.3.1 Construction Requirements. Control areas shall be separated from each other's fire barriers in accordance with the adopted building code.

6.3.2 Number of Control Areas.

6.3.2.1 The maximum number of control areas within a building shall be in accordance with the adopted building code.

6.3.2.2 Where only one control area is present in a building, no special construction provisions shall be required. [**400:**5.2.2.2]

6.4 Occupancy Classification.

6.4.1 Quantity Thresholds for GH_2 or LH_2 Requiring Special Provisions.

6.4.1.1 Threshold Exceedences.

Δ **6.4.1.1.1** Where the quantities of GH_2 or LH_2 stored or used within an indoor control area exceed those shown in Table 6.4.1.1.1, the area shall meet the requirements for the occupancy classification in accordance with the adopted building code, based on the requirements of 6.4.2.

6.4.1.1.2 Pressure relief devices or stationary or portable containers shall be vented directly outdoors or to an exhaust hood.

Δ **6.4.1.2 Aggregate Allowable Quantities.** The aggregate quantity in use and storage shall not exceed the quantity listed for storage.

Δ **6.4.1.3 Incompatible Materials.** When the classification of materials in individual containers requires the area to be placed in more than one occupancy classification, the separation of occupancies shall not be required, provided the area is constructed to meet the requirements of the most restrictive occupancy classification and that the incompatible materials are separated as required by 7.2.1.1.

6.4.1.4 Multiple Hazards. GH_2 blended with other gases having multiple hazards shall also comply with NFPA 55.

6.4.1.5 GH_2.

Δ **6.4.1.5.1*** GH_2 shall not be stored or used in other than industrial or storage occupancies, or laboratory work areas of business occupancies.

Δ **6.4.1.5.1.1** 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.

6.4.1.5.1.2 Piping systems used to supply GH_2 in accordance with 6.5.1 shall be allowed.

6.4.1.5.1.3 Hydrogen gas systems located in a hydrogen gas room that meet the requirements of Section 6.6 are permissible in quantities up to those allowed by Table 6.4.1.1.1 for assembly, educational, institutional, residential, or business occupancies.

6.4.2 Classification of Occupancy. The occupancy classification required shall be based on the hazard class of the material involved as indicated in 6.4.2.1.

6.4.2.1 Occupancy Classification. Occupancies used for the storage or use of GH_2 or LH_2 in quantities that exceed the quantity thresholds for gases requiring special provisions shall be classified in accordance with the adopted building code.

6.5* Piping.

Δ **6.5.1* Piping Systems.** Piping, tubing, valves, and fittings shall be designed and installed in accordance with applicable sections of ASME B31, *Code for Pressure Piping*, and Sections 704.1.2.3, 704.1.2.4, and 704.1.2.5 of the ICC *International Fuel Gas Code (IFGC)*. Cast, ductile, malleable, or high-silicon iron pipe, valves, and fittings shall not be used.

Δ **6.5.1.1** Prior to acceptance and initial operation, all piping installations shall be inspected and pressure tested in accordance with ASME B31, *Code for Pressure Piping*, and Section 705 of the ICC *International Fuel Gas Code (IFGC)*.

Δ **6.5.1.2** In addition to the requirements of 6.5.1, brazing materials used for joints in piping and tubing systems shall have a melting point above 1000°F (538°C).

Δ **6.5.1.3** Underground piping systems shall be in accordance with 6.5.3.

Δ **6.5.1.4 Integrity.** Piping, tubing, pressure regulators, valves, and other apparatus shall be kept gastight to prevent leakage.

Δ **6.5.1.5 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.

6.5.2 Equipment Assembly.

Δ **6.5.2.1** Valves, gauges, regulators, and other accessories used for hydrogen systems shall be specified for hydrogen service by the manufacturer or the hydrogen supplier.

Δ **6.5.2.2** Storage containers, piping, valves, regulating equipment, and other appurtenances serving hydrogen systems shall be accessible and shall be protected against physical damage and tampering.

Δ **6.5.2.3** Cabinets or enclosures containing hydrogen control or operating equipment shall be ventilated to prevent the accumulation of hydrogen.

Δ **Table 6.4.1.1.1 Maximum Allowable Quantity of Hydrogen per Control Area (Quantity Thresholds Requiring Special Provisions)**

	Unsprinklered Areas		Sprinklered Areas	
Material	No Gas Cabinet, Gas Room, or Exhausted Enclosure	Gas Cabinet, Gas Room, or Exhausted Enclosure	No Gas Cabinet, Gas Room, or Exhausted Enclosure	Gas Cabinet, Gas Room, or Exhausted Enclosure
LH_2	0 gal (0 L)	45 gal (170 L) *	45 gal (170 L)	45 gal (170 L)
GH_2	1000 scf (26.3 Nm^3)	2000 scf (52.6 Nm^3)	2000 scf (52.6 Nm^3)	4000 scf (105.1 Nm^3)

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

Note: 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, and pressure-relief devices for stationary or portable containers vented directly outdoors or to an exhaust hood.

*A gas cabinet or exhausted enclosure is required *(see also 6.4.1.1.2)*.

Δ **6.5.2.4** Mobile hydrogen supply units used as part of a hydrogen system shall be secured to prevent movement.

Δ **6.5.2.5** Mobile hydrogen supply units shall be electrically bonded to the storage system before hydrogen is discharged from the supply unit.

6.5.3 Underground Piping.

Δ **6.5.3.1** Underground piping shall be of welded construction without valves, unwelded mechanical joints, or connections installed underground.

Δ **6.5.3.1.1** 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.

Δ **6.5.3.1.2** 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 adopted building code for areas designated as vehicular driveways and yards, subject to trucking.

Δ **6.5.3.1.3*** Piping installed in trench systems located below grade where the trench is open to above shall not be considered to be underground.

6.5.3.2 Contact with Earth.

Δ **6.5.3.2.1** Piping in contact with earth or other material that could corrode the piping shall be protected against corrosion in an approved manner.

Δ **6.5.3.2.2** When cathodic protection is provided, it shall be in accordance with 7.1.17.

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

6.5.3.4 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]

6.5.3.5 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]

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

Δ **6.5.3.7** 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.

6.5.3.8 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]

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

6.5.3.10 Two or more levels of piping 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]

6.5.3.11 "As-built" drawings of the underground piping installation shall be maintained by the owner and shall be available upon request by the AHJ.

Δ **6.6 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 10 through 18, the room shall meet the requirements of 6.6.1 through 6.6.5.

Δ **6.6.1 Pressure Control.** Gas rooms shall operate at a negative pressure in relationship to the surrounding area.

Δ **6.6.2 Exhaust Ventilation.** Gas rooms shall be provided with an exhaust ventilation system.

Δ **6.6.3 Construction.** Gas rooms shall be constructed in accordance with the adopted building code.

Δ **6.6.4 Separation.** Gas rooms shall be separated from other occupancies by a minimum of 1-hour fire resistance.

6.6.5 Limitation on Contents.

Δ **6.6.5.1** The function of compressed gas rooms shall be limited to storage and use of compressed gases and associated equipment and supplies.

6.6.5.2 Where GH_2 or LH_2 is stored and used in gas rooms it shall comply with 6.6.5.1.

6.7 Weather Protection.

6.7.1 Classification of Weather Protection as an Indoor Versus Outdoor Area.

6.7.1.1 A weather protection structure shall be allowed to be used for sheltering hydrogen in outdoor storage or use areas, without requiring these areas to be classified as indoor storage.

Δ **6.7.1.2** Weather protected areas constructed in accordance with 6.7.1.4 shall be regulated as outdoor storage or use.

Δ **6.7.1.3** Weather protected areas that are not constructed in accordance with 6.7.1.4 shall be regulated as indoor storage or use.

Δ **6.7.1.4** 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 and 8.

6.8* Electrical Equipment. Electrical wiring and equipment shall be in accordance with Section 6.8, *NFPA 70*, and NFPA 79, as applicable.

6.8.1 Standby Power.

Δ **6.8.1.1** Where the following systems are required by this code for the storage or use of GH_2 or LH_2 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*:

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

Δ **6.8.1.2** The requirements of 6.8.1.1 shall not apply where emergency power is provided in accordance with 6.8.2 and *NFPA 70*.

Δ **6.8.2 Emergency Power.** When emergency power is required, the system shall meet the requirements for a Level 2 system in accordance with NFPA 110 or NFPA 111.

Δ **6.8.2.1** When standby power is required, the system shall meet the requirements for a Level 2 system in accordance with NFPA 111.

Δ **6.9* 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 4.6.1, or for reaction time for safe egress of employees from the workplace or the immediate work area, or both.

6.10* Explosion Control.

6.10.1 Explosion control shall be provided where the quantity of GH_2 or LH_2 in storage or use exceeds the quantity thresholds requiring special provisions as listed in Table 6.4.1.1.1 or where otherwise required.

6.10.2 Where explosion control is required, it shall be provided by one or both of the following methods:

(1) Explosion prevention in accordance with 6.10.3
(2) Deflagration venting in accordance with 6.10.4

6.10.3* Explosion Prevention. Where provided, explosion prevention shall be in accordance with one or more of the methods specified in NFPA 69.

6.10.4 Deflagration Venting. Where provided, explosion protection by the use of deflagration venting shall be in accordance with NFPA 68.

6.11 Fire Protection Systems. Buildings, or portions thereof, required to comply with the requirements for hazardous occupancies shall be protected by an approved automatic fire sprinkler system complying with NFPA 13.

Δ **6.11.1 Sprinkler System Design.** When sprinkler protection is required, the area in which GH_2 or LH_2 is stored or used shall be protected with a sprinkler system designed to be not less than that required by 11.2.3.11 of NFPA 13 for the Extra Hazard Group 1 density/area curve.

6.12 Fire Alarm Systems.

6.12.1 A manual fire alarm system shall be provided in accordance with the adopted building code.

6.12.2 The system shall be designed, installed, and maintained in accordance with *NFPA 72*.

6.13* GH_2 Detection Systems.

6.13.1 Gas detection equipment shall be listed or approved.

6.13.2 Where GH_2 detection systems are installed, they shall be designed, installed, tested, inspected, calibrated, and maintained in accordance with the following:

(1) Manufacturer's requirements
(2) Equipment listing requirements

6.13.2.1 Maintenance, inspection, calibration, and testing shall be conducted by trained personnel.

6.13.2.1.1* Testing shall be conducted at least annually.

6.13.2.1.2 Maintenance, inspection, calibration, and testing records shall be retained for a minimum of 3 years.

Δ **6.14* Lighting.** Approved lighting by natural or artificial means shall be provided for areas of storage or use.

6.15 Spill Control, Drainage, and Secondary Containment.

Δ **6.15.1 GH_2.** Spill control, drainage, and secondary containment shall not be required for GH_2.

Δ **6.15.2 LH_2.** Diking shall not be used to contain an LH_2 spill.

Δ **6.15.2.1 LH_2** Diking or berms shall be permitted to direct the spill away from exposures.

6.16 Shelving.

Δ **6.16.1** 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.

Δ **6.16.2** Shelves and containers shall be secured from overturning.

Δ **6.17* Vent System Termination.** Hydrogen-venting systems serving pressure relief devices discharging hydrogen to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*.

6.17.1 Exits of vent stacks shall be located outdoors and away from personnel areas, ignition sources, air intakes, building openings, and overhangs.

N **6.17.2*** The area classifications and extent of the hazardous (classified) volume surrounding the vent pipe termination shall be determined using IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*.

N **6.17.3** The vertical dimension of the vent exit elevation shall be the greatest of the following:

(1) The thermal radiation and impingement distance determined in Section 6.17
(2) The extent of the hazardous area determined in 6.17.2
(3) A minimum of 10 ft (3 m) above grade, 2 ft (0.61 m) above adjacent equipment, or 5 ft (1.5 m) above rooftops

N **6.17.4*** The horizontal separation distance from the vent pipe termination to Exposures Group 1 and Exposures Group 2 in Table 7.3.2.3.1.2(B)(a) shall be the greatest of the following:

(1) The horizontal component of the thermal radiation and impingement distance determined in Section 6.17
(2) The horizontal component of the extent of the hazardous (classified) area determined in 6.17.2

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Δ **6.18* Ventilation.** Indoor storage and use areas and storage buildings for GH_2 and LH_2 shall be provided with mechanical exhaust ventilation or fixed natural ventilation, where natural ventilation is shown to be acceptable for the GH_2 or LH_2 as stored.

Δ **6.18.1 Ventilation Rate.** Mechanical exhaust or fixed natural ventilation shall be provided at a rate of not less than 1 scf/min/ft^2 (0.0051 m^3/sec/m^2) of floor area over the area of storage or use.

6.18.2 Mechanical Exhaust Ventilation.

Δ **6.18.2.1 Ventilation Systems.** In addition to the requirements of Section 6.18, ventilation systems shall be designed and installed in accordance with the requirements of the adopted mechanical code.

Δ **6.18.2.1.1 Continuous Operation.** When operation of ventilation systems is required, systems shall operate continuously unless an alternative design is approved by the AHJ.

Δ **6.18.2.1.2 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.

Δ **6.18.2.1.3 Manual Shutoff Switch.** The switch shall be the breakglass or equivalent type and shall be labeled as follows:

WARNING:

VENTILATION SYSTEM EMERGENCY SHUTOFF

6.18.2.1.4 Exhaust System.

Δ **6.18.2.1.4.1** The exhaust ventilation system design shall take into account the density of the potential gases released.

Δ **6.18.2.1.4.2** 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.

6.18.2.1.4.3* The inlets to the exhaust systems shall be either designed to prevent blockage due to debris, foliage, ice, snow, and so on, or the exhaust system shall detect and react to the blockage.

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

Δ **6.18.2.1.6** Exhaust ventilation shall not be recirculated.

6.18.2.1.7* Ventilation Discharge. Ventilation discharge systems conveying hydrogen mixtures exceeding 25 percent LFL in any normal or emergency operating mode shall terminate at a point outdoors not less than 30 ft (9.1 m) from property lines, 10 ft (3 m) from operable openings into buildings and public access, 6 ft (1.8 m) from exterior walls and roofs, 30 ft (9.1 m) from combustible walls and operable openings into buildings that are in the direction of the exhaust discharge, and 10 ft (3 m) above adjoining grade.

N **6.18.2.1.8 Ventilation Failure.**

N **6.18.2.1.8.1*** Where a mechanical ventilation system is used to reduce the area classification, it shall include a means to detect the loss of air flow.

N **6.18.2.1.8.2** Upon detection of loss of air flow or other ventilation failure, the system shall accomplish the following:

(1) Stop all hydrogen generation processes
(2) Close all supply valves that feed hydrogen or other flammable materials to the ventilated area
(3) De-energize all ignition sources in the ventilated area that are not suitable for the area classification that would apply without ventilation.

N **6.18.2.1.8.3*** The components of the ventilation system, detection system, and the circuit or system that accomplishes 6.18.2.1.8.2 shall be suitable for the area classification that would apply without ventilation.

Δ **6.19 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 6.19.1 through 6.19.4.

6.19.1 Construction.

Δ **6.19.1.1 Materials of Construction.** The gas cabinet shall be constructed of not less than 0.097 in. (2.46 mm) (12 gauge) steel.

Δ **6.19.1.2 Access to Controls.** The gas cabinet shall be provided with self-closing limited access ports or noncombustible windows to give access to equipment controls.

Δ **6.19.1.3 Self-Closing Doors.** The gas cabinet shall be provided with self-closing doors.

Δ **6.19.2 Ventilation Requirements.** The gas cabinet shall be provided with an exhaust ventilation system designed to operate at a negative pressure relative to the surrounding area.

Δ **6.19.3 Quantity Limits.** Gas cabinets shall contain not more than three cylinders, containers, or tanks.

Δ **6.19.4 Separation of Incompatibles.** Incompatible gases, as defined by Table 7.2.1.1, shall be stored or used within separate gas cabinets.

6.20 Exhausted Enclosures.

Δ **6.20.1 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.

6.20.2 Separation of Incompatible Gases within Enclosures.

Δ **6.20.2.1** Cylinders, containers, and tanks within enclosures shall be separated in accordance with Table 7.2.1.1.

Δ **6.20.2.2** Incompatible gases, as defined by Table 7.2.1.1, shall be stored or used within separate exhausted enclosures.

Δ **6.20.3 Fire Protection.** Exhausted enclosures shall be internally sprinklered.

Δ **6.21* Source Valve.** Bulk gas systems shall be provided with a source valve.

Δ **6.21.1** The source valve shall be marked.

Δ **6.21.2** The source valve shall be designated on the design drawings for the installation.

N **6.21.3*** If the source valve has a remote source of actuation, the energy source and isolation device shall be clearly labeled.

6.22 Cleaning, Purging, and Repairing of Piping Systems.

6.22.1 General.

Δ **6.22.1.1** Hydrogen systems shall be cleaned and purged in accordance with the requirements of Section 6.22 when one or more of the following conditions exist:

(1) The system is installed and prior to being placed into service
(2) There is a change in service
(3)* 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
(4)* The design standards or written procedures specify cleaning or purging

Δ **6.22.1.2** Cleaning and purging of the internal surfaces of hydrogen 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.

Δ **6.22.1.3*** A written cleaning or purging procedure shall be provided to establish the requirements for the cleaning and purging operations to be conducted.

Δ **6.22.1.3.1*** An independent or third-party review of the written procedure shall be conducted after the procedure has been written and shall accomplish the following:

(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 necessary

Δ **6.22.1.3.2** 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

Δ **6.22.1.3.3** Where generic cleaning or purging procedures have been established, a job-specific operating procedure shall not be required.

Δ **6.22.1.3.4** Generic procedures shall be reviewed when originally published or when the procedure or operation is changed.

6.22.1.4 Written procedures to manage change to process materials, technology, equipment, procedures, and facilities shall be established and implemented.

6.22.1.4.1 The management-of-change procedures shall ensure that the following issues are addressed prior to any change:

(1) The technical basis for the proposed change
(2) The safety and health implications
(3) Whether the change is permanent or temporary
(4) Modifications to the cleaning and purging procedures
(5) Employee training requirements
(6) Authorization requirements for the proposed change

[**56:**4.6.1]

6.22.1.4.2* Implementation of the management-of-change procedures shall not be required for replacements-in-kind. [**56:**4.6.2]

6.22.1.4.3 The written cleaning and purging procedure, as required by 6.22.1.3, shall be updated to incorporate the change. [**56:**4.6.3]

Δ **6.22.1.5** Prior to cleaning or purging, hydrogen 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.

Δ **6.22.1.5.1** Inspection and testing of piping systems shall not be required to remove a system from service.

Δ **6.22.1.5.2*** 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.

N **6.22.1.6*** Manual and automatic shutoff valves required for isolation shall be closed, locked, and tagged prior to repairs involving disconnecting piping or piping components.

Chapter 7 Gaseous Hydrogen

7.1 General.

7.1.1 The storage, use, and handling of GH_2 shall comply with this chapter in addition to other applicable requirements of this code.

7.1.1.1 Where specific requirements are provided in other chapters, those specific requirements shall apply.

7.1.1.2 Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.

7.1.1.3 The occupancy of a building or structure, or portion thereof, where hydrogen is stored or used shall be classified in accordance with the adopted building code.

7.1.2* GH_2 Systems.

Δ **7.1.2.1 System Design.** GH_2 systems shall be designed for the intended use and shall be designed by persons competent in such design.

Δ **7.1.2.2 Installation.** Installation of bulk GH_2 systems shall be supervised by personnel knowledgeable in the application of the standards for their construction and use.

7.1.2.3 Controls.

Δ **7.1.2.3.1** GH_2 system controls shall be designed to prevent materials from entering or leaving the process at an unintended time, rate, or path.

Δ **7.1.2.3.2** Automatic controls shall be designed to be fail-safe.

7.1.2.4 GH_2 shall not be used to operate any device or equipment that has not been designed for GH_2 service.

Δ **7.1.3 Listed or Approved Hydrogen Equipment.** Listed or approved hydrogen-generating and hydrogen-consuming equipment shall be in accordance with the listing requirements and manufacturers' instructions.

7.1.4* Metal Hydride Storage Systems.

7.1.4.1 General.

Δ **7.1.4.1.1 Metal Hydride Storage System Requirements.** The storage and use of metal hydride storage systems shall be in accordance with 7.1.4.

Δ **7.1.4.1.2 Metal Hydride Systems Storing or Supplying GH_2.** Those portions of the system that are used as a means to store or supply GH_2 shall also comply with Sections 7.2 or 7.3 as applicable.

Δ **7.1.4.1.3 Classification.** The hazard classification of the metal hydride storage system, as required by 5.1.1 and 5.1.3 of NFPA 55, shall be based on the GH_2 stored without regard to the metal hydride content.

Δ **7.1.4.1.4* 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.

Δ **7.1.4.1.5 Design and Construction of Containers.** GH_2 cylinders, containers, and tanks used for metal hydride storage systems shall be designed and constructed in accordance with 7.1.5.1.

Δ **7.1.4.1.6 Service Life and Inspection of Containers.** Metal hydride storage system cylinders, containers, and tanks shall be inspected at intervals not to exceed 5 years.

Δ **7.1.4.1.7 Marking and Labeling.** Marking and labeling of cylinders, containers, tanks, and systems shall be in accordance with 7.1.5 and the requirements in 7.1.4.1.7.1 through 7.1.4.1.7.4.

Δ **7.1.4.1.7.1 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

Δ **7.1.4.1.7.2 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

Δ **7.1.4.1.7.3 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

Δ **(A)** 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.

Δ **7.1.4.1.7.4 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

Δ **7.1.4.1.8 Temperature Extremes.** Metal hydride storage systems, whether full or partially full, shall not be exposed to temperatures exceeding the range stipulated by the manufacturer.

Δ **7.1.4.1.9 Falling Objects.** Metal hydride storage systems shall not be placed in areas where they are capable of being damaged by falling objects.

Δ **7.1.4.1.10 Refilling of Containers.** The refilling of listed or approved metal hydride storage systems shall be in accordance with the listing requirements and manufacturers' instructions.

7.1.4.1.10.1 Industrial Trucks. The refilling of metal hydride storage systems serving powered industrial trucks shall be in accordance with the requirements of Chapter 10.

Δ **7.1.4.1.10.2 Hydrogen Purity.** The purity of GH_2 used for the purpose of refilling containers shall be in accordance with the listing and the manufacturers' instructions.

Δ **7.1.4.1.11 Electrical.** Electrical components for metal hydride storage systems shall be designed, constructed, and installed in accordance with *NFPA 70*.

7.1.4.2 Portable Containers or Systems.

Δ **7.1.4.2.1 Securing Containers.** Cylinders, containers, and tanks shall be secured in accordance with 7.1.7.4.

Δ **7.1.4.2.1.1 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.

7.1.4.2.1.2 Motorized Equipment.

Δ **(A)** 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.

Δ **(B)** Metal hydride storage systems, including cylinders, containers, tanks, and fittings, shall not extend beyond the platform of the mobile equipment.

Δ **7.1.4.2.2 Valves.** Valves on cylinders, containers, and tanks shall remain closed except when containers are connected to closed systems and ready for use.

7.1.5 Cylinders, Containers, and Tanks.

Δ **7.1.5.1 Design and Construction.** Cylinders, containers, and tanks shall be designed, fabricated, tested, and marked (i.e., stamped) in accordance with Department of Transportation (DOT) regulations, Transport Canada's (TC) *Transportation of Dangerous Goods Regulations*, or the ASME *Boiler and Pressure Vessel Code*.

7.1.5.2 Defective Cylinders, Containers, and Tanks.

Δ **7.1.5.2.1** Defective cylinders, containers, and tanks shall be returned to the supplier.

Δ **7.1.5.2.2** Suppliers shall repair the cylinders, containers, and tanks, remove them from service, or dispose of them in an approved manner.

Δ **7.1.5.2.3** Cylinders, containers, and tanks shall be repaired or removed from service and disposed of in an approved manner.

Δ **7.1.5.3 Supports.** Stationary cylinders, containers, and tanks shall be provided with engineered supports of noncombustible material on noncombustible foundations.

Δ **7.1.5.4 Cylinders, Containers, and Tanks Containing Residual Gas.** GH_2 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.

7.1.5.5 Pressure Relief Devices.

Δ **7.1.5.5.1** When required by 7.1.5.5.2, pressure relief devices shall be provided to protect containers and systems containing GH_2 from rupture in the event of overpressure from thermal exposure.

Δ **7.1.5.5.2** 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.

Δ **7.1.5.5.3** Pressure relief devices shall be sized in accordance with the specifications to which the container was fabricated.

Δ **7.1.5.5.4** The pressure relief device shall have the capacity to prevent the maximum design pressure of the container or system from being exceeded.

Δ **7.1.5.5.5** 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.

Δ **7.1.5.5.6** 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.

7.1.6 Labeling Requirements.

Δ **7.1.6.1 Containers.** Individual GH_2 cylinders, containers, and tanks shall be marked or labeled in accordance with DOT requirements or those of the applicable regulatory agency.

Δ **7.1.6.2 Label Maintenance.** The labels applied by the gas manufacturer to identify the liquefied or nonliquefied GH_2 cylinder contents shall not be altered or removed by the user.

7.1.6.3 Stationary GH_2 Cylinders, Containers, and Tanks.

Δ **7.1.6.3.1** Stationary GH_2 cylinders, containers, and tanks shall be marked in accordance with NFPA 704.

Δ **7.1.6.3.2** Markings shall be visible from any direction of approach.

7.1.6.4 Piping Systems.

Δ **7.1.6.4.1** Except as provided in 7.1.6.4.2, piping systems shall be marked in accordance with ASME A13.1, *Scheme for the Identification of Piping Systems*, or other applicable approved codes and 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

Δ **7.1.6.4.2** Piping within gas manufacturing plants, gas processing plants, refineries, and similar occupancies shall be marked in an approved manner.

7.1.6.5 Marking.

Δ **7.1.6.5.1** Hazard identification signs shall be provided in accordance with 4.13.2.

Δ **7.1.6.5.2** 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

7.1.7 Security.

Δ **7.1.7.1 General.** GH_2 cylinders, containers, tanks, and systems shall be secured against accidental dislodgement and against access by unauthorized personnel.

Δ **7.1.7.2* Security of Areas.** Storage, use, and handling areas shall be secured against unauthorized entry.

Δ **7.1.7.2.1** 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.

7.1.7.3 Physical Protection.

Δ **7.1.7.3.1** GH_2 cylinders, containers, tanks, and systems that could be exposed to physical damage shall be protected.

Δ **7.1.7.3.2** Guard posts or other means shall be provided to protect GH_2 cylinders, containers, tanks, and systems indoors and outdoors from vehicular damage in accordance with Section 4.14.

7.1.7.3.3 Where guard posts are installed, they shall be in accordance with 4.14.1.2.

Δ **7.1.7.4 Securing GH_2 Cylinders, Containers, and Tanks.** GH_2 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 7.1.7.4.1 and 7.1.7.4.2.

Δ **7.1.7.4.1** GH_2 cylinders, containers, and tanks in the process of examination, servicing, and refilling shall not be required to be secured.

Δ **7.1.7.4.2** 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.

7.1.8 Valve Protection.

Δ **7.1.8.1* General.** GH_2 cylinder, container, and tank valves shall be protected from physical damage by means of protective caps, collars, or similar devices.

Δ **7.1.8.1.1** 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.

Δ **7.1.8.1.1.1** 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 portable equipped with manifolds, that are provided with physical protection in accordance with 4.1.4 and 7.1.7.3 or other approved means. Protective systems required by DOT for over the road transport shall provide an acceptable means of protection.

Δ **7.1.8.2 Valve-Protective Caps.** Where GH_2 cylinders, containers, and tanks are designed to accept valve-protective caps, the user shall keep such caps on the GH_2 cylinders, containers, and tanks at all times, except when empty, being processed, or connected for use.

7.1.9 Separation from Hazardous Conditions.

Δ **7.1.9.1 General.** GH_2 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.

Δ **7.1.9.1.1* Clearance from Combustibles and Vegetation.** Combustible waste, vegetation, and similar materials shall be kept a minimum of 10 ft (3.1 m) from GH_2 cylinders, containers, tanks, and systems.

Δ **7.1.9.1.1.1** 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.

Δ **7.1.9.1.1.2** The noncombustible partition shall be either an independent structure or the exterior wall of the building adjacent to the storage area.

Δ **7.1.9.1.2 Ledges, Platforms, and Elevators.** GH_2 cylinders, containers, and tanks shall not be placed near elevators, unprotected platform ledges, or other areas where GH_2 cylinders, containers, or tanks could fall distances exceeding one-half the height of the container, cylinder, or tank.

Δ **7.1.9.1.3 Temperature Extremes.** GH_2 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.

Δ **7.1.9.1.3.1** GH_2 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.

Δ **7.1.9.1.4 Falling Objects.** GH_2 cylinders, containers, and tanks shall not be placed in areas where they are capable of being damaged by falling objects.

Δ **7.1.9.1.5 Heating.** GH_2 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).

Δ **7.1.9.1.5.1 Electrically Powered Heating Devices.** Electrical heating devices shall be in accordance with *NFPA 70*.

Δ **7.1.9.1.5.2 Fail-Safe Design.** Devices designed to maintain individual GH_2 cylinders, containers, and tanks at constant temperature shall be designed to be fail-safe.

Δ **7.1.9.1.6 Sources of Ignition.** Open flames and high-temperature devices shall not be used in a manner that creates a hazardous condition.

Δ **7.1.9.1.7 Exposure to Chemicals.** GH_2 cylinders, containers, and tanks shall not be exposed to corrosive chemicals or fumes that could damage cylinders, containers, tanks, or valve-protective caps.

Δ **7.1.9.1.8 Exposure to Electrical Circuits.** GH_2 cylinders, containers, and tanks shall not be placed where they could become a part of an electrical circuit.

Δ **7.1.9.1.8.1*** Electrical devices mounted on GH_2 piping, cylinders, containers, or tanks shall be installed, grounded, and bonded in accordance with the methods specified in *NFPA 70* (NEC).

Δ **7.1.10 Service and Repair.** Service, repair, modification, or removal of valves, pressure relief devices, or other GH_2 cylinder, container, and tank appurtenances shall be performed by trained personnel and with the permission of the container owner.

Δ **7.1.11 Unauthorized Use.** GH_2 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.

Δ **7.1.12 Cylinders, Containers, and Tanks Exposed to Fire.** GH_2 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.

7.1.13 Leaks, Damage, or Corrosion.

Δ **7.1.13.1* Removal From Service.** Leaking, damaged, or corroded GH_2 cylinders, containers, and tanks shall be removed from service.

Δ **7.1.13.2 Replacement and Repair.** Leaking, damaged, or corroded GH_2 systems shall be replaced or repaired.

Δ **7.1.13.3* Handling of Cylinders, Containers, and Tanks Removed from Service.** GH_2 cylinders, containers, and tanks that have been removed from service shall be handled in an approved manner.

7.1.14 Surfaces.

Δ **7.1.14.1** To prevent bottom corrosion, cylinders, containers, and tanks shall be protected from direct contact with soil or surfaces where water might accumulate.

Δ **7.1.14.2** Surfaces shall be graded to prevent accumulation of water.

7.1.15 Valves.

Δ **7.1.15.1** Valves utilized on GH_2 systems shall be designed for the gas or gases and pressure intended and shall be accessible.

Δ **7.1.15.2** Valve handles or actuators for required shutoff valves shall not be removed or otherwise altered to prevent access.

Δ **7.1.16 GH_2 Venting Systems.** Hydrogen-venting systems serving pressure relief devices discharging GH_2 to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*.

Δ **7.1.16.1** 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.

Δ **7.1.16.1.1** 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.

7.1.16.2 Vent Pipe Termination.

Δ **7.1.16.2.1** Venting of GH_2 shall be directed to an approved location.

Δ **7.1.16.2.2** 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 6.17.

Δ **7.1.17 Cathodic Protection.** Where required, cathodic protection shall be in accordance with 7.1.17.

Δ **7.1.17.1 Operation.** Where installed, cathodic protection systems shall be operated and maintained to continuously provide corrosion protection.

Δ **7.1.17.2 Inspection.** Container systems equipped with cathodic protection shall be inspected for proper operation by a cathodic protection tester. The frequency of inspection shall be determined by the designer of the cathodic protection system.

Δ **7.1.17.2.1** The cathodic protection tester shall be certified as being qualified by the National Association of Corrosion Engineers, International (NACE).

Δ **7.1.17.3 Impressed Current Systems.** Systems equipped with impressed current cathodic protection systems shall be inspected in accordance with the requirements of the design and 7.1.17.2.

Δ **7.1.17.3.1** The design limits of the cathodic protection system shall be available to the AHJ upon request.

Δ **7.1.17.3.2** 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

Δ **7.1.17.4 Corrosion Expert.** Repairs, maintenance, or replacement of a cathodic protection system shall be under the supervision of a corrosion expert certified by NACE.

Δ **7.1.17.4.1** 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.

Δ **7.1.18 Transfer.** Transfer of GH_2 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*.

Δ **7.1.19 Compression and Processing Equipment.** Compression and gas processing equipment integral to hydrogen compressed gas storage systems shall be designed for use with GH_2 and for maximum pressures and temperatures to which it can be subjected under normal operating conditions.

Δ **7.1.19.1** 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.

Δ **7.1.19.2** Where GH_2 compression equipment is operated unattended, it shall be equipped with a high discharge and a low suction pressure automatic shutdown control.

Δ **7.1.19.3** When an automatic shutdown control shuts down a system, the system shall remain out of service until personnel authorized by the owner determines the cause of the shutdown and that the system is safe to restart.

7.1.20 Stationary Compressors.

7.1.20.1 Valves.

Δ **(A)** Valves shall be installed such that each compressor is able to be isolated for maintenance.

Δ **(B)** 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.

7.1.20.2 Foundations.

Δ **(A)** Foundations used for supporting equipment shall be designed and constructed to prevent frost heaving.

Δ **(B)** The structural aspects of such foundations shall be designed and constructed in accordance with the provisions of the adopted building code.

Δ **7.1.20.3 Emergency Shutdown.** When an emergency shutdown system (ESS) is required, activation of the ESS shall shut down operation of all compressors serving a single gas installation.

7.1.20.4 Relief Valves.

Δ **(A)** Each compressor shall be provided with a vent or relief device that will prevent overpressurizing of the compressor under normal or upset conditions.

Δ **(B)** Pressure relief devices used to serve pumps or compression equipment shall be connected to a vent pipe system in accordance with 7.1.16.

7.1.20.5 Pressure Monitoring.

Δ **7.1.20.5.1** The pressure on the compressor discharge shall be monitored by a control system.

Δ **7.1.20.5.2** Discharge pressures in excess of the equipment maximum operating pressure shall cause the compressor to shut down.

Δ **7.1.20.6 Protection.** Transfer piping and compressors shall be protected from vehicular damage.

7.1.21 Use of GH_2 for Inflation. Inflatable equipment, devices, or balloons shall not be pressurized or filled with GH_2 unless the balloon is designed specifically for hydrogen as a lift gas.

N **7.1.21.1** Balloons used for meteorological sounding flights and inflated with hydrogen shall comply with 7.1.21.1.

N **7.1.21.1.1** Hydrogen-filled meteorological balloons shall meet the following:

(1) Be inflated indoors in a purpose-built, dedicated area, room, or building
(2) Lift only meteorological sounding instrument(s)
(3)* Not be intended to land

N **7.1.21.1.2*** Hydrogen inflation facilities for meteorological balloons shall be certified as meeting the requirements of this code and being adequately safe by qualified engineer(s) with expertise and competence in hydrogen balloon inflation and hydrogen fire safety.

N **7.1.22** Piloted balloons shall be permitted to be filled with GH_2 when all of the following are met:

(1) The piloted balloon is designed and approved for use with GH_2.
(2)* The piloted balloon is operated, maintained, and inspected in accordance with applicable aviation regulations and is registered with a recognized national aviation authority.
(3)* The piloted balloon's structural conductive components and inflation system are bonded together via means recommended by the balloon's manufacturer.
(4)* The piloted balloon inflation system is bonded to the GH_2 supply container(s) and grounded via a grounding electrode conductor connected to a grounding electrode installed into the earth.
(5) The piloted balloon inflation assembly bonded elements have a resistance less than 106 ohms between the grounding electrode and the diffuser.
(6) The piloted balloon is filled outdoors, within an established inflation safety zone that meets the following conditions:
    (a)* It is marked or delineated by signage to prevent public access.
    (b) It is restricted to authorized personnel necessary for the inflation.
    (c) All potential ignition sources within the inflation safety zone, including vehicles, are prohibited during the inflation process.
(7)* The piloted balloon GH_2 source is immobile or has been rendered immobile.
(8) The piloted balloon inflation hose is described as follows:
    (a) Designed for GH_2 service at the flow rates used for inflation
    (b) Rated with a hydrostatic pressure appropriate for the GH_2 source
    (c) Electrically conductive or static dissipative with a smooth-bore liner
    (d) Visually inspected for damage prior to use
    (e) Purged of air, filled with GH_2, pressurized, and leak-checked prior to inflation
(9) Each piloted balloon inflation is coordinated by a single designated person who is responsible for the following:
    (a)* Being certificated or licensed as a pilot of GH_2 balloons by a recognized national aviation authority
    (b) Providing a safety briefing to all personnel involved in the inflation
    (c) Ensuring that the gas supply main shut-off valve is staffed at all times by an operator trained in GH_2 safety
    (d) Maintaining continuous visual contact with the gas supply's main shut-off valve operator when gas is flowing

7.1.23 Hydrogen Equipment Enclosures.

Δ **7.1.23.1** Hydrogen equipment enclosures (HEEs) shall be in accordance with the approved building code or 7.1.23 when the total quantity of hydrogen stored in or piped into the enclosure exceeds 1000 scf (28.3 Nm^3) or where the enclosure contains hydrogen processing or generating equipment.

Δ **7.1.23.1.1** Subsection 7.1.23 shall not apply to any of the following:

(1) Gas cabinets in accordance with Section 6.19
(2) Exhausted enclosures in accordance with Section 6.20
(3) Ventilated enclosures with sufficient dilution to maintain an unclassified area in the interior in accordance with Section 4.12
(4) Enclosures integral to fuel cell systems that are listed or approved in accordance with Chapter 12
(5) Enclosures integral to hydrogen generators that are listed or approved in accordance with Chapter 13

Δ Table 7.1.23.9.1 Protection Features Based on Use

HEE or a compartment in an HEE contains:	GH_2 storage	GH_2 storage	Hydrogen generation, compression and/or processing equipment	Support equipment room (in an HEE)
Enclosure Volume:	<200 ft^3	≥200 ft^3	Not limited	Not limited
Contains or is connected to a source of hydrogen:	Yes	Yes	Yes	No
Automatic isolation from GH_2 storage	Not required	Not required	Required	Not applicable
Ventilation	Natural or mechanical	Natural or mechanical	Mechanical	No additional requirement
Storage compartment separation	Not applicable	Not applicable	Required	Required
Electrical equipment	Per *NFPA 70*, Chapter 5	Per *NFPA 70*, Chapter 5	Per *NFPA 70*, Chapter 5	Unclassified
Bonding/grounding	Required	Required	Required	Per *NFPA 70*
Explosion control	Not required	Required	Required	Not required
Detection	Loss of ventilation*	GH_2, Loss of ventilation*	GH_2, Fire and Loss of ventilation	GH_2 if necessary to meet the requirements of 7.1.23.10.3.1

*Where mechanical ventilation is provided

7.1.23.1.2 HEE shall be constructed of noncombustible materials.

7.1.23.2 HEE grounding and equipment bonding within the enclosure shall comply with all of the following:

(1) The HEE structure shall be grounded in accordance with *NFPA 70*.
(2) All conductive parts of the enclosure shall be grounded or bonded.
(3) Hydrogen piping and equipment shall be bonded to the HEE structure to prevent static discharge.

7.1.23.3 Hydrogen Vent Systems.

7.1.23.3.1 GH_2 shall not be vented within the HEE or to compartments within an HEE.

7.1.23.3.2 Vent pipes shall be in accordance with Section 6.17 and 7.1.16.

7.1.23.3.3 Pressure relief devices and valves discharging to the atmosphere shall be vented in accordance with 7.1.5.5.5.

7.1.23.4 Oxygen Deficiency. An HEE that can be entered and contains or is connected to a source of GH_2 shall be evaluated for the potential of an oxygen-deficient atmosphere during normal or off-normal conditions.

7.1.23.4.1 Alarms.

7.1.23.4.1.1 Where the potential exists for an oxygen-deficient atmosphere, detection and notification appliances shall be provided to warn personnel of an oxygen-deficient atmosphere.

7.1.23.4.1.2 Notification appliances shall produce a distinctive audible and visual alarm and be located outside the entrance to all locations where the oxygen-deficient condition could exist.

7.1.23.4.1.3 If a GH_2 detection system is provided in accordance with Section 6.13, oxygen detectors are not required.

7.1.23.5 Security.

7.1.23.5.1 Exterior access doors for a HEE shall be secured against unauthorized entry.

7.1.23.5.1.1 Exterior access doors shall not be required to be secured if a secured perimeter fence or wall is provided to prevent unauthorized entry.

7.1.23.5.2 Locks or latches shall not require the use of a key, a tool, or special knowledge or effort for the operation from the egress side.

7.1.23.6* Means of egress for a HEE shall be in accordance with 7.1.23.6.1, unless the HEE cannot be entered.

7.1.23.6.1 Not fewer than two means of egress shall be provided from each equipment enclosure or equipment compartment, unless all of the following criteria are met:

(1) Undivided HEE or equipment compartments do not exceed 200 ft^2 (18.6 m^2).
(2) HEE or equipment compartments have a travel distance to the room or compartment exit door(s) not exceeding 15 ft (4.6 m).

7.1.23.6.1.1 The means of egress shall have the following:

(1) A minimum of 28 in. (710 mm) clear width
(2) A minimum headroom of not less than 6 ft 8 in. (2030 mm) along the entire designated means of egress path

7.1.23.7 A means shall be provided to isolate, depressurize, and make equipment and piping systems safe prior to replacement, maintenance, or service.

7.1.23.8 A HEE shall be secured to a structure or foundation in a manner approved by the authority having jurisdiction (AHJ).

7.1.23.9 Isolation of GH_2 Storage.

7.1.23.9.1 Where required by Table 7.1.23.9.1, a means for isolation of GH_2 storage shall be provided in accordance with 7.1.23.9.

7.1.23.9.2* GH_2 storage shall be equipped with automatic emergency shutoff valves to isolate the source of hydrogen from the delivery piping system.

7.1.23.9.3 Automatic emergency shutoff valves shall be located within the same compartment as the hydrogen storage.

7.1.23.9.4 Automatic emergency shutoff valves shall operate on GH_2 detection alarms, fire alarms, and ESS activations.

7.1.23.9.5 Automatic emergency shutoff valves shall be fail-safe to close upon loss of power or air pressure.

7.1.23.9.6 GH_2 generation and compression equipment within an HEE that supplies hydrogen to external storage containers shall be equipped with either an external automatic emergency shutoff valve or non-return valve on the exit piping outside the enclosure or compartment.

7.1.23.10 Ventilation.

7.1.23.10.1 Where required by Table 7.1.23.9.1, ventilation shall be provided in accordance with 7.1.23.10.

7.1.23.10.2 A HEE and compartments within an HEE that contain GH_2 storage, equipment, or piping shall be provided with ventilation in accordance with Section 6.18.

7.1.23.10.3 Natural ventilation openings and air intakes for mechanical ventilation systems shall be separated from non-bulk sources of GH_2 in accordance with 7.2.2.3.2.4 and from bulk sources of GH_2 in accordance with 7.3.2.3.1.2.

7.1.23.10.3.1 Air intakes and ventilation openings shall not be required to meet the requirements of Section 6.18 and 7.1.23.10.3 where the compartment is provided with GH_2 detection in accordance with 7.1.23.14, which initiates the emergency shutdown system (ESS) for the equipment within the enclosure upon detection of 25 percent of the LFL.

7.1.23.11 Storage Area Separation.

7.1.23.11.1 Where required by Table 7.1.23.9.1, storage area separation shall be provided in accordance with 7.1.23.11.

7.1.23.11.2 Fuel cell equipment, compressors, hydrogen generators, electrical distribution equipment, and similar appliances shall be separated from bulk GH_2 storage areas within the HEE by a one-hour fire-rated barrier that is also capable of preventing gas transmission.

7.1.23.12 Electrical Equipment.

7.1.23.12.1 All electrical equipment in an HEE that has GH_2 piping, storage, generation, or processing equipment shall be selected and installed in accordance with Articles 500 through 505 of *NFPA 70*.

7.1.23.12.2* Electrical equipment within 15 ft (4.6 m) of any natural ventilation opening or required exhaust discharge of an HEE shall be selected and installed in accordance with the requirements of Articles 500 through 505 of *NFPA 70*.

7.1.23.13 Emergency Shutdown System (ESS).

7.1.23.13.1 An ESS shall be provided for the HEE.

7.1.23.13.1.1 The ESS shall operate on GH_2 detection alarms, fire alarms, and loss of ventilation alarms, where these are required by Table 7.1.23.9.1.

7.1.23.13.1.2 The ESS shall operate upon activation of a manual emergency shutdown device (ESD).

7.1.23.13.1.3 The ESS shall operate across all interconnected HEE at a common site.

7.1.23.13.1.4 Where activated, the ESS shall de-energize unclassified electrical equipment inside compartments containing hydrogen or other flammable gases and close all automatic shutoff control valves on piping into and from interconnected HEE and HEE compartments containing hydrogen equipment.

7.1.23.13.1.5 A manual ESD shall be accessible, located exterior to the HEE, and in the immediate area of each HEE that is interconnected to the hydrogen system.

(A) The ESD shall be identified by a sign located at the exterior of the equipment enclosure.

7.1.23.13.1.6 A remote emergency shutdown shall be located not less than 25 ft (7.6 m) and not more than 100 ft (30 m) from HEE equipped with individual ESDs.

7.1.23.13.1.7 Activation of the ESS shall be indicated by a visible notification device mounted on the exterior of the HEE.

7.1.23.14 Detection.

7.1.23.14.1 Where required by Table 7.1.23.9.1, GH_2 detection, fire detection, and loss of ventilation detection shall be provided in accordance with 7.1.23.14.

7.1.23.14.2 GH_2 Detection.

7.1.23.14.2.1 GH_2 detection shall be provided in accordance with Section 6.13.

7.1.23.14.2.2 Detection of hydrogen above 25 percent of the LFL shall result in activation of the ESS.

7.1.23.14.3 Fire Detection.

7.1.23.14.3.1 Fire detection shall be provided.

7.1.23.14.3.2 The type of detection shall be as determined by a risk assessment.

7.1.23.14.3.3 Fire detection shall comply with both of the following:.

(1) Be in accordance with *NFPA 72*
(2) Activate the ESS

7.1.23.14.4 Ventilation Detection.

7.1.23.14.4.1 A device shall be provided to detect failure of the ventilation system.

7.1.23.14.4.2 The device shall activate the ESS when airflow drops below 75 percent of the required flow.

7.1.23.15 Explosion Control.

7.1.23.15.1 Where required by Table 7.1.23.9.1, explosion control shall be provided in accordance with Section 6.10.

7.1.23.15.1.1 Explosion vents, where used, shall not discharge into adjacent HEE compartments.

7.1.23.16 HEE Walls Used for Separation Distance Reductions.

7.1.23.16.1 Where a wall of an HEE is constructed as a fire barrier and used to reduce separation distances per 7.3.2.3.1.4, in 7.1.23.16.1.1 through 7.1.23.16.1.5 shall apply.

7.1.23.16.1.1 Penetrations.

Δ **(A)** The fire barrier wall shall be without openings or penetrations.

Δ **(B)** 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 adopted building code.

Δ **7.1.23.16.1.2*** Fire barrier walls shall have a minimum fire resistance rating of not less than 2 hours.

Δ **7.1.23.16.1.3** The fire barrier wall shall interrupt the line of sight between the bulk hydrogen compressed gas system and the exposure.

7.1.23.16.1.4 Only one fire barrier wall of an HEE shall be allowed to be used to reduce separation distances per 7.3.2.3.1.4.

7.1.23.16.1.5 Fire barrier walls shall be designed and constructed in accordance with the requirements of the adopted building code.

7.1.24 Emergency Shutoff Valves.

Δ **7.1.24.1** Accessible manual or automatic emergency shutoff valves shall be provided to shut off the flow of GH_2 in case of emergency.

Δ **7.1.24.1.1*** Manual emergency shutoff valves or the device that activates an automatic emergency shutoff valve on a bulk source or piping system serving the bulk supply shall be identified by means of a sign.

Δ **7.1.24.2** 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.

7.1.25 Emergency Isolation.

Δ **7.1.25.1** Where GH_2 from sources in excess of the quantity threshold in Table 6.4.1.1.1 is carried in pressurized piping above a gauge pressure of 15 psi (103 kPa), an approved method of emergency isolation shall be provided.

Δ **7.1.25.2** Approved means of meeting the requirements for emergency isolation shall include any of the following:

(1) Automatic shutoff valves, located as close to the bulk source as practical, tied to leak detection systems
(2) Attended control stations where trained personnel can monitor alarms or supervisory signals and can trigger emergency responses
(3) A constantly monitored control station with an alarm and remote shutoff of the gas supply system
(4) Excess flow valves at the bulk source

Δ **7.1.25.3** The requirements of 7.1.25 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

Δ **7.1.25.4 Location Exemptions.** The requirements of 7.1.25.1 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 GH_2

Δ **7.1.26 Ignition Source Control.** Ignition sources in areas containing GH_2 shall be in accordance with 7.1.26.

Δ **7.1.26.1 Static Producing Equipment.** Static producing equipment located in GH_2 areas shall be grounded.

Δ **7.1.26.2 No Smoking or Open Flame.** Signs shall be posted in areas containing GH_2 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.

7.1.27 Operating Instructions.

Δ **(A)** 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.

Δ **(B)** Instructions shall be maintained at the operating site at a location acceptable to the AHJ.

7.2 Non-Bulk GH_2.

7.2.1 General.

Δ **7.2.1.1* Incompatible Materials.** GH_2 cylinders, containers, and tanks shall be separated in accordance with Table 7.2.1.1.

7.2.1.1.1 GH_2 systems in outdoor storage or use shall be separated from other compressed gases in accordance with Table 7.3.2.3.1.2(B)(a).

Δ **7.2.1.1.2** Subparagraph 7.2.1.1.1 shall not apply to GH_2 contained within closed piping systems.

Δ **7.2.1.1.3** The distances shown in Table 7.2.1.1 shall be permitted to be reduced without limit where GH_2 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.

Δ **7.2.1.1.4** 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.

Δ **7.2.1.1.5** Cylinders without pressure relief devices shall not be stored without separation from flammable and pyrophoric gases with pressure relief devices.

Δ **7.2.1.1.6** Spatial separation shall not be required between cylinders deemed to be incompatible in gas production facili-

Δ **Table 7.2.1.1 Separation of Gas Cylinders, Containers, and Tanks by Hazard Class from Non-Bulk GH_2 Cylinders, Containers, Tanks, and Systems**

	GH_2*	
Gas Category	**ft**	**m**
Toxic or highly toxic	20	6.1
Pyrophoric	20	6.1
Flammable	—	—
Oxidizing	20	6.1
Corrosive	20	6.1
Unstable reactive Class 2, Class 3, or Class 4	20	6.1
Other gas	NR	NR

NR: No separation required.
*See flammable gas column from Table 7.1.10.2 of NFPA 55.

ties 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.

Δ **7.2.1.2 Bonding and Grounding.** The hydrogen compressed gas system shall be electrically bonded and grounded.

Δ **7.2.1.2.1** Mobile hydrogen supply units shall be electrically bonded to the storage system before hydrogen is discharged from the supply unit.

7.2.2 Non-Bulk GH_2 Storage.

7.2.2.1 General.

Δ **7.2.2.1.1 Applicability.** The storage of GH_2 exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.4.1.1.1 shall be in accordance with Chapters 1 through 6 as applicable and Sections 7.1 through 7.2.

Δ **7.2.2.1.2 Classification of Weather Protection as an Indoor Versus 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.

Δ **7.2.2.2 Indoor Storage.** Indoor storage of GH_2 shall be in accordance with the applicable provisions of Section 7.1.

7.2.2.2.1 Indoor GH_2 systems in control areas with less than the maximum allowable quantities per control area shown in Table 6.4.1.1.1 shall be located in accordance with the applicable provisions of Table 7.2.1.1.

7.2.2.2.2 Indoor Hydrogen System Location.

Δ **7.2.2.2.2.1** Hydrogen systems of less than 5000 scf (141.6 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 6.18
(2) Separated from incompatible materials in accordance with the provisions of 7.2.1.1
(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* 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 7.1.24.
(5) A distance of 50 ft (15 m) from other flammable gas storage
(6) Protected against damage in accordance with the provisions of 7.1.7.3

7.2.2.2.2.2 Systems Installed in One Room.

Δ **(A)** More than one system of 5000 scf (141.6 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.

Δ **(B)** The separation distance between multiple systems of 5000 scf (141.6 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 occupancies in accordance with the requirements of Section 6.11.

Δ **(C)** 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 7.2.2.2.2.2(A) or 7.2.2.2.2.2(B) when such facilities are provided with Protection Level 2 controls and the applicable requirements of Chapters 1 through 7.

7.2.2.3 Outdoor Storage.

Δ **7.2.2.3.1 General.** Exterior storage of GH_2 shall be in accordance with the material-specific provisions of 7.2.1, 7.2.2.1, and 7.2.2.3.

Δ **7.2.2.3.2* Distance to Exposures.** The outdoor storage or use of GH_2 shall be located from lot lines, public streets, public alleys, public ways, or buildings not associated with the manufacture or distribution of GH_2 in accordance with Table 7.2.2.3.2.

7.2.2.3.2.1 The minimum required distances in Table 7.2.2.3.2 shall not apply when fire barriers without openings or penetrations having a minimum fire resistive rating of two hours interrupt the line of sight between the storage and the exposure.

7.2.2.3.2.2 The configuration of the fire barriers in Table 7.2.2.3.2 shall be designed to allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

7.2.2.3.2.3 Fire Barriers.

Δ **(A)*** Where a fire barrier is used to protect GH_2 systems, the system shall terminate downstream of the source valve.

Δ **(B)** The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

Δ **(C)** The fire barrier wall shall be without openings or penetrations.

(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 adopted building code.

Δ **(D)** The configuration of the fire barrier shall be designed to allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

Δ **7.2.2.3.2.4 Air Intakes.** Storage and use of GH_2 shall not be located within 20 ft (6 m) of air intakes.

Δ **7.2.2.3.2.5 Building Openings.** Storage and use of GH_2 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.

Δ **Table 7.2.2.3.2 Distance to Exposures for Non-Bulk GH_2**

Maximum Amount Per Storage Area (ft^3)	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 do 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.

7.2.3 Non-Bulk GH_2 Use.

7.2.3.1 General.

Δ **7.2.3.1.1 Applicability.** The use of GH_2 exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.4.1.1.1 shall be in accordance with Chapters 1 through 6 as applicable and Sections 7.1 and 7.2.

Δ **7.2.3.2 Indoor Use.** Indoor use of GH_2 shall be in accordance with the requirements of Section 7.1.

Δ **7.2.3.3 Outdoor Use.** Exterior use of GH_2 shall be in accordance with the applicable requirements of Section 7.1.

7.2.4 Non-Bulk GH_2 Handling.

Δ **7.2.4.1 Applicability.** The storage or use of GH_2 exceeding the quantity thresholds for gases requiring special provisions as specified in Table 6.4.1.1.1 shall be in accordance with Chapters 1 through 6 as applicable and Sections 7.1 and 7.2.

7.2.4.2 Carts and Trucks.

Δ **7.2.4.2.1** Cylinders, containers, and tanks shall be moved using an approved method.

Δ **7.2.4.2.2** 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.

Δ **7.2.4.3 Lifting Devices.** Ropes, chains, or slings shall not be used to suspend GH_2 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.

7.2.4.4 Cargo Transport Unloading. Cargo transport unloading shall be in accordance with 7.3.4.2.

7.3 Bulk GH_2 Systems.

7.3.1 Bulk GH_2 Systems — General.

Δ **7.3.1.1 Applicability.** The storage, use, and handling of bulk GH_2 systems shall be in accordance with the applicable provisions of Chapters 1 through 6, and Section 7.3.

Δ **7.3.1.2 Bonding and Grounding.** The bulk hydrogen compressed gas system shall be electrically bonded and grounded.

7.3.2 Bulk GH_2 Systems Storage.

7.3.2.1 General.

Δ **7.3.2.1.1 Bulk Hydrogen Compressed Gas.** Systems located above ground either at grade or above grade shall be in accordance with 7.3.2.

Δ **7.3.2.1.2* Fire Protection.** Fire protection shall be in accordance with the requirements of Section 6.11.

7.3.2.1.3 Installation in Vaults Above and Below Ground. Generation, compression, storage, and dispensing equipment for compressed gases shall be allowed to be located in either abovegrade or belowgrade vaults in accordance with 5303.16 of the *International Fire Code*.

7.3.2.2 Indoor Storage.

Δ **7.3.2.2.1** The location of bulk GH_2 systems shall be in accordance with Table 7.3.2.2.1.

7.3.2.2.2 Detached Buildings.

Δ **7.3.2.2.2.1** Detached buildings shall be constructed of noncombustible or limited-combustible materials in accordance with the requirements of Section 6.6.

Δ **7.3.2.2.2.2** Ventilation shall be provided in accordance with the requirements of Section 6.18.

Δ **(A)** Outlet openings shall be located at the high point of the room in exterior walls or the roof.

Δ **(B)** 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.

Δ **(C)** Discharge from outlet openings shall be directed or conducted to the atmosphere.

Δ **7.3.2.2.2.3*** Explosion control shall be provided in accordance with the requirements of Section 6.10.

Δ **7.3.2.2.2.4** Electrical equipment shall be in accordance with Article 501 of *NFPA 70* for Class I, Division 2 locations.

Δ **Table 7.3.2.2.1 Location of GH_2 Systems**

	Quantity of Hydrogen	
Location	≥5000 scf to <15,000 scf (≥142 Nm^3 to <425 Nm^3)	≥15,000 scf (≥425 Nm^3)
In a detached building in accordance with Section 6.5	A	A
In a Protection Level 2 occupancy, in accordance with Section 6.4	A	Detached building required in accordance with Section 6.5
Not in a Protection Level 2 occupancy	N/A	Detached building required in accordance with Section 6.5

A: Allowed. N/A: Not allowed.

Δ **7.3.2.2.2.5** 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 7.3.2.2.2.4.

7.3.2.2.3 Hydrogen Gas Rooms.

Δ **7.3.2.2.3.1** Floors, walls, and ceilings shall be constructed of noncombustible or limited-combustible materials in accordance with the requirements of the adopted building code.

Δ **(A)** 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.

Δ **(B)** Not less than 25 percent of the perimeter wall shall be an exterior wall.

Δ **(C)** Openings to other parts of the building shall not be permitted.

Δ **(D)** Windows and doors shall be in exterior walls only.

Δ **7.3.2.2.3.2** Ventilation shall be as provided in Section 6.18.

Δ **7.3.2.2.3.3** Explosion control shall be provided in accordance with the requirements of Section 6.10.

Δ **7.3.2.2.3.4** There shall be no sources of ignition from open flames, electrical equipment, or heating equipment.

Δ **7.3.2.2.3.5*** Electrical equipment shall be in accordance with Article 501 of *NFPA 70* for Class I, Division 2 locations.

Δ **7.3.2.2.3.6** 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 7.3.2.2.3.5.

7.3.2.3 Outdoor Storage.

7.3.2.3.1 Aboveground Locations.

N **7.3.2.3.1.1*** The minimum distance to exposure for individual components of the bulk hydrogen compressed gas system shall be taken from Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), and Table 7.3.2.3.1.2(B)(c) based on the maximum internal diameter and respective system design in which they are installed.

Δ **7.3.2.3.1.2* Minimum Distance for Aboveground Locations.** The minimum distance from a GH_2 system located outdoors to specified exposures shall be in accordance with Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), or Table 7.3.2.3.1.2(B)(c).

N **(A)** The vent stack shall not be considered part of the bulk hydrogen compressed gas system for determining separation distances in 7.3.2.3.1.1.

Δ **(B) 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 7.3.2.3.1.2(B)(a) when in accordance with Table 7.3.2.3.1.2(B)(b) or Table 7.3.2.3.1.2(B)(c).

(1) The separation distance for piping systems with internal diameters other than those specified in Table 7.3.2.3.1.2(B)(a) for the pressure range selected shall be permitted with tabular distances determined based on the use of Table 7.3.2.3.1.2(B)(b) or Table 7.3.2.3.1.2(B)(c).
(2) Separation distances determined based on the use of Table 7.3.2.3.1.2(B)(b) or Table 7.3.2.3.1.2(B)(c) shall be subject to review and approval by the AHJ.
(3) The separation distance shall be measured from the part of the bulk hydrogen compressed gas system closest to the exposure.
(4)* **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 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b) or Table 7.3.2.3.1.2(B)(c) shall be determined based on that portion of the system with the greatest maximum internal diameter.
(5)* **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 (141.6N m^3), irrespective of those portions of the system elevated to a higher pressure.

N **7.3.2.3.1.3** Distances in Table 7.3.2.3.1.2(B)(a) to air intakes shall apply only to mechanical piping connections or potential leak points that are part of the outdoor bulk hydrogen compressed gas system.

7.3.2.3.1.4* Reduction of Distance by Mitigation Means. Fire barrier walls located and constructed per 7.3.2.3.1.4(A) shall not permit the reduction of distances to air intakes.

Δ **(A)* Passive Means.** The distances to Group 1 and 2 exposures shown in Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), and Table 7.3.2.3.1.2(B)(c) are permitted to be reduced to 0 ft (0 m) where fire barrier walls are located between the system

Δ **Table 7.3.2.3.1.2(B)(a) Minimum Distance (D) from Outdoor Bulk Hydrogen Compressed Gas Systems to Exposures — Typical Maximum Pipe Size**

Pressure	>15 to ≤250 psig		>250 to ≤3000 psig		>3000 to ≤7500 psig		>7500 to ≤15000 psig	
Internal Pipe Diameter (ID)	>103.4 to ≤1724 kPa		>1724 to ≤20,684 kPa		>20,684 to ≤51,711 kPa		>51,711 to ≤103,421 kPa	
d_{mm}	$d = 52.5_{mm}$		$d = 18.97_{mm}$		$d = 7.31_{mm}$		$d = 7.16_{mm}$	
Exposures Group 1	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**
Lot lines Air intakes (HVAC, compressors, other) Operable openings in buildings and structures Ignition sources such as open flames and welding	5	16	6	20	4	13	5	16
Exposures Group 2	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**
Exposed persons other than those servicing the system Parked cars	5	16	6	20	3	10	4	13
Exposures Group 3	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**
Buildings of non-combustible non-fire-rated construction Buildings of combustible construction Flammable gas storage systems above or below ground Hazardous materials storage systems above or below ground Heavy timber, coal, or other slow-burning combustible solids 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 Unopenable openings in building and structures Encroachment by overhead utilities (horizontal distance from the vertical plane Below the nearest overhead electrical wire of building service) Piping containing other hazardous materials Flammable gas metering and regulating stations such as natural gas or propane.	4	13	5	16	3	10	4	13

and the exposure and constructed in accordance with all of the following:

(1) The fire barrier wall shall be without openings or penetrations.

(a) 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 adopted building code.

(2) Fire barrier walls shall have a minimum fire resistance rating of not less than 2 hours.

(3) The fire barrier wall shall interrupt the line of sight between the bulk hydrogen compressed gas system and the exposure.

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

(5) The 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), except as provided in 7.3.2.3.1.4(A)(5).

(6)* 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 8.3.2.3.1.5(D).

(7) Where the number of fire barrier walls creates a court or enclosed court, the requirements of 7.3.2.5 shall apply

(8) 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 and shall be designed to resist the overturning effects or failure caused by lateral forces due to deflagration, overpressure, wind, soil, flood, and seismic events.

(9) 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.

(10) The construction of a fire barrier wall that is part of a hydrogen equipment enclosure and used to reduce separation distances shall be in accordance with 7.1.23.16.

Δ Table 7.3.2.3.1.2(B)(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	
		D = 0.0952d		D = 0.1019d - 0.3485		D = 0.0762		D = 0.3168d		D = 0.3384d - 0.4188		D = 0.2636d	
ID (in.)	d (mm)	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft
0.2	5.1	0.5	2	0.2	1	0.4	1	1.6	5	1.3	4	1.3	4
0.3	7.6	0.7	2	0.4	1	0.6	2	2.4	8	2.2	7	2.0	7
0.4	10.2	1.0	3	0.7	2	0.8	3	3.2	11	3.0	10	2.7	9
0.5	12.7	1.2	4	0.9	3	1.0	3	4.0	13	3.9	13	3.3	11
0.6	15.2	1.4	5	1.2	4	1.2	4	4.8	16	4.7	16	4.0	13
0.7	17.8	1.7	6	1.5	5	1.4	4	5.6	19	5.6	18	4.7	15
0.8	20.3	1.9	6	1.7	6	1.5	5	6.4	21	6.5	21	5.4	18
0.9	22.9	2.2	7	2.0	7	1.7	6	7.3	24	7.3	24	6.0	20
1.0	25.4	2.4	8	2.2	7	1.9	6	8.0	26	8.2	27	6.7	22
1.1	27.9	2.7	9	2.5	8	2.1	7	8.8	29	9.0	30	7.4	24
1.2	30.5	2.9	10	2.8	9	2.3	8	9.7	32	9.9	32	8.0	26
1.3	33.0	3.1	10	3.0	10	2.5	8	10.5	34	10.7	35	8.7	29
1.4	35.6	3.4	11	3.3	11	2.7	9	11.3	37	11.6	38	9.4	31
1.5	38.1	3.6	12	3.5	12	2.9	10	12.1	40	12.5	41	10.0	33
1.6	40.6	3.9	13	3.8	12	3.1	10	12.9	42	13.3	44	10.7	35
1.7	43.2	4.1	13	4.1	13	3.3	11	13.7	45	14.2	47	11.4	37
1.8	45.7	4.4	14	4.3	14	3.5	11	14.5	47	15.0	49	12.0	40
1.9	48.3	4.6	15	4.6	15	3.7	12	15.3	50	15.9	52	12.7	42
2.0	50.8	4.8	16	4.8	16	3.9	13	16.1	53	16.8	55	13.4	44
2.1	53.3	5.1	17	5.1	17	4.1	13	16.9	55	17.6	58	14.0	46

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 7.3.2.3.1.2(B)(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.

Δ **(B)* 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.

Δ **7.3.2.3.1.5 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 Sections 7.3.2.3.1.5(A) through 7.3.2.3.1.5(D).

Δ **(A)** Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), or Table 7.3.2.3.1.2(B)(c) than the distances given for the storage system.

Δ **(B)** The separation distance between independent gaseous and liquid systems shall meet the minimum distance requirements for Group 3 Exposures shown in Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), and Table 7.3.2.3.1.2(B)(c).

N **(C)** The separation distance between integrated gaseous and liquid systems shall be permitted to be reduced to 0 ft (0 m) where such systems are integrated with a shared control system.

Δ **(D)** 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.

Δ Table 7.3.2.3.1.2(B)(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	
		D = 1.105d - 4.078		D = 0.6831d - 1.99		D = 0.459d - 0.355		D = 1.448d - 5.368		D = 0.9291d - 2.65		D = 0.602d - 0.3103	
ID (in.)	d (mm)	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft
0.2	5.1	1.6	5	1.5	5	2	7	2	7	2	7	3	9
0.3	7.6	4.3	14	3.2	11	3	10	6	18	4	14	4	14
0.4	10.2	7.2	24	5.0	16	4	14	9	31	7	22	6	19
0.5	12.7	10.0	33	6.7	22	5	18	13	43	9	30	7	24
0.6	15.2	12.7	42	8.4	28	7	22	17	55	11	38	9	29
0.7	17.8	15.6	51	10.2	33	8	26	20	67	14	46	10	34
0.8	20.3	18.4	60	11.9	39	9	29	24	79	16	53	12	39
0.9	22.9	21.2	70	13.7	45	10	33	28	91	19	61	13	44
1.0	25.4	24.0	79	15.4	50	11	37	31	103	21	69	15	49
1.1	27.9	26.8	88	17.1	56	12	41	35	115	23	76	16	54
1.2	30.5	29.6	97	18.8	62	14	45	39	127	26	84	18	59
1.3	33	32.4	106	20.6	67	15	49	42	139	28	92	20	64
1.4	35.6	35.3	116	22.3	73	16	52	46	152	30	100	21	69
1.5	38.1	38.0	125	24.0	79	17	56	50	163	33	107	23	74
1.6	40.6	40.8	134	25.7	84	18	60	53	175	35	115	24	79
1.7	43.2	43.7	143	27.5	90	19	64	57	188	37	123	26	84
1.8	45.7	46.4	152	29.2	96	21	68	61	199	40	131	27	89
1.9	48.3	49.3	162	31.0	102	22	72	65	212	42	139	29	94
2.0	50.8	52.1	171	32.7	107	23	75	68	224	45	146	30	99

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 7.3.2.3.1.2(B)(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.

Δ **7.3.2.3.1.6** 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.

N **7.3.2.3.1.7 Area Classification.** The area classification around storage equipment and related vents shall be in accordance with Article 500.5 or Article 505.5 of *NFPA 70* and with Table 7.3.2.3.1.7.1.

N **7.3.2.3.1.7.1*** Specific locations for Class 1, Division 1, Group B (hydrogen) and Class 1, Division 2, Group B (hydrogen) areas shall be in accordance with Table 7.3.2.3.1.7.1.

Δ **7.3.2.3.1.8 Electrical Equipment.** Electrical wiring and equipment shall be in accordance with Articles 500, 501, and 504 of *NFPA 70* or with Article 505 of *NFPA 70*.

Δ **7.3.2.4 Underground Systems.** Bulk hydrogen compressed gas systems installed underground where GH_2 containers are to be buried in contact with earth or fill shall be in accordance with 7.3.2.4.

Δ **7.3.2.4.1 Container Design.** Pressure-compressed GH_2 containers installed underground using burial methods shall be of seamless construction in accordance with the ASME *Boiler and Pressure Vessel Code*.

Δ **7.3.2.4.1.1*** GH_2 containers shall be designed to include cyclic pressure life calculations using fracture mechanics methods.

Δ **Table 7.3.2.3.1.7.1 Electrical Area Classification**

Location	Classification	Extent of Classified Area
Within 3 ft (1 m) of any vent outlet and any points where hydrogen is vented to the atmosphere under normal operations	Class 1, Division 1, Group B or Class I, Zone 1, Group IIC	Between 0 ft (0 m) and 3 ft (0.9 m) and measured spherically from the outlet.
Between 3 ft (1 m) and 15 ft (4.6 m) of any vent outlet and any points where hydrogen is vented to the atmosphere under normal operations.	Class I, Division 2, Group B or Class I, Zone 2, Group IIC	Between 3 ft (0.9 m) and 15 ft (4.6 m) and measured spherically from the vent outlet
Storage equipment excluding the piping system downstream of the source valve	Class I, Division 2, Group B or Class I, Zone 2, Group IIC	Between 0 ft (0 m) and 15 ft (4.6 m) and measured spherically from the source

7.3.2.4.1.2 GH_2 Container Examination.

Δ **(A)** Compressed GH_2 containers shall be examined for internal and external surface flaws and inclusions before burial or at the time of manufacture.

Δ **(B)** Compressed GH_2 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.

7.3.2.4.1.3 Composite Containers. (Reserved)

Δ **7.3.2.4.2 Corrosion Protection.** Compressed GH_2 containers and underground piping shall be protected from corrosion in accordance with 7.1.9.1.7, 7.1.14, and 6.5.3 as applicable.

7.3.2.4.3* Outlet Connections.

Δ **7.3.2.4.3.1** Threaded GH_2 container outlet connections shall be designed with primary and secondary seals that shall be tested for functionality.

Δ **7.3.2.4.3.2** The seal design shall include a method of detecting a leak in the primary seal.

7.3.2.4.4 Piping Systems.

Δ **7.3.2.4.4.1** Joints in the piping system shall be installed and inspected in accordance with the requirements of ASME B31, *Code for Pressure Piping*, or other approved standards.

Δ **7.3.2.4.4.2** Valves, controls, safety devices, and instrumentation shall be above ground and accessible to authorized personnel.

Δ **7.3.2.4.5 Location.** GH_2 containers shall be located in accordance with 7.3.2.4.5.1 through 7.3.2.4.5.6.

Δ **7.3.2.4.5.1** Underground GH_2 containers shall not be located beneath buildings.

Δ **7.3.2.4.5.2** GH_2 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.

Δ **7.3.2.4.5.3** The distance from any part of the GH_2 container to the nearest wall of a basement, pit, cellar, or lot line shall not be less than 10 ft (3.1 m).

Δ **7.3.2.4.5.4** 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.

Δ **7.3.2.4.5.5** A minimum distance of 1 ft (0.3 m), shell to shell, shall be maintained between adjacent underground containers.

Δ **7.3.2.4.5.6*** A minimum distance of 3 ft (0.9 m) shall be maintained between GH_2 containers and buried utilities.

Δ **7.3.2.4.6 Foundations.** Underground GH_2 containers shall be set on foundations constructed in accordance with the adopted building code, and surrounded with not less than 6 in. (152 mm) of noncorrosive material.

Δ **7.3.2.4.6.1** The concrete shall extend a minimum of 1 ft (0.3 m) horizontally beyond the footprint of the tank in all directions.

Δ **7.3.2.4.7 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.

Δ **7.3.2.4.8* Anchorage and Security.** GH_2 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.

Δ **7.3.2.4.9 Venting of Underground GH_2 Containers.** Vent pipes for underground GH_2 containers shall be in accordance with Section 6.5.

Δ **7.3.2.4.10 Overfill Protection and Prevention Systems.** An approved means or method shall be provided to prevent the overfilling of the storage containers.

Δ **7.3.2.4.11 Physical Protection.** Piping and control equipment ancillary to underground containers that is located above ground shall be protected from physical damage in accordance with 7.1.7.3.

N **7.3.2.5 Courts.** Where a bulk gas system is located in a court or enclosed court, the installation shall meet all of the following requirements:

(1) Courts shall have natural or mechanical ventilation in accordance with Section 6.18.
(2) Explosion control shall be provided in accordance with the requirements of Section 6.10.

(3) The distance from any part of the system to exterior building walls and related exposures shall meet the requirements of Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), or Table 7.3.2.3.1.2(B)(c).
(4) Fire barrier walls shall meet the requirements of 7.3.2.3.1.4(A)(1) through 7.3.2.3.1.4(A)(4) and 7.3.2.3.1.4(A)(7) through 7.3.2.3.1.4(A)(9).
(5) Vents and ventilation exhausts shall terminate above the walls or outside of the court.

7.3.3 Bulk GH_2 Systems Use.

7.3.3.1 The use of bulk GH_2 systems shall be in accordance with Section 7.1.

Δ **7.3.3.2 Good Practice Standards.** Where nationally recognized good practices or standards have been established for the process employed, such practices and standards shall be followed.

7.3.4 Handling of Bulk GH_2 Systems.

7.3.4.1 The handling of GH_2 shall be in accordance with 7.2.4.

7.3.4.2 Cargo Transport Unloading.

7.3.4.2.1 Personnel conducting transfer operations from the bulk transport vehicle shall be trained.

Δ **7.3.4.2.2** Unloading connections on delivery equipment shall not be positioned closer to any of the exposures than the distances given for the bulk GH_2 compressed gas storage system.

Δ **7.3.4.2.3** During transfer of hydrogen from cargo vehicles to the bulk GH_2 compressed gas storage system, the hand or emergency brake of the vehicle shall be set, and chock blocks shall be used to prevent the vehicle from moving.

Δ **7.3.4.2.4** 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.

Δ **7.3.4.2.5** Mobile hydrogen supply units shall be electrically bonded to the bulk hydrogen gas storage system before hydrogen is discharged from the supply unit.

7.3.4.2.6 Transfer System Depressurization.

Δ **7.3.4.2.6.1** The transfer systems shall be capable of depressurizing to facilitate disconnection.

Δ **7.3.4.2.6.2** Bleed connections shall be connected to a hydrogen venting system in accordance with 7.1.16.

Δ **7.3.4.2.7** Where required, check valves on delivery systems shall be in accordance with 6.5.1.5.

Δ **7.3.4.2.8** Prohibitions on smoking or the use of open flame shall be in accordance with 7.1.26.2.

Δ **7.3.4.2.9** An emergency shutoff valve shall be provided in accordance with 7.1.24.

7.3.5 Maintenance.

Δ **7.3.5.1** Maintenance shall be performed annually by a qualified representative of the equipment owner.

Δ **7.3.5.2** 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.

Δ **7.3.5.3** Scheduled maintenance and retest activities shall be formally documented, and records shall be maintained a minimum of 3 years.

Chapter 8 Liquefied Hydrogen

8.1 General. The storage, use, and handling of LH_2 in LH_2 storage systems shall comply with this chapter in addition to other applicable requirements of this code.

8.1.1 Where specific requirements are provided in other chapters, those specific requirements shall apply.

8.1.1.1 Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.

8.1.1.2 The occupancy of a building or structure, or portion thereof, where hydrogen is stored or used, shall be classified in accordance with the adopted building code.

Δ **8.1.2* Containers — Design, Construction, and Maintenance.** Containers employed for the storage or use of LH_2 shall be designed, fabricated, tested, marked (i.e., stamped), and maintained in accordance with Department of Transportation (DOT) regulations, Transport Canada's (TC) *Transportation of Dangerous Goods Regulations*, the ASME *Boiler and Pressure Vessel Code*, or regulations of other administering agencies.

Δ **8.1.3 Design.** LH_2 systems shall be designed for the intended use and shall be designed by persons competent in such design.

8.1.3.1 Piping Systems. Piping, tubing, fittings, and related components shall be designed, fabricated, and tested in accordance with the requirements of ASME B31.12, *Hydrogen Piping and Pipelines*, or other approved standards and shall be in accordance with 8.1.3.1.1.

8.1.3.1.1 Piping and Appurtenances.

Δ **8.1.3.1.1.1** Piping systems shall be designed for the use intended through the full range of pressure and temperature to which they will be subjected.

Δ **8.1.3.1.1.2** 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, *Pressure Piping*.

Δ **8.1.3.1.1.3** Piping systems shall be designed and constructed to allow for expansion, contraction, vibration, settlement, and fire exposure.

8.1.3.1.2 Joints.

Δ **8.1.3.1.2.1** Joints in piping and tubing shall be in accordance with the requirements of ASME B31, *Pressure Piping*.

Δ **8.1.3.1.2.2** Brazing materials, where used, shall have a melting point above 1000°F (538°C).

Δ **8.1.3.1.3 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.

Δ **8.1.3.1.4 Shutoff Valves on Containers.** Shutoff valves shall be provided on all container connections, except for pressure relief devices.

Δ **8.1.3.1.4.1** Shutoff valves for containers with multiple pressure relief devices shall be permitted in accordance with 8.1.4.7.

Δ **8.1.3.1.4.2** Shutoff valves shall be accessible and located as close as practical to the container.

8.1.3.1.5 Shutoff Valves on Piping.

Δ **8.1.3.1.5.1** Shutoff valves shall be installed in piping containing LH_2 where needed to limit the volume of liquid discharged in the event of piping or equipment failure.

Δ **8.1.3.1.5.2*** Pressure relief valves shall be installed where liquid or cold gas can be trapped between shutoff valves in the piping system. *(See 8.1.4.)*

8.1.3.1.6 Physical Protection and Support.

Δ **8.1.3.1.6.1** Aboveground piping systems shall be supported and protected from physical damage.

Δ **8.1.3.1.6.2** Piping passing through walls shall be protected from mechanical damage.

8.1.3.1.7 Corrosion Protection.

Δ **8.1.3.1.7.1** Aboveground piping that is subject to corrosion shall be protected against corrosion.

Δ **8.1.3.1.7.2** Belowground piping shall be protected against corrosion.

Δ **8.1.3.1.8 Cathodic Protection.** Where required, cathodic protection shall be in accordance with 8.1.3.1.8.

Δ **8.1.3.1.8.1 Operation.**

8.1.3.1.8.2 Inspection.

Δ **(A)** Container systems equipped with cathodic protection shall be inspected for the intended operation by a cathodic protection tester.

Δ **(B)** The examinations shall be documented.

Δ **(C)** A record of the examination history shall be maintained by the owner and shall be available to the authority having jurisdiction upon request.

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

8.1.3.1.8.3 Impressed Current Systems.

Δ **(A)** Systems equipped with impressed current cathodic protection systems shall be inspected in accordance with the requirements of the design and 8.1.3.1.8.2.

Δ **(B)** The design limits shall be available to the AHJ upon request.

Δ **(C)** 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

8.1.3.1.8.4 Corrosion Expert.

Δ **(A)** Repairs, maintenance, or replacement of a cathodic protection system shall be under the supervision of a corrosion expert certified by NACE.

Δ **(B)** 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.

8.1.3.1.9 Testing.

Δ **8.1.3.1.9.1** 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.

Δ **8.1.3.1.9.2** 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.

8.1.4 Pressure-Relief Devices.

8.1.4.1 General.

Δ **8.1.4.1.1** Pressure relief devices shall be provided to protect containers and piping systems containing LH_2 from damage due to overpressure.

Δ **8.1.4.1.2** 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.

Δ **8.1.4.2 Containers Open to the Atmosphere.** Portable containers that are open to the atmosphere and are designed to contain LH_2 at atmospheric pressure shall not be required to be equipped with pressure relief devices.

8.1.4.2.1 Containers shall be equipped with approved controls to prevent the condensation of air within the container.

8.1.4.2.2 Containers located indoors shall be within a zone of local exhaust using a mechanical exhaust system.

8.1.4.2.2.1 The exhaust system shall operate continuously when LH_2 is present and shall be designed in accordance with the mechanical code for the removal of flammable vapors.

8.1.4.2.2.2 The duct system used to exhaust the hydrogen released from open containers shall be considered to be a hazardous exhaust system.

Δ **8.1.4.3 Equipment Other Than Containers.** Heat exchangers, vaporizers, insulation casings surrounding containers, vessels, and coaxial piping systems in which LH_2 could be trapped due to leakage from the primary container shall be provided with a pressure relief device.

8.1.4.4 Sizing.

Δ **8.1.4.4.1** Pressure relief devices shall be sized in accordance with the specifications to which the container was fabricated.

Δ **8.1.4.4.2** The pressure relief device shall have the capacity to prevent the maximum design pressure of the container or system from being exceeded.

Δ **8.1.4.5 Accessibility.** Pressure relief devices shall be located such that they are accessible for inspection and repair.

Δ **8.1.4.5.1*** 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.

Δ **8.1.4.5.2** Non-ASME pressure relief valves shall not be field adjusted.

8.1.4.6 Arrangement.

Δ **8.1.4.6.1 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.

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

Δ **8.1.4.6.2.1** 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.

Δ **8.1.4.6.2.2** Additional safeguards regarding placement or arrangement shall not be required.

8.1.4.7 Shutoffs Between Pressure Relief Devices and Containers.

Δ **8.1.4.7.1 General.** Shutoff valves installed between pressure relief devices and containers shall be in accordance with 8.1.4.7.

Δ **8.1.4.7.2 Location.** Shutoff valves shall not be installed between pressure relief devices and containers unless the valves or their use meet the requirements of 8.1.4.7.2.1 or 8.1.4.7.2.2.

Δ **8.1.4.7.2.1 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.*

Δ **8.1.4.7.2.2 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 relief devices at all times.

Δ **8.1.4.8 Temperature Limits.** Pressure relief devices shall not be subjected to LH_2 fluid temperatures except when operating.

8.1.5 Pressure Relief Vent Piping.

Δ **8.1.5.1 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 8.1.5.

Δ **8.1.5.2 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.

Δ **8.1.5.3 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.

Δ **8.1.5.4 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.

Δ **8.1.5.5 Overfilling.** Controls shall be provided to prevent overfilling of stationary containers.

8.1.6 Marking.

Δ **8.1.6.1 General.** LH_2 containers and systems shall be marked in accordance with nationally recognized standards and in accordance with 8.1.6.

8.1.6.1.1 Portable Containers.

Δ **8.1.6.1.1.1** Portable LH_2 containers shall be marked in accordance with CGA C-7, *Guide to Classification and Labeling of Compressed Gas.*

Δ **8.1.6.1.1.2*** All DOT-4L/TC-4LM liquid cylinders shall have product identification visible from all directions with minimum 2 in. (51 mm) high letters.

Δ **8.1.6.1.2 Stationary Tanks.** Stationary tanks shall be marked in accordance with NFPA 704.

Δ **8.1.6.1.3 Identification Signs.** Visible hazard identification signs shall be provided in accordance with NFPA 704 at entrances to buildings or areas in which LH_2 is stored, handled, or used.

Δ **8.1.6.2 Identification of Contents.** Stationary containers shall be placarded with the identity of their contents to indicate the name of the material contained.

Δ **8.1.6.3 Container Specification.** Stationary containers shall be marked with the manufacturing specification and maximum allowable working pressure on a permanent nameplate.

Δ **8.1.6.3.1** The nameplate shall be installed on the container in an accessible location.

Δ **8.1.6.3.2** The nameplate shall be marked in accordance with nationally recognized standards.

8.1.6.4 Identification of Container Connections.

Δ **8.1.6.4.1** Container inlet and outlet connections, liquid-level limit controls, valves, and pressure gauges shall be identified using one of the methods prescribed by 8.1.6.4.1.1 through 8.1.6.4.1.2.

Δ **8.1.6.4.1.1** They shall be marked with a permanent tag or label identifying their function.

Δ **8.1.6.4.1.2** 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.

Δ **(A)** When a schematic drawing is provided, it shall be attached to the container and maintained in a legible condition.

Δ **8.1.6.5 Identification of Piping Systems.** Piping systems shall be identified in accordance with ASME A13.1, *Scheme for the Identification of Piping Systems.*

Δ **8.1.6.6 Identification of Emergency Shutoff Valves.** Emergency shutoff valves on stationary containers shall be identified, visible, and indicated by means of a sign.

8.1.7 Security.

Δ **8.1.7.1 General.** LH_2 containers and systems shall be secured against accidental dislodgement and against access by unauthorized personnel in accordance with 8.1.7.

8.1.7.2 Area Security.

Δ **8.1.7.2.1*** User storage sites shall be fenced or otherwise secured and posted to prevent entry by unauthorized personnel.

Δ **8.1.7.2.2** 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.

Δ **8.1.7.3 Securing of Containers.** Stationary containers shall be secured to foundations in accordance with the adopted building code.

Δ **8.1.7.3.1** Portable containers subject to shifting or upset shall be secured.

Δ **8.1.7.3.2** Nesting shall be permitted as a means of securing portable containers.

Δ **8.1.7.4 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.

Δ **8.1.7.5 Physical Protection.** Containers, piping, valves, pressure relief devices, regulating equipment, and other appurtenances shall be protected against physical damage and tampering.

Δ **8.1.8 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 LH_2 in the container.

8.1.9 Electrical Wiring and Equipment.

Δ **8.1.9.1 General.** Electrical wiring and equipment shall be in accordance with *NFPA 70* and NFPA 79, as applicable, and 8.1.9.

Δ **8.1.9.2 Location.** Containers and systems shall not be located where they could become part of an electrical circuit.

Δ **8.1.9.3 Electrical Ground and Bonding.** Containers and systems shall not be used for electrical grounding.

Δ **8.1.9.3.1** When electrical grounding and bonding are required, the system shall be in accordance with *NFPA 70*.

Δ **8.1.9.3.2** The grounding system shall be protected against corrosion, including corrosion caused by stray electrical currents.

Δ **8.1.10 Service and Repair.** Service, repair, modification, or removal of valves, pressure relief devices, or other container appurtenances shall be in accordance with nationally recognized codes and standards.

Δ **8.1.10.1 Containers.** Containers that have been removed from service shall be handled in an approved manner.

Δ **8.1.10.1.1 Testing.** Containers out of service in excess of 1 year shall be inspected and tested as required in 8.1.10.1.2.

Δ **8.1.10.1.2 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.

Δ **8.1.10.1.3** Containers that have previously been used for LH_2 and have been removed from service shall be purged with an inert gas to remove residual LH_2 and stored with all valves closed and the valve outlets plugged.

Δ **8.1.10.2 Systems.** Service and repair of containers or systems shall be performed by trained personnel in accordance with nationally recognized codes and standards and with the permission of the container owner.

Δ **8.1.11 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.

8.1.12 Leaks, Damage, and Corrosion.

Δ **8.1.12.1** Leaking, damaged, or corroded containers shall be removed from service.

Δ **8.1.12.2** Leaking, damaged, or corroded systems shall be replaced, repaired, or removed from service.

Δ **8.1.13 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.

8.1.14 Emergency Shutoff Valves.

8.1.14.1 Accessible manual or automatic emergency shutoff valves shall be provided to shut off the LH_2 supply in case of emergency.

8.1.14.1.1 Emergency shutoff valves on a bulk source or piping systems serving the bulk supply shall be identified by means of a sign.

8.1.14.1.2 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.

Δ **8.1.15 Dispensing Areas.** Dispensing of LH_2 associated with physical or health hazards shall be conducted in approved locations.

Δ **8.1.15.1 Indoor Dispensing Areas.** Dispensing indoors shall be conducted in areas constructed in accordance with the adopted building code.

8.1.15.2 Ventilation. Indoor areas in which LH_2 is dispensed shall be ventilated in accordance with the requirements of Section 6.18.

Δ **8.1.15.3 Piping Systems.** Piping systems utilized for filling or dispensing of LH_2 shall be designed and constructed in accordance with 8.1.3.1.1.

8.1.16 Operation.

8.1.16.1 Securing Equipment. Mobile LH_2 supply units used as part of a hydrogen system shall be restrained to resist movement.

Δ **8.1.16.2 Bonding and Grounding.** The mobile LH_2 supply units shall be electrically bonded and grounded.

8.2 Non-Bulk LH_2.

8.2.1 Non-Bulk LH_2 — General.

8.2.1.1 The storage, use, and handling of LH_2 in LH_2 storage systems shall be in accordance with the provisions of Chapters 1 through 6, and Chapter 8 as applicable.

8.2.1.2 Containers and systems having a total LH_2 content of more than 39.7 gal (150 L) shall be in accordance with Section 8.3.

8.2.2 Non-Bulk LH_2 Storage.

8.2.2.1 General. (Reserved)

8.2.2.2 Indoor Storage.

8.2.2.2.1 Installation. Containers stored indoors shall be installed in accordance with Sections 8.1 and 8.2.

Δ **8.2.2.2.2 Storage Locations LH_2.** LH_2 in stationary or portable containers stored indoors shall be stored in buildings, rooms, or areas constructed in accordance with the adopted building code.

Δ **8.2.2.2.3 Ventilation.** Ventilation shall be in accordance with Section 6.18.

Δ **8.2.2.2.4 Installation of LH_2 Inside Buildings Other Than Detached Buildings and Gas Rooms.** Portable LH_2 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.
(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 8.1.7.5.
(6) Containers shall be secured in accordance with the requirements of 8.1.7.3.
(7) Welding or cutting operations and smoking shall be prohibited while hydrogen is in the room, and signs shall be provided as required by 4.13.3.
(8) Ventilation shall be provided in accordance with the requirements of Section 6.18.
(9) Pressure relief devices on stationary or portable containers shall be vented directly outdoors or to an exhaust hood. (*See 8.1.4.6.*)

8.2.2.3 Outdoor Storage.

Δ **8.2.2.3.1 General.** LH_2 in stationary or portable containers stored outdoors shall be in accordance with 8.2.2.3.

Δ **8.2.2.3.2 Distance to Exposures.** LH_2 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 8.2.2.3.2.

Δ **8.2.2.3.3 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 LH_2in the container.

Δ **8.2.2.3.4 Separation Distance.** Non-bulk portable containers of liquefied hydrogen shall be separated from exposure hazards in accordance with Table 8.2.2.3.4.

Δ **8.2.2.3.4.1 Fire Barriers.** A 2-hour fire barrier wall shall be permitted in lieu of the distances specified by Table 8.2.2.3.4 when in accordance with the provisions of 8.2.2.3.4.1(A) through 8.2.2.3.4.1(E).

Δ **(A)** The fire barrier wall shall be without openings or penetrations.

Δ **(B)** 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.

Δ **(C)** The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage system.

Δ **(D)** The fire barrier wall shall be located not less than 5 ft (1.5 m) from any exposure.

Δ **(E)** 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).

Δ **8.2.2.3.4.2 Air Intakes.** Storage and use of LH_2 shall not be located within 50 ft (15.2 m) of air intakes or the minimum distance from a bulk storage system per Table 8.3.2.3.1.6(a), whichever is less.

Δ **8.2.2.3.4.3 Building Openings.** Storage and use of LH_2 outside of buildings shall be separated from building openings by 25 ft (7.6 m) or the minimum distance from a hydrogen bulk storage system per Table 8.3.2.3.1.6(a), whichever is less.

N **8.2.2.3.4.3.1** 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.

8.2.2.3.5 Access.

Δ **8.2.2.3.5.1** Stationary containers shall be located to provide access by mobile supply equipment and authorized personnel.

Δ **8.2.2.3.5.2** 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).

8.2.2.3.6 Physical Protection.

Δ **8.2.2.3.6.1** LH_2 containers, cylinders, tanks, and systems that could be exposed to physical damage shall be protected.

Δ **8.2.2.3.6.2** Guard posts or other means shall be provided to protect LH_2 containers, cylinders, tanks, and systems indoors and outdoors from vehicular damage. *(See Section 4.14.)*

Δ **8.2.2.3.7 Diked Areas Containing Other Hazardous Materials.** Containers of LH_2 shall not be located within diked areas with other hazardous materials.

Δ **8.2.2.3.8* 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 adopted building code.

Δ **8.2.2.3.8.1 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.

Δ **8.2.2.3.8.2 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.

8.2.2.3.9 Drainage.

Δ **8.2.2.3.9.1** The area surrounding stationary and portable containers shall be provided with a means to prevent accidental discharge of LH_2 from endangering personnel, containers, equipment, and adjacent structures and from entering enclosed spaces in accordance with the adopted fire prevention code.

Δ **8.2.2.3.9.2** The stationary container shall not be placed where spilled or discharged LH_2 will be retained around the container. *(See 8.2.2.3.7.)*

Δ **8.2.2.3.9.3** The provisions of 8.2.2.3.9.2 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 LH_2 to be stored

8.2.2.3.9.4 Grade.

Δ **(A)** The grade for a distance of not less than 50 ft (15.2 m) from where LH_2 storage or delivery systems are installed shall be higher than the grade on which flammable or combustible liquids are stored or used.

Δ **(B)* Drainage Control.**

(1) Where the grade differential between the storage or delivery system and the flammable or combustible liquids storage or use area is not in accordance with 8.2.2.3.9.4(A), diversion curbs or other means of drainage control shall be used to divert the flow of flammable or combustible liquids away from the LH_2 system.
(2) The means of drainage control shall prevent the flow of flammable or combustible liquid to a distance not less than 50 ft (15.2 m) from all parts of the delivery system.

8.2.3 Non-Bulk LH_2 Use.

8.2.3.1 General.

Δ **8.2.3.1.1** Use and handling of containers and systems shall be in accordance with 8.2.3.1.1 through 8.2.3.1.10.2.

Δ **8.2.3.1.1.1 Operating Instructions.** Operating instructions shall be provided for installations that require the operation of equipment.

Δ **8.2.3.1.1.2 Attended Delivery.** A qualified person shall be in attendance at all times LH_2 is transferred from mobile supply units to a storage system.

8.2.3.1.1.3 Inspection.

Δ **(A)** LH_2 storage systems shall be inspected and maintained by a qualified representative of the equipment owner.

(1) The interval between inspections shall be based on nationally recognized good practices or standards.
(2) A record of the inspection shall be prepared and provided to the user or the authority having jurisdiction upon request.

8.2.3.1.1.4 Design.

Δ **(A) Nationally Recognized Good Practices.** Where nationally recognized good practices or codes and standards have been

Δ **Table 8.2.2.3.4 Distance to Exposures for Non-Bulk Liquefied Hydrogen LH_2**

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)	Minimum Distance to Buildings on the Same Property: Less than 2-Hour Construction	Minimum Distance to Buildings on the Same Property: 2-Hour Construction	Minimum Distance to Buildings on the Same Property: 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 8.2.2.3.4.2.

(2) For requirements on minimum distance to building openings including exits, see 8.2.2.3.4.3.

(3) When 8.2.2.3.4.1 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.

established for the process employed, such practices and codes and standards shall be followed.

Δ **(B) Piping Systems.** Piping, tubing, fittings and related components shall be designed, fabricated, and tested in accordance with the requirements of ASME B31.3, *Process Piping*, or other approved standards and shall be in accordance with 8.2.3.1.2.

8.2.3.1.2 Piping and Appurtenances.

Δ **8.2.3.1.2.1** Piping systems shall be designed for the use intended through the full range of pressure and temperature to which they will be subjected.

Δ **8.2.3.1.2.2** Piping systems shall be designed and constructed to allow for expansion, contraction, vibration, settlement, and fire exposure.

Δ **8.2.3.1.3 Joints.** Joints in piping and tubing shall be in accordance with the requirements of ASME B31.3, *Process Piping*, or other approved standards.

Δ **8.2.3.1.4 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.

Δ **8.2.3.1.5 Shutoff Valves on Containers.** Shutoff valves shall be provided on all container connections, except for pressure relief devices.

Δ **8.2.3.1.5.1** Shutoff valves for containers with multiple pressure relief devices shall be permitted in accordance with 8.1.4.7.

Δ **8.2.3.1.5.2** Shutoff valves shall be accessible and located as close as practical to the container.

8.2.3.1.6 Shutoff Valves on Piping.

Δ **8.2.3.1.6.1** Shutoff valves shall be installed in piping containing LH_2 where needed to limit the volume of liquid discharged in the event of piping or equipment failure.

Δ **8.2.3.1.6.2** Pressure relief valves shall be installed where liquid or cold gas can be trapped between shutoff valves in the piping system. (*See 8.1.4.*)

8.2.3.1.7 Physical Protection and Support.

Δ **8.2.3.1.7.1** Aboveground piping systems shall be supported and protected from physical damage.

Δ **8.2.3.1.7.2** Piping passing through walls shall be protected from mechanical damage.

8.2.3.1.8 Corrosion Protection.

Δ **8.2.3.1.8.1** Aboveground piping that is subject to corrosion shall be protected against corrosion.

Δ **8.2.3.1.8.2** Belowground piping shall be protected against corrosion.

Δ **8.2.3.1.9 Cathodic Protection.** Where required, cathodic protection shall be in accordance with 8.2.3.1.9.

Δ **8.2.3.1.9.1 Operation.** Where installed, cathodic protection systems shall be operated and maintained to continuously provide corrosion protection.

8.2.3.1.9.2 Inspection.

Δ **(A)** Container systems equipped with cathodic protection shall be inspected for the intended operation by a cathodic protection tester.

Δ **(B)** The examinations shall be documented.

Δ **(C)** A record of the examination history shall be maintained by the owner and shall be available to the authority having jurisdiction upon request.

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

8.2.3.1.9.3 Impressed Current Systems.

Δ **(A)** Systems equipped with impressed current cathodic protection systems shall be inspected in accordance with the requirements of the design and 8.2.3.1.9.2.

Δ **(B)** The design limits shall be available to the AHJ upon request.

Δ **(C)** 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

8.2.3.1.9.4 Corrosion Expert.

Δ **(A)** Repairs, maintenance, or replacement of a cathodic protection system shall be under the supervision of a corrosion expert certified by NACE.

Δ **(B)** 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.

8.2.3.1.10 Testing.

Δ **8.2.3.1.10.1** 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.

Δ **8.2.3.1.10.2** 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.

8.2.3.2 Indoor Use.

8.2.3.2.1 Filling and Dispensing.

Δ **8.2.3.2.1.1 General.** A qualified person shall be in attendance at all times LH_2 is transferred from mobile supply units to a storage system.

Δ **8.2.3.2.1.2 Indoor Dispensing Areas.** Dispensing indoors shall be conducted in areas constructed in accordance with the adopted building code.

8.2.3.2.1.3 Ventilation. Indoor areas in which LH_2 is dispensed shall be ventilated in accordance with the requirements of Section 6.18.

8.2.3.3 Outdoor Use. (Reserved)

8.2.4 Non-Bulk LH_2 Handling.

Δ **8.2.4.1 Non-Bulk LH_2** Handling of LH_2 containers shall be in accordance with 8.2.4.

8.2.4.2 Carts and Trucks.

Δ **8.2.4.2.1** LH_2 containers shall be moved using an approved method.

Δ **8.2.4.2.2** Where LH_2 containers are moved by hand cart, hand truck, or other mobile device, that device shall be designed for the secure movement of the container.

Δ **8.2.4.3 Design.** Carts and trucks used to transport LH_2 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.

8.2.4.4 Closed Containers.

Δ **8.2.4.4.1** Pressurized containers shall be closed while being transported.

Δ **8.2.4.4.2** Containers designed for use at atmospheric conditions shall be transported with appropriate loose-fitting covers in place to prevent spillage.

8.3 Bulk LH_2 Systems.

8.3.1 Bulk LH_2 Systems — General. The storage, use, and handling of LH_2 in LH_2 storage systems shall be in accordance with the provisions of Chapters 1 through 6 and Chapter 8, as applicable.

8.3.1.1 Section 8.3 shall not apply to individual systems using containers having a total hydrogen content of less than 39.7 gal (150 L).

8.3.1.2 Design of LH_2 Systems.

8.3.1.2.1 Fire Protection of Structural Supports.

Δ **8.3.1.2.1.1*** Steel supports in excess of 18 in. (457 mm) in height shall have a minimum 2-hour fire resistance rating in accordance with ASTM E1529, *Determining the Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*.

Δ **8.3.1.2.2 Pressure Relief Devices.** Stationary and portable containers and tanks shall be provided with pressure relief devices in accordance with the requirements of 8.1.4 and 8.3.1.2.2.1 through 8.3.1.2.2.3.

Δ **8.3.1.2.2.1** Pressure relief valves or vent piping shall be designed or located so that moisture cannot collect and freeze in a manner that would interfere with the operation of the device.

Δ **8.3.1.2.2.2** Pressure relief devices serving stationary containers shall be in accordance with the provisions of 8.1.4.6.1 and arranged to discharge unobstructed to the outdoors.

Δ **8.3.1.2.2.3** Hydrogen venting systems discharging to the atmosphere shall be in accordance with CGA G-5.5, *Hydrogen Vent Systems*.

Δ **8.3.1.2.2.4** 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.

8.3.1.2.3* Piping, Tubing, and Fittings.

Δ **8.3.1.2.3.1** Piping and tubing shall be in accordance with the requirements of ASME B31, *Pressure Piping*.

Δ **8.3.1.2.3.2*** 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, *Pressure Piping*.

Δ **8.3.1.2.3.3** Piping and tubing materials that have a minimum design metal temperature (MDMT) of −425°F (254°C) or lower, as defined and specified in ASME B31, *Pressure Piping*, shall be permitted to be used without impact testing.

Δ **8.3.1.2.3.4** Piping and tubing materials that have an MDMT greater than −425°F (−254°C) shall be permitted to be used after impact testing has been performed and the materials have passed.

Δ **8.3.1.2.3.5** Joints in piping and tubing shall be in accordance with the requirements of ASME B31, *Pressure Piping*.

Δ **8.3.1.2.3.6** Brazing materials, where used, shall have a melting point above 1000°F (538°C).

Δ **8.3.1.2.3.7** Aluminum piping systems and components external to the storage vessel shall not be used with LH_2, except for ambient air vaporizers.

Δ **8.3.1.2.3.8*** Means shall be provided to minimize exposure of persons to piping operating at low temperatures and to prevent air condensate from contacting piping, structural members, and surfaces not designed for LH_2 temperatures.

Δ **(A)** Insulation on piping systems used to convey LH_2 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.

Δ **(B)** The insulation material and outside shield shall be designed to prevent deterioration of the insulation due to normal operating conditions.

Δ **8.3.1.2.3.9** Uninsulated piping and equipment that operates at LH_2 temperatures shall not be installed above asphalt or other combustible materials or surfaces in order to prevent the contact of liquid air with such materials.

Δ **8.3.1.2.3.10** Drip pans shall be allowed to be installed under uninsulated piping and equipment to retain and vaporize condensed liquid air.

8.3.1.2.3.11 Cleaning and purging of piping systems shall be in accordance with Section 6.22.

8.3.1.2.4 Equipment Assembly.

Δ **8.3.1.2.4.1** Installation of bulk LH_2 systems shall be supervised by personnel knowledgeable about the applicable codes and the construction and use of the system to be installed.

Δ **8.3.1.2.4.2** Storage containers, piping, valves, regulating equipment, and other accessories shall be accessible and shall be protected against physical damage and tampering.

Δ **(A)** Emergency shutoff valves shall be located in liquid and vapor use lines as close to the container as practical to terminate all flow to use lines during an emergency.

Δ **(B)** Containers exceeding 2000 gal (7570 L) capacity shall be provided with an automatic emergency shutoff valve.

(1) The remotely operated emergency isolation valve shall be operated by a remotely located, manually activated shutdown control.
(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.
(3) Connections downstream of the shutoff valve shall be in accordance with ASME B31, *Pressure Piping*.

Δ **8.3.1.2.4.3** Cabinets or enclosures containing hydrogen control equipment shall be ventilated to prevent any accumulation of hydrogen gas.

8.3.1.2.5 LH_2 Vaporizers.

Δ **8.3.1.2.5.1*** Heat supplied to a LH_2 vaporizer shall be by indirect means utilizing a transfer medium.

Δ **8.3.1.2.5.2*** A low-temperature shutoff switch or valve shall be provided in the vaporizer discharge piping to prevent flow of LH_2 downstream of the vaporizer in the event that liquid is discharged from the vaporizer.

Δ **8.3.1.2.6 Electrical Systems.** Electrical wiring and equipment shall be in accordance with Article 500 of *NFPA 70*.

Δ **8.3.1.2.6.1** Specific locations for the Class 1, Division 1, Group B (hydrogen) and Class 1, Division 1, Group B (hydrogen) areas shall be classified in accordance with Table 8.3.1.2.6.1.

Δ **8.3.1.2.6.2** 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
(2) Intrinsically safe

Δ **8.3.1.2.6.3** Electrical equipment installed on mobile supply trucks or tank cars from which the storage container is filled shall not be subject to 8.3.1.2.6.2.

Δ **8.3.1.2.7 Bonding and Grounding.** The LH_2 system shall be electrically bonded and grounded.

8.3.1.2.8 Stationary Pumps and Compressors.

8.3.1.2.8.1 Valve Isolation.

Δ **(A)** Valves shall be installed such that each pump or compressor can be isolated for maintenance.

Δ **(B)** 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.

8.3.1.2.8.2 Foundation Design and Construction.

Δ **(A)** Foundations used for supporting pumps and equipment shall be designed and constructed to prevent frost heaving.

Δ **(B)** The structural aspects of such foundations shall be designed and constructed in accordance with the provisions of the adopted building code.

Δ **8.3.1.2.8.3 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.

8.3.1.2.8.4 Pump and Compressor Venting.

Δ **(A)** 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.

Δ **(B)** Pressure relief devices used to serve pumps or compression equipment shall be connected to a vent pipe system in accordance with 8.3.1.2.2.3.

Δ **8.3.1.2.8.5* Pressure Monitoring.** The pressure on the pump or compressor discharge shall be monitored by a control system.

Δ **(A)** Discharge pressures in excess of the equipment design pressures shall cause the pump or compressor to shut down.

Δ **8.3.1.2.8.6 Protection of Transfer Piping, Pumps, and Compressors.** Transfer piping, pumps, and compressors shall be protected from vehicular damage.

Δ **8.3.1.2.9 Emergency Shutdown System.**

8.3.1.2.9.1 Emergency isolation shall comply with 7.1.25.1, 8.3.1.2.4.2, and 8.3.1.2.9.

Δ **8.3.1.2.9.2** An emergency shutdown (ESD) system shall be provided at the bulk source to stop the flow of liquid and gas into the use line when actuated.

Δ **Table 8.3.1.2.6.1 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) measured spherically from system fill connection, system pressure relief vent outlets, other points of release when the system is operating as designed
	2	Between 3 ft (1 m) and 25 ft (7.6 m) measured spherically from the system fill connection, any vent outlet, and within 25 ft (7.6 m) of any portion of the bulk supply system that contains liquefied hydrogen

Δ **8.3.1.2.9.3** 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.

Δ **8.3.1.2.9.4** Reactivation of the ESD system after ESD shall require that the ESD system be manually reset.

Δ **8.3.1.2.9.5** The ESD system shall be identified by means of a sign.

Δ **8.3.1.3 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 8.3.2.3.1.6(a).

8.3.2 Bulk LH_2 Systems Storage.

8.3.2.1 General.

Δ **8.3.2.1.1** Stationary storage containers shall be located so that they are accessible from mobile supply equipment.

Δ **8.3.2.1.2*** Diking shall not be used to contain a LH_2 spill.

Δ **8.3.2.1.3** LH_2 diking or berms shall be permitted to direct the spill away from exposures.

Δ **8.3.2.1.4** Storage sites shall be placarded as follows:

WARNING:

LIQUEFIED HYDROGEN

FLAMMABLE GAS

NO SMOKING — NO OPEN FLAMES

Δ **8.3.2.1.5 Aboveground Tanks.** Aboveground tanks for the storage of LH_2 shall be in accordance with 8.3.2.1.5.

Δ **8.3.2.1.5.1 Construction of the Inner Vessel.** The inner vessel of storage tanks in LH_2 service shall be designed and constructed in accordance with the ASME *Boiler and Pressure Vessel Code* and shall be vacuum jacketed in accordance with 8.3.2.1.5.2.

8.3.2.1.5.2 Construction of the Vacuum Jacket (Outer Vessel).

Δ **(A)** The vacuum jacket used as an outer vessel for storage tanks in LH_2 service shall be designed to withstand the maximum internal and external pressure to which it will be subjected under operating conditions, including emergency pressure relief of the annular space between the inner vessel and the outer vessel.

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

Δ **(C) Vacuum Level Monitoring.**

(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.
(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.

8.3.2.1.5.3 Nonstandard Containers.

Δ **(A)** 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.

Δ **(B)** 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

Δ **8.3.2.1.5.4 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 8.3.2.1.5.4(A) through 8.3.2.1.5.4(E) also shall apply.

Δ **(A) Excessive Loads.** Stationary tanks shall be supported to prevent the concentration of excessive loads on the supporting portion of the shell.

Δ **(B) Expansion and Contraction.** Foundations for horizontal containers shall be constructed to accommodate expansion and contraction of the container.

Δ **(C)* Support of Ancilliary Equipment.**

(1) Foundations shall be provided to support the weight of vaporizers or heat exchangers.
(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.

Δ **(D) 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 LH_2 spillage.

Δ **(E) Corrosion Protection.** Portions of stationary tanks in contact with foundations or saddles shall be painted to protect against corrosion.

8.3.2.1.6 Underground Tanks. Underground tanks shall not be located under buildings. *(See 8.3.2.3.1.7.)*

8.3.2.2 Indoor Storage.

8.3.2.2.1 Installation. Stationary containers stored indoors shall be installed in accordance with Sections 8.1 and 8.3.

Δ **8.3.2.2.1.1 Stationary Containers.** Stationary containers shall be in accordance with 8.1.2.

Δ **8.3.2.2.1.2 LH_2 Fluids.** LH_2 in stationary or portable containers stored indoors shall be stored in buildings, rooms, or areas constructed in accordance with the adopted building code.

Δ **8.3.2.2.1.3 Ventilation.** Ventilation shall be in accordance with Section 6.18.

Δ **8.3.2.2.1.4 Specific Locations.** The location of bulk LH_2 storage systems, as determined by the maximum total quantity of LH_2, shall be in accordance with Table 8.3.2.2.1.4.

Δ **Table 8.3.2.2.1.4 Location of LH_2 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.

8.3.2.2.2 Detached Buildings.

8.3.2.2.2.1 Explosion Control.

Δ **(A)** Detached buildings containing more than 300 gal (1136 L) of LH_2 shall be constructed of noncombustible or limited-combustible materials in accordance with the requirements of the adopted building code.

Δ **(B)** Explosion control shall be provided in accordance with the requirements of Section 6.10.

Δ **8.3.2.2.2.2 Ventilation.** Ventilation shall be provided in accordance with the requirements of Section 6.18 and 8.3.2.2.2.2(A) through 8.3.2.2.2.2(D).

Δ **(A)** Inlet openings shall be located within 18 in. (0.46 m) of the floor in exterior walls only.

Δ **(B)** Outlet openings shall be located at the high point of the room in exterior walls or the roof.

Δ **(C)** 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.

Δ **(D)** 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.

Δ **8.3.2.2.2.3* Ignition Sources.** There shall be no sources of ignition within the room or area where the hydrogen system is installed.

8.3.2.2.2.4 Heating.

Δ **(A)** Heating, if provided, shall be by indirect means such as steam or hot water.

Δ **(B)** Electrical heating in accordance with 8.1.9 shall be allowed.

8.3.2.2.3 Gas Rooms.

Δ **8.3.2.2.3.1** Heating, if provided, shall be by steam, hot water, or other indirect means.

Δ **8.3.2.2.3.2** Explosion control shall be provided in accordance with the requirements of Section 6.10.

Δ **8.3.2.2.3.3** Electrical heating in accordance with 8.1.9 shall be allowed.

Δ **8.3.2.3 Outdoor Storage.** LH_2 in stationary or portable containers stored outdoors shall be in accordance with 8.3.2.3.

8.3.2.3.1 Aboveground Tanks.

8.3.2.3.1.1 Access.

Δ **(A)** Stationary containers shall be located to provide access by mobile supply equipment and authorized personnel.

Δ **(B)** 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).

8.3.2.3.1.2 Physical Protection.

Δ **(A)** LH_2 containers, cylinders, tanks, and systems that could be exposed to physical damage shall be protected.

Δ **(B)** Guard posts or other means shall be provided to protect LH_2 containers, cylinders, tanks, and systems indoors and outdoors from vehicular damage. *(See Section 4.14.)*

Δ **8.3.2.3.1.3* 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 adopted building code.

Δ **(A) 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.

8.3.2.3.1.4 Drainage.

Δ **(A)** 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 the adopted fire prevention code.

Δ **(B)** The stationary container shall not be placed where spilled or discharged LH_2 will be retained around the container.

Δ **(C)** The provisions of 8.3.2.3.1.4(B) 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

Δ **(D) Grade.** 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.

(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 8.3.2.3.1.4(D), diversion curbs or other means of drainage control shall be used to divert the flow of flammable or combustible liquids away from the LH_2.

(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.

8.3.2.3.1.5 Design Considerations at Specific Locations.

Δ **(A) Outdoor Locations.** Roadways and yard surfaces located below LH_2 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.

(1) The area of noncombustible surfacing provided under liquid mobile supply equipments shall have a width not less than 12 ft (3.7 m) and a length not less than 12 ft (3.7 m) in the direction of the vehicle axis.
(2) Asphalt and bitumastic paving shall be assumed to be combustible.
(3) Expansion joints and fillers used in the construction of concrete slabs shall be of noncombustible materials.

(B) Weather protection shall be constructed in accordance with the requirements of the adopted building code.

Δ **(C)* Enclosed Courts.** Stationary containers shall not be installed within enclosed courts.

Δ **(D)* Open 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 8.3.2.3.1.6(a) or the material-specific tables in Chapters 9, 11, 13, and 16 of NFPA 55.

(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.
(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.

Δ **(E) Fenced Areas.**

(1)* User storage sites shall be fenced or otherwise secured and posted to prevent entry by unauthorized personnel.

(a) 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.
(b) At least two means of egress shall be provided from any fenced area.

8.3.2.3.1.6* Siting Locations. The minimum distance from bulk liquefied hydrogen (LH_2) systems to specified exposures shall be in accordance with Table 8.3.2.3.1.6(a) based on typical maximum pipe size, or in accordance with Table 8.3.2.3.1.6(b) based on specific pressure and pipe diameter.

N **(A)** The vent stack shall not be considered part of the bulk liquid hydrogen system for determining separation distances in accordance with Table 8.3.2.3.1.6(a) and Table 8.3.2.3.1.6(b).

N **(B)** Separation distances determined based on the use of Table 8.3.2.3.1.6(a) or Table 8.3.2.3.1.6(b) shall be as follows:

(1) The distance shall be measured from the part of the bulk liquefied hydrogen system closest to the exposure.
(2) The internal diameter of the piping system size used in the application of Table 8.3.2.3.1.6(a) and Table 8.3.2.3.1.6(b) shall be determined based on that portion of the system with the greatest internal diameter.
(3)* The pressure used in the application of Table 8.3.2.3.1.6(a) and Table 8.3.2.3.1.6(b) shall be determined based on the maximum operating pressure (MOP) of the tank.
(4) The distances to exposures shall be allowed to be reduced by two-thirds for vacuum-insulated portions of the system with no mechanical connections, joints, or leak sources.
(5) Inlets to sewer openings shall be located not less than 10 ft (3 m) from the LH_2 system and connections used during delivery.

N **(C)** The separation distances specified in Table 8.3.2.3.1.6(a) and Table 8.3.2.3.1.6(b) shall be allowed to be reduced by passive and active means as follows:

(1) Passive means shall comply with all of the following:

(a) Fire barrier walls located and constructed per 8.3.2.3.1.6(C)(1)(b)(vii) shall allow the reduction of distances to air intakes by one-half but not less than 15 ft (4.6 m)
(b) The distances to Groups 1 and 2 exposures shown in Table 8.3.2.3.1.6(a) and Table 8.3.2.3.1.6(b) shall be allowed to be reduced by one-half, and Group 3 exposures shall be allowed to be reduced to 0 ft (0 m) from the wall where fire barrier walls are located between the system and the exposure and constructed in accordance with all of the following requirements:

i. The fire barrier wall shall be without openings or non-fire rated windows or doors.
ii. 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 adopted building code.
iii. Fire barrier walls shall have a minimum fire resistance rating of not less than 2 hours.
iv. The fire barrier wall shall interrupt the line of sight between the uninsulated portions of the system and the exposure.
v. The configuration of the fire barrier wall shall allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

vi.* The fire barrier wall shall not have more than two sides at a 90-degree (1.57 rad) direction or not more than three sides with connecting angles of not less than 135 degrees (2.36 rad), except as provided in Figure A.8.3.2.3.1.5(D)(1).

vii.* Piping and control systems serving stationary tank systems with fire barrier walls on three sides shall be located at the open side of the enclosure created by the barrier walls to provide access for filling and ventilation.

viii. Fire barrier walls shall be designed and constructed in accordance with the requirements of the adopted building code without exceeding the specified allowable stresses for the materials of construction and shall be designed to resist the overturning effects or failure caused by lateral forces due to deflagration overpressure, wind, flood, and seismic events.

ix. Where clearance is required between the bulk liquid hydrogen 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.

x. 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.

N **Table 8.3.2.3.1.6(a) Minimum Distance from Outdoor Bulk Liquefied Hydrogen (LH_2) Systems to Exposures, Up to 75,000 gal (280,000 L) — Typical Inner Diameter *(d)* 1.5 in. (38.1 mm)**

Maximum Operating Pressure (MOP) (gauge)	<60 psi (<414 kPa)		60 to 120 psi (414 kPa to 827 kPa)		>120 psi (>827 kPa)	
Exposures Group 1	**ft**	**m**	**ft**	**m**	**ft**	**m**
1. Lot lines 2. Air intakes (e.g., HVAC, compressors) 3. Operable openings in buildings and structures 4. Ignition sources such as open flames and welding	44	13.3	48	14.5	49	14.9
Exposures Group 2	**ft**	**m**	**ft**	**m**	**ft**	**m**
5. Exposed persons other than those servicing the system 6. Parked cars 7. Buildings of combustible construction 8. Hazardous materials storage systems above ground or fill/vent openings for belowground storage systems 9. 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	31	9.4	36	11.1	38	11.6
Exposures Group 3	**ft**	**m**	**ft**	**m**	**ft**	**m**
10. Buildings of noncombustible non-fire-rated construction 11. Flammable gas storage systems above or below ground 12. Heavy timber, coal, or other slow-burning combustible solids 13. Unopenable openings in buildings and structures 14. Encroachment by overhead utilities (horizontal distance from the vertical plane below the nearest overhead electrical wire of building service) 15. Piping containing other hazardous materials 16. Flammable gas metering and regulating stations such as natural gas or propane	26	8.0	31	9.5	33	10.0

(2)* Active means shall comply with all of the following:

(a) Active control systems or design functions beyond base code requirements 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.

(b)* Bulk liquified hydrogen systems located at public refueling stations shall be equipped with an automatic emergency shutdown system (ESS).

Δ **(D)** Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 8.3.2.3.1.6(a) and Table 8.3.2.3.1.6(b) than the distances given for the storage system.

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N **(E)** For public refueling stations, the following active mitigation methods shall be installed and employed as standard practice at the bulk liquid hydrogen storage site:

(1) The installed bulk liquid hydrogen system shall include equipment to allow for connection of both liquid transfer delivery hose and a separate trailer head space vent hose to connect to the bulk storage system vent stack.

(2) All liquid hydrogen delivery trailers shall utilize a vent hose connection method to vent the trailer head space to the bulk storage vent stack system at the end of the bulk liquid hydrogen trans-fill process.

(3) The liquid hydrogen delivery procedures shall incorporate the physical changes required in 8.3.2.3.1.6(E)(1) and 8.3.2.3.1.6(E)(2) to eliminate end-of-trans-fill venting at the trailer vent stack.

(4) All liquid hydrogen delivery trailers trans-filling at the site shall be equipped with an emergency shutdown device (ESD) system and fast-acting liquid hydrogen shut-off valve that can isolate the trailer in the event of an emergency during the trans-fill process.

(5) The trailer ESD system and bulk hydrogen system ESS shall be interconnected to shut down the tank fill process if either system is activated.

(6) A sign indicating that the trailer head space must be connected to the bulk liquid hydrogen system vent stack before transferring hydrogen to the system shall be installed at the bulk liquid hydrogen connection.

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Δ **8.3.2.3.1.7 Underground Tanks.** Underground tanks for the storage of LH_2 shall be in accordance with this subsection.

Δ **(A) Construction.** Storage tanks for liquid hydrogen shall be designed and constructed in accordance with the ASME *Boiler and Pressure Vessel Code* and shall be vacuum-jacketed in accordance with 8.3.2.3.1.7(A)(1).

(1) Vacuum Jacket Construction.

(a) The vacuum jacket shall be designed and constructed in accordance with the ASME *Boiler and Pressure Vessel Code* and shall be designed to withstand the anticipated loading, including loading from vehicular traffic, where applicable.

(b) Portions of the vacuum jacket installed below grade shall be designed to withstand anticipated soil, hydrostatic, and seismic loading.

(c) The vacuum jacket shall be constructed of stainless steel or other approved corrosion-resistant material.

(d) 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.

Δ **(B) Location.** Tanks shall be located in accordance with 8.3.2.3.1.7(B)(1) through 8.3.2.3.1.7(B)(4).

(1) Underground storage tanks shall not be located beneath buildings.

(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.

N **Table 8.3.2.3.1.6(b) Minimum Distance from Outdoor Bulk Liquefied Hydrogen (LH_2) Systems to Exposures by Inner Diameter *(d)***

Maximum Operating Pressure (MOP) (gauge)		<60 psi (<414 kPa)						60 psi to 120 psi (414 kPa to 827 kPa)						>120 psi (>827 kPa)					
Inner Diameter (*d*)		Group 1		Group 2		Group 3		Group 1		Group 2		Group 3		Group 1		Group 2		Group 3	
		$0.34d + 0.24$		$0.20d + 1.84$		$0.15d + 2.08$		$0.37d + 0.53$		$0.24d + 1.96$		$0.19d + 2.19$		$0.38d + 0.57$		$0.25d + 1.93$		$0.20d + 2.16$	
in.	mm	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
0.5	12.7	15	4.7	14	4.2	13	4.0	18	5.4	16	4.8	15	4.5	18	5.5	16	5.0	15	4.6
1.0	25.4	29	8.9	23	7.0	20	6.1	32	9.7	27	8.1	23	7.1	33	10.0	28	8.5	24	7.5
1.5	38.1	44	13.3	31	9.4	26	8.0	48	14.5	36	11.1	31	9.5	49	14.9	38	11.6	33	10.0
2.0	50.6	58	17.8	38	11.7	32	9.8	63	19.3	45	13.8	38	11.6	65	19.9	48	14.6	41	12.3

(1) Linear interpolation of internal pipe diameters and distances between table entries is allowed.
(2) For a list of exposures in each exposure group, see column 1 of Table 8.3.2.3.1.6(a).
(3) When calculating the minimum separation distance using the formulas indicated, based on the exposure group and pressure indicated, the inner diameter (*d*) is entered in millimeters (mm). The calculated distance is returned in units of measure in meters (m). To convert distance to units of measure in feet, multiply the value in meters by 3.2808 and round to the nearest whole foot.

(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).
(4) A minimum distance of 1 ft (0.3 m), shell to shell, shall be maintained between adjacent underground tanks.

Δ **(C) Depth, Cover, and Fill.**

(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.
(2) The concrete shall extend a minimum of 1 ft (0.3 m) horizontally beyond the footprint of the tank in all directions.
(3) Underground tanks shall be set on foundations constructed in accordance with the adopted building code and surrounded with not less than 6 in. (152 mm) of noncorrosive inert material.
(4) The vertical extension of the vacuum jacket required for service connections shall be allowed to extend above grade.

Δ **(D) Anchorage and Security.** Tanks and systems shall be secured against accidental dislodgment due to seismic events or flooding.

(1)* 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 adopted building code.
  (a) 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.

Δ **(E) Venting of Underground Tanks.** Vent pipes for underground storage tanks shall be in accordance with 8.3.1.2.2.3.

Δ **(F) Underground LH_2 Piping.**

(1) Underground LH_2 piping shall be vacuum jacketed.
(2) Unjacketed piping shall not be buried and shall exit the tank annular space above grade.

Δ **(G) Overfill Protection and Prevention Systems.** An approved means or method shall be provided to prevent the overfilling of storage tanks.

Δ **(H) Vacuum Level Monitoring.** An approved monitoring method shall be provided to indicate vacuum degradation within the vacuum jacket(s).

Δ **(I) Physical Protection.** Piping and control equipment ancillary to the underground tank located above ground shall be protected from physical damage in accordance with 8.1.7.5.

Δ **(J) Tanks Not in Service.**

(1)* Tanks not in service shall be maintained in accordance with 8.3.2.3.1.7(J)(2).
(2) Corrosion protection shall be maintained in operation.

8.3.3 Bulk LH_2 Systems Use.

8.3.3.1 General.

Δ **8.3.3.1.1 General.** Use of containers and systems shall be in accordance with 8.3.3.

8.3.3.1.2 Nationally Recognized Good Practices. Where nationally recognized good practices or codes and standards have been established for the process employed, such practices and codes and standards shall be followed.

Δ **8.3.3.1.3 Operating Instructions.** Operating instructions shall be provided for installations that require the operation of equipment.

Δ **8.3.3.1.4 Attended Delivery.** A qualified person shall be in attendance at all times LH_2 is transferred from mobile supply units to a storage system.

8.3.3.1.4.1 Cleaning and Purging of Gas Piping Systems. Cleaning and purging of piping systems shall be in accordance with Section 6.22.

8.3.3.1.5 Inspection.

Δ **8.3.3.1.5.1** LH_2 storage systems shall be inspected and maintained by a qualified representative of the equipment owner.

Δ **(A)** The interval between inspections shall be based on nationally recognized good practices or standards.

Δ **8.3.3.1.5.2** A record of the inspection shall be prepared and provided to the user or the authority having jurisdiction upon request.

8.3.3.2 Indoor Use.

8.3.3.2.1 Filling and Dispensing.

Δ **8.3.3.2.1.1 General.** Filling and dispensing of LH_2 shall be in accordance with 8.3.3.1.4.

Δ **8.3.3.2.1.2 Indoor Dispensing Areas.** Dispensing indoors shall be conducted in areas constructed in accordance with the adopted building code.

8.3.3.2.1.3 Ventilation. Indoor areas in which LH_2 is dispensed shall be ventilated in accordance with the requirements of Section 6.18.

8.3.3.3 Outdoor Use. (Reserved)

8.3.4 Bulk LH_2 Systems Handling.

Δ **8.3.4.1 Bulk LH_2 Systems.** Handling of LH_2 containers shall be in accordance with 8.3.4.

8.3.4.2 Carts and Trucks.

Δ **8.3.4.2.1** LH_2 containers shall be moved using an approved method.

Δ **8.3.4.2.2** Where LH_2 containers are moved by hand cart, hand truck, or other mobile device, that device shall be designed for the secure movement of the container.

Δ **8.3.4.3 Design.** Carts and trucks used to transport LH_2 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.

8.3.4.4 Closed Containers.

Δ **8.3.4.4.1** Pressurized containers shall be closed while being transported.

Δ **8.3.4.4.2** Containers designed for use at atmospheric conditions shall be transported with appropriate loose-fitting covers in place to prevent spillage.

8.3.4.5 Cargo Transport Unloading.

8.3.4.5.1 Personnel conducting transfer operations from the bulk transport vehicle shall be trained.

Δ **8.3.4.5.2** Unloading connections on delivery equipment shall not be positioned closer to any of the exposures cited in Table 8.3.2.3.1.6(a) than the distances given for the storage system.

8.3.4.5.3 Prior to connection, a cargo transport vehicle's wheels shall be rendered immobile.

Δ **8.3.4.5.4** 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.

Δ **8.3.4.5.5** 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.

Δ **8.3.4.5.6** Mobile hydrogen supply units shall be electrically bonded to the storage system before hydrogen is discharged from the supply unit.

8.3.4.5.7 The cargo transport vehicle's engine shall be shut off while the transfer hose or piping is being connected or disconnected. If required for LH_2 trailer pumping transfer, the engine pump drive motor shall be permitted to be started and used during the liquid transfer operations.

8.3.4.5.8 When transfers are made into fueling facility containers, the LH_2 shall be transferred at a pressure that shall not overpressurize the receiving tank.

8.3.4.5.9 The transfer piping shall be equipped with a check valve to prevent backflow from the container being filled to the transport vehicle.

8.3.4.5.10* When the tank to be filled is directly buried or installed in an inaccessible, sealed, and corrosion-resistant area that does not create a confined space as defined by applicable occupational safety and health regulations, the following shall apply:

(1) Controls shall be provided and visible to the operator to prevent overfilling of the tank
(2) The controls shall be provided in the unloading area and as a minimum shall include a liquid level indicator, pressure indicator, and a fill termination device

Δ **8.3.4.5.11** The transfer systems shall be capable of depressurizing to facilitate disconnection. Bleed connections shall be connected to a hydrogen venting system in accordance with 8.3.1.2.2.3.

Δ **8.3.4.5.12** Prohibitions on smoking or the use of open flame shall be in accordance with 8.3.2.1.4.

8.3.4.5.13 Sources of ignition shall not be permitted in the unloading area while transfer is in progress.

Δ **8.3.4.5.14** An emergency shutoff valve shall be provided in accordance with 8.1.14.1.

N **8.3.4.5.15** The liquid hydrogen trailer and delivery connection shall be either of the following:

(1) At least 10 ft (3.1 m) from a canopy
(2) In accordance with 10.3.15(1), 10.3.15(3), and 11.3.1.17

Δ **8.3.4.6 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.

Δ **8.3.4.6.1** 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.

8.3.5 Maintenance.

Δ **8.3.5.1** Maintenance shall be performed annually by a qualified representative of the equipment owner.

Δ **8.3.5.2** The maintenance shall include inspection for physical damage, leaktightness, 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.

Δ **8.3.5.3** Scheduled maintenance and retest activities shall be formally documented, and records shall be maintained a minimum of 3 years.

Chapter 9 Explosion Protection (Reserved)

Chapter 10 GH_2 Vehicle Fueling Facilities

10.1 Scope. This chapter shall apply to the design, construction, and installation of GH_2 systems to be utilized for vehicle fueling.

10.1.1 Application. The requirements of this chapter shall apply to fueling operations, irrespective of the system capacity of either the fueling source or the vehicle being fueled.

10.1.1.1 Hydrogen dispensing systems for vehicular fueling shall comply with Chapter 10.

10.1.1.2 The storage, use, and handling of GH_2 in any quantity shall also comply with the requirements of Chapters 1 and 4 and the applicable requirements of Chapters 5 through 7.

10.1.1.3 Hydrogen generation systems shall be designed in accordance with Chapter 13.

10.1.1.4 Where there is a conflict between a fundamental requirement and a use-specific requirement, the use-specific requirement shall apply.

N **10.1.1.5*** This chapter shall not apply to facilities that fill containers or trailers for the purposes of transporting hydrogen when in accordance with and regulated by 49 CFR 100–199.

10.2 General.

10.2.1* System Approvals.

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

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

10.2.2* System Component Qualifications. The following systems and system components shall be listed or approved:

(1) Hose and hose connections
(2) Vehicle fueling connections (e.g., nozzle)
(3) Electrical equipment used with GH_2 systems
(4) Gas detection equipment and alarms
(5) Hydrogen dispensers
(6) Pressure switches
(7) Flow meters
(8) Breakaway devices
(9) Compressor

10.2.3 Vehicles shall not be considered a source of ignition with respect to the requirements of this chapter.

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10.2.4 Where an overpressure incident that results in operation of the overpressure protection system occurs, the dispenser pressure control system shall be examined and certified by a qualified technician prior to being returned to service.

10.3 Design.

10.3.1 Design and Construction of Cylinders, Containers, and Tanks.

10.3.1.1 Components shall be designed, installed, or protected so their operation is not affected by freezing rain, sleet, snow, ice, mud, insects, or debris.

10.3.1.2 Cylinders, containers, and tanks shall be fabricated, installed, and maintained in accordance with Chapters 6 and 7 of this document.

10.3.2 Pressure Relief Devices.

10.3.2.1 Pressure relief devices designed and installed in accordance with 10.6.3.1 shall be examined and tested in accordance with the applicable requirements of the ASME *Boiler and Pressure Vessel Code*.

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

10.3.2.3 The set pressure of the overpressure protection device for the dispensing system shall not exceed 138 percent of the service pressure of the fueling nozzle it supplies.

Δ **10.3.2.4*** The capacity of pressure relief devices installed on hydrogen dispensers shall exceed the full flow capacity of the supply.

10.3.2.5 A relief device is not required on a hydrogen dispenser if there are equivalent means of protecting for overpressure upstream of the dispenser.

10.3.2.6 Pressure relief valves for GH_2 service shall not be fitted with lifting devices.

10.3.2.6.1 The adjustment, if external, shall be provided with a means for sealing the adjustment to resist tampering.

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

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

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

10.3.3 Pressure Gauges.

10.3.3.1 A pressure gauge, if provided, shall be capable of reading at least 1.2 times the system's maximum allowable working pressure (MAWP).

10.3.3.2 Gauges or other suitable readout devices shall be installed to indicate dispenser discharge pressure.

10.3.3.3 Pressure gauges shall be constructed such that the gauge will protect personnel under overpressure conditions (e.g., blow-out back or secondary containment and release).

10.3.4 Pressure Regulators.

10.3.4.1 A pressure regulator inlet and each chamber shall be designed in accordance with ASME B31, *Code for Pressure Piping*.

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

10.3.5 Fuel Lines and Piping Systems.

10.3.5.1 Pipe, tubing, and fittings shall be suitable for hydrogen service and for maximum pressures and minimum and maximum temperatures. Piping components in contact with hydrogen shall be compatible with hydrogen service conditions.

10.3.5.1.1 Cast, ductile, malleable, or high-silicon iron pipe, valves, and fittings shall not be used.

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10.3.5.2* Hydrogen gas pipe, tubing, and fittings shall be designed, fabricated, and tested in accordance with ASME B31, *Code for Pressure Piping*.

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

10.3.5.3.1 Seal welds shall not be considered as contributing any strength to the joints.

10.3.5.3.2* A threaded joint to be seal welded shall be made up without thread compound.

10.3.6 Hose and Hose Connections.

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

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

Δ **10.3.6.3** Prior to use, hose assemblies shall be tested by the original equipment manufacturer (OEM) or their designated representative at a pressure at least twice the assembly rated pressure.

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

10.3.6.5 The use of hose in a hydrogen dispensing system shall be limited to vehicle fueling hose.

10.3.6.5.1 Each section shall be installed so that it is protected against mechanical damage and accessible for inspection.

10.3.6.6 A breakaway device that causes hydrogen gas flow to stop shall be installed between the connection of the hose to the dispenser and the filling nozzle. Where a separate vent hose is used, the vent hose connection also shall be equipped with a breakaway device.

10.3.6.6.1 Such devices shall be arranged to separate using a force not greater than 150 lb (667 N) when applied in any direction that the vehicle would move.

10.3.6.6.2 All other connections shall not prevent the operation of the gas flow breakaway devices.

10.3.7 Valves.

10.3.7.1 All system components shall be listed or approved for the hydrogen service pressures, internal and external temperatures, and operating environment of the hydrogen dispensing system.

10.3.7.1.1 Shutoff valves shall have a rated service pressure not less than the rated service pressure of the entire system and shall be designed with a minimum safety factor of 3.

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

10.3.8 Transfer systems shall be capable of depressurizing to facilitate disconnection.

10.3.9 Pneumatic gas supply systems for control devices shall be designed to prevent internal and external freezing. Fuel gas controls shall be installed to prevent external freezing.

10.3.10 Vehicle Fueling Connection.

Δ **10.3.10.1** Fueling nozzles for dispensing into hydrogen motor vehicles shall be listed in accordance with SAE J2600, *Compressed Hydrogen Surface Refueling Connection Devices*, or ISO 17268, *Gaseous Hydrogen Land Vehicle Refuelling Connection Devices*, or approved.

10.3.10.2* The use of adapters to transition from the nozzle to the vehicle shall be prohibited.

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

10.3.10.4 Hydrogen that is vented when the dispenser nozzle is disconnected from the vehicle shall be directed to a safe point of discharge.

N **10.3.10.5*** The fueling nozzle shall be rated to the same or lower pressure class as the fuel supply containers it is intended to fuel.

10.3.11 Stray or Impressed Currents and Bonding.

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

10.3.11.2 Additional static protection shall not be required where GH_2 is transferred by conductive hose, flexible metallic tubing, or pipe connections where both halves of the metallic coupling are in continuous electrical contact.

10.3.12 Detection. Dispensing equipment shall be provided with hydrogen gas detection, leak detection, and flame detection at the fueling area.

10.3.12.1 Activation of the detection systems shall automatically stop dispensing and activate the automatic emergency shutoff valve. Reactivation of the dispenser shall require a manual restart following the requirements of this chapter.

10.3.12.2 Dispenser enclosure shall be designed to prevent the accumulation of flammable gas within the enclosure.

10.3.13 Emergency Shutdown Equipment.

10.3.13.1 Manually Operated Container Valve.

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

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

10.3.13.1.3 The valve in 10.3.13.1.2 shall be located downstream of the backflow check valve specified in 10.3.13.2.

10.3.13.2 The compressor discharge line supplying the storage container shall be equipped with a backflow check valve near the container to prevent discharge of hydrogen from the container in case of the rupture of the line, hose, or fittings.

Δ **10.3.13.3** Where excess-flow valves are used, the closing flow shall be greater than the maximum system design flow rate and less than the flow rating of the piping system that results from a complete line failure between the excess-flow valve and the equipment downstream of the excess-flow valve.

10.3.13.4 Gas piping from an outdoor compressor or storage system into a building shall be provided with an automatic emergency shutoff valve located outside the building.

10.3.13.4.1 When supplying an indoor dispenser, a redundant automatic emergency shutoff shall be installed where the hydrogen piping enters the building.

(A) The valve as stated in 10.3.13.4.1 shall be located outside.

(B) The valve as stated in 10.3.13.4.1 shall shut when the dispensing area gas detection system actuates.

10.3.13.5 An emergency manual shutdown device shall be provided at the dispensing area and also at a location remote from the dispensing area.

10.3.13.5.1 This device, when activated, shall shut off the power supply and isolate the gas supply from the hydrogen source to the dispenser.

10.3.13.5.2 When GH_2 is being produced from the conversion of LH_2, the emergency shutdown system also shall shut off the liquid supply and power to the LH_2 transfer equipment necessary for the conversion process.

N **10.3.13.5.3** Signage for emergency shutdown devices shall meet the requirements in 10.4.8.

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

10.3.13.7 The emergency shutdown system shall include an automatic emergency shutoff valve at the hydrogen storage and supply system.

10.3.13.7.1 The automatic emergency shutdown valve(s) shall close when an emergency shutdown is activated.

10.3.13.7.2 The automatic emergency shutdown valve(s) shall be fail closed.

10.3.14 Storage.

10.3.14.1 General. The indoor and outdoor storage of GH_2 in bulk and non-bulk gas installations shall be in accordance with the applicable requirements of Chapters 6 and 7.

10.3.14.2 Indoor Storage. GH_2 stored in vehicle-mounted fuel supply containers shall not be considered as part of the MAQ.

10.3.14.3 Vaults for Aboveground Containers. (Reserved)

10.3.14.4 Underground Storage Systems. (Reserved)

N **10.3.14.5 Cargo Transport Unloading.**

N **10.3.14.5.1** Cargo transport unloading shall comply with 7.3.4.2 and 8.3.4.5.

N **10.3.14.5.2** The delivery vehicle shall be located so that all parts of the vehicle are on the premises when delivery is made. [**30A:**9.2.2.4]

N **10.3.14.5.3** The hydrogen site shall be designed with a traffic pattern for the cargo transport vehicle.

Δ **10.3.15 Canopies Used to Support Gaseous Hydrogen Systems.** Canopies that are used to shelter dispensing operations where flammable compressed gases are located on the roof of the canopy shall be in accordance with the following:

(1) The canopy shall meet or exceed Type I construction requirements of the adopted building code.
(2) Operations located under canopies shall be limited to refueling only.
(3) The canopy shall be constructed in a manner that prevents the accumulation of hydrogen gas.

10.4 Installation.

10.4.1 General. Hydrogen dispensing systems shall be protected to minimize damage from vehicles and vandals.

10.4.1.1 Vehicle fueling areas shall be constructed with a length and width to accommodate the types of vehicles to be fueled.

10.4.2 Installation of Pressure Regulators on Dispensing Systems.

10.4.2.1 The regulator protection in 10.3.1.1 shall be permitted to be integral with the regulator.

10.4.3 Installation of Piping and Hoses on Dispensing Systems.

10.4.3.1 Piping and hose shall be run as directly as practical and with provisions to protect the piping from the effects of expansion, contraction, jarring, vibration, and settling.

10.4.3.2 Exterior piping shall be protected against mechanical damage.

10.4.3.3 A pipe thread jointing material impervious to the action of the hydrogen used in the system shall be applied to all male pipe threads prior to assembly.

10.4.3.4 Mechanical joints shall be located in an accessible location.

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

10.4.3.6* Mechanical connections in hydrogen piping shall not be buried.

10.4.3.7 A bend in piping or tubing shall have the pressure rating reduced according to ASME B31, *Code for Pressure Piping*.

10.4.4* Hydrogen shall be vented in accordance with Section 6.17.

10.4.5 System Testing.

10.4.5.1* Hydrogen dispensing systems shall be leak tested after final installation to prove them free from leaks at a pressure equal to at least the normal service pressure of that portion of the system.

10.4.5.2 This leak test shall be in addition to the ASME B31, *Code for Pressure Piping*, testing required by 10.3.5.2.

10.4.5.3 Leakage shall not occur when tested in accordance with the requirements of ASME B31, *Code for Pressure Piping*, either pneumatically or hydrostatically. The test pressure shall be not less than 110 percent of the rated service pressure when tested pneumatically, using an inert gas as the medium, nor less than 150 percent of the rated service pressure when tested hydrostatically.

10.4.5.4 The assembly shall be leak tested using hydrogen.

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

10.4.6 Installation of Electrical Equipment.

10.4.6.1 Fixed electrical equipment and wiring within areas specified in Table 10.4.6.1 shall be as follows:

(1) Compliant with Table 10.4.6.1
(2) Installed in accordance with *NFPA 70*

10.4.6.1.1 The electrical area classification shall not apply to vehicles.

10.4.6.2 With the approval of the AHJ, the classified areas specified in Table 10.4.6.1 for dispenser interior electrical enclosures shall be permitted to be reduced or eliminated by positive-pressure ventilation from a source of clean air or inert gas in conjunction with effective safeguards against ventilation system failure by purging methods recognized in NFPA 496.

10.4.6.2.1 Modifications shall be approved by a qualified engineer with expertise in fire safety and gaseous fuels.

10.4.6.3 Classified areas shall not extend beyond an unpierced wall, roof, or gastight partition.

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

Δ **Table 10.4.6.1 Electrical Installations**

Location	Division or Zone	Extent of Classified Area
Outdoor dispenser enclosure — exterior and interior	2	Up to 5 ft (1.5 m) from dispenser
Indoor dispenser enclosure — exterior and interior	2	15 ft (4.6 m) from the point of transfer in accordance with 10.5.3.4.3.4
Outdoor discharge from relief valves or vents	1	5 ft (1.5 m) from source
Outdoor discharge from relief valves or vents	2	15 ft (4.6 m) from source
Discharge from relief valves within 15 degrees of the line of discharge	1	15 ft (4.6 m) from source

10.4.6.4.1 Listed dispensers shall be allowed to be installed within classified areas in accordance with the terms of the listing.

Δ **10.4.7* Fire Protection.** A minimum 10 lb (4.54 kg) ABC dry chemical portable fire extinguisher having an agent discharge rate of at least 1 lb/sec (0.45 kg/sec) shall be provided at the dispensing area in approved locations not more than 50 ft (15.2 m) away from the dispensing area.

10.4.8 Signage.

10.4.8.1 Warning Signs. Warning signs shall be conspicuously posted in the dispensing area and shall incorporate the following, or equivalent wording approved by the AHJ:

WARNING

It is unlawful and potentially hazardous to dispense hydrogen into unapproved containers.

WARNING HYDROGEN — NO SMOKING — COMPRESSED FLAMMABLE GAS HYDROGEN HAS NO ODOR.

If a fire or leak starts, do not remove nozzle—back away immediately

10.4.8.2 The signage shall comply with ANSI Z535 2, *Environmental and Facility Safety Signs*; ANSI Z535.3, *Criteria for Safety Symbols*; and ANSI Z535.4, *Product Safety Signs and Labels*.

10.4.8.3 For public dispensing, the following additional signage shall be required:

Turn off vehicle

Discharge your static electricity before fueling by touching a metal surface away from the nozzle

Do not re-enter your vehicle while hydrogen is dispensing

Do not allow individuals under licensed age to use the dispenser

10.4.8.4 Other Signs.

10.4.8.4.1 Fueling Nozzle. The pressure class of each fueling nozzle shall be clearly labeled on or next to the fueling nozzle.

10.4.8.4.2* Operating Instructions. The operating instructions shall be clearly displayed on the dispenser. The operating instructions shall be understandable by an untrained user.

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

10.5 Dispensing.

10.5.1* General.

10.5.1.1 Vehicle Fueling Dispenser System Operation.

10.5.1.1.1* Fueling Hose Integrity Tests. Controllers on hydrogen dispensing systems shall be designed to verify the integrity of the fuel hose, breakaway, nozzle, and receptacle by pressurizing these components to at least the vehicle back pressure and monitoring pressure decay over a period of at least five seconds prior to the start of fueling.

10.5.1.1.2 Hydrogen dispensing integrity checks once the fueling event has started shall be as follows:

(1) 350 bar fueling events shall have a second integrity check repeated at 80 to 90 percent of the dispenser nozzle service pressure by stopping flow and checking the pressure decay over a period of five seconds.
(2) 700 bar fueling events with a starting pressure of less than 200 bar shall have a second integrity test at 40 to 50 percent and third integrity test at 80 to 90 percent of the dispenser nozzle service pressure by stopping flow and checking the pressure decay over a period of at least five seconds.
(3) 700 bar fueling events with a starting pressure of greater than 200 bar shall have a second integrity test at 80 to 90 percent of the dispenser nozzle service pressure by stopping flow and checking the pressure decay over a period of at least five seconds.

10.5.1.1.3 The transfer of GH_2 into a fuel supply container shall be performed in accordance with instructions posted at the dispensing station.

10.5.1.1.4 Sources of ignition shall be in accordance with Section 4.12.

10.5.1.1.5 A means shall be provided to bring the system to a safe condition in the event of failure of the hydrogen dispensing system logic controller.

10.5.1.1.5.1 The means of protection shall stop the dispensing of hydrogen if the dispenser pressure or dispenser fuel temperature deviates from the operating parameters.

10.5.1.1.6 The dispenser shall not exceed the rated temperature of the container over the range of dispenser operating conditions.

10.5.1.2 Overfilling Protection.

10.5.1.2.1 A hydrogen container shall not be charged in excess of the service pressure that is stamped on the container and displayed on a label near the filling connection when compensated for differences in temperature from 59°F (15°C).

10.5.1.2.2 A hydrogen container shall not be subjected to pressure in excess of 125 percent of its marked service pressure.

N **10.5.1.3 Fueling Protocols for Hydrogen Motor Vehicles.** All public dispensers intended to fuel hydrogen motor vehicles shall use a standard light-duty fueling protocol as their default protocol.

Δ **10.5.1.3.1** GH_2 dispensing systems shall stop fuel flow automatically when a fuel supply container reaches the temperature-corrected fill pressure.

Δ **10.5.1.3.2** The dispenser gas temperature shall not be less than −40°F (−40°C).

10.5.1.3.3 A dispenser shall only dispense hydrogen when the ambient temperature is between −40°F (−40°C) and 122°F (50°C) unless designed for extreme temperatures and per 10.5.1.1.6.

10.5.1.4* Fueling Protocols for Light-Duty Hydrogen Motor Vehicles. All public dispensers and all dispensers intended to fuel light-duty hydrogen motor vehicles shall use a standard automotive fueling protocol as their default protocol.

10.5.1.4.1* The dispenser using a standard automotive protocol shall be listed, approved, or tested to CSA/ANSI HGV 4.3, *Test Methods for Hydrogen Fueling Parameter Evaluation.*

10.5.1.4.2* All public dispensers and all dispensers intended to fuel light-duty hydrogen motor vehicles that can be accessed by a hydrogen vehicle using a nonstandard fueling protocol shall meet the requirements in 10.5.1.4.2.1 through 10.5.1.4.2.2.

10.5.1.4.2.1* All public dispensers and all dispensers intended to fuel light-duty hydrogen motor vehicles that can be accessed by a hydrogen vehicle using a nonstandard automotive fueling protocol shall have means to prevent the fueling of vehicles not designed to use the dispenser.

10.5.1.4.2.2* Trained attendants of dispensers shall be permitted to authorize the use of a nonstandard fueling protocol.

10.5.1.4.2.3 Dispensers that have the capability to use both standard and nonstandard fueling protocol shall prevent the authorization of nonstandard protocol by public users of the dispenser.

N **10.5.1.4.3** If measured, the dispenser gas temperature shall be measured as close to the hose breakaway as possible.

10.5.1.4.4* The flowrate of a hydrogen dispenser for light-duty vehicles shall not exceed 0.1323 lb (60 g) of hydrogen per second.

10.5.1.4.4.1 The limit of 0.1323 lb (60 g) per second does not include transient excursions due to valve actuation.

N **10.5.1.5 Fueling Protocols for Medium- and Heavy-Duty Hydrogen Motor Vehicles.**

N **10.5.1.5.1** The dispenser shall use a standard fueling protocol.

N **10.5.1.5.1.1*** The standard fueling protocol shall be approved.

N **10.5.1.5.2** For all public dispensers and dispensers intended to fuel both light- and medium-/heavy-duty hydrogen motor vehicles, the non-light-duty vehicle protocol shall be treated as a nonstandard fueling protocol and meet the requirements of 10.5.1.4.2.1 through 10.5.1.4.2.3.

N **10.5.1.5.2.1** All public dispensers and dispensers intended to fuel light-duty hydrogen motor vehicles that can fuel a hydrogen vehicle using a nonstandard automotive fueling protocol shall have means to prevent the fueling of vehicles not designed to use the dispenser.

10.5.1.6 Vehicle-to-Dispenser Communications System.

10.5.1.6.1* All public dispensers that use a vehicle-to-dispenser communication system for its default fueling protocol shall use a standard automotive communication system.

10.5.1.6.2 Dispensers using a communications protocol to control the fueling shall abort the fill or revert to a noncommunication fueling strategy in the event of a communications failure or if the dispenser determines the vehicle is using an unrecognized automotive communication system.

10.5.1.7 Pressure Compatibility.

10.5.1.7.1 The primary means of protection of ensuring the pressure compatibility of the container with the dispenser shall be fueling nozzle compliance with the requirements of 10.3.10.

10.5.1.7.2* For H70 dispensing, there shall be a second means of preventing dispensing that is not compatible with the pressure rating of the container.

10.5.1.8 Public Dispensing Into Containers.

10.5.1.8.1 Public dispensers shall only dispense GH_2 into containers that are compatible with the fueling protocol requirements in 10.5.1.4.

10.5.1.8.2* Public dispensers shall only dispense GH_2 into fuel supply containers on hydrogen motor vehicles that comply with at least one of the following standards:

(1) SAE J2579, *Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles*
(2) UN Global Technical Regulation No. 13, *Global technical regulation on hydrogen and fuel cell vehicles*

10.5.1.8.3 Public dispensing into containers other than fuel supply containers shall be prohibited unless approved by the station operator and AHJ.

10.5.1.8.4 This section shall not apply to dispensing into containers for fuel station testing purposes when approved by the operator.

10.5.2 Dispensing to The Public.

10.5.2.1 General.

10.5.2.1.1 GH_2 compression, hydrogen generation equipment, storage, and dispensing shall be located and conducted outdoors or indoors in compliance with 10.5.2.

10.5.2.1.1.1 Compression, gas processing, dispensing equipment, and storage containers connected for public use shall be allowed to be located inside of buildings reserved exclusively for these purposes or in rooms within or attached to buildings used for other purposes in accordance with Chapters 6 and 7.

10.5.2.1.1.2 Dispensing equipment shall be installed on foundations with anchoring systems designed to meet the requirements of the adopted building code for the appropriate seismic and wind conditions. [**52:**9.3.3]

10.5.2.2 Outdoor Public Fueling.

10.5.2.2.1 General.

10.5.2.2.1.1 A facility in which GH_2 compression, gas processing, hydrogen generation equipment, storage, and dispensing equipment are sheltered by an enclosure that is constructed as weather protection in accordance with Section 6.7 with a roof designed for ventilation and dispersal of escaped gas shall be considered to be located outdoors.

10.5.2.2.1.2* Equipment located above grade shall be installed on engineered support structures.

10.5.2.2.1.3* The vehicle fueling pad shall be of concrete or a material having a resistivity not exceeding 1 megaohm as determined by an approved method unless the vehicle is grounded by other means, such as a grounding cable.

10.5.2.2.1.4 The outdoor installation of hydrogen dispensers shall meet the separation distances shown in Table 10.5.2.2.1.4.

10.5.2.2.1.5 Dispensing equipment and points of transfer shall be allowed to be located at a lesser distance from buildings or walls constructed of concrete or masonry materials or of other material having a fire resistance rating of at least 2 hours, but at least 10 ft (3.0 m) from any building openings.

N **10.5.2.2.1.6** Motor vehicle traffic patterns at motor fuel dispensing facilities shall be designed to inhibit movement of vehicles that are not being fueled from passing through the dispensing area. [**30A:**6.3.7]

10.5.2.2.2 Outdoor Public Full-Service Fueling. (Reserved)

10.5.2.2.3 Outdoor Public Attended Self-Service Fueling. (Reserved)

10.5.2.2.4 Outdoor Public Unattended Self-Service Fueling. (Reserved)

10.5.3 Dispensing to Nonpublic Users.

10.5.3.1 General. (Reserved)

N **10.5.3.2 Gas Dispensing Equipment for Hydrogen-Powered Industrial Trucks (HPITs).**

N **10.5.3.2.1 Dispensing Equipment Listing.** Gas dispensing equipment for HPITs shall be listed to CSA HPIT 2 or approved.

N **10.5.3.2.2* Dispensing Equipment for Slow-Fill of HPITs.** Slow-fill gas dispensing equipment for HPITs shall use the fueling protocol of SAE J2601-3, *Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks*, or the "Design by rule for HPIT dispensers" option of CSA HPIT 2 to limit the fueling rate.

N **10.5.3.2.3* Dispensing Equipment for Fast-Fill of HPITs.** Gas dispensing equipment for HPITs shall use the fueling protocol of SAE J2601-3, *Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks.*

10.5.3.3 Outdoor Nonpublic Fueling.

10.5.3.3.1 General. Outdoor, nonpublic fueling installations shall meet the requirements of 10.5.2.2.1.

10.5.3.3.2 Outdoor Nonpublic Gas Dispensing Equipment for Hydrogen-Powered Industrial Trucks (HPITs). Gas dispensing equipment shall be listed or approved for outdoor use in addition to the requirements of 10.5.3.2.1 and either 10.5.3.2.2 or 10.5.3.2.3.

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10.5.3.4* Indoor Nonpublic Fueling.

10.5.3.4.1 General.

10.5.3.4.1.1 Indoor dispensing to nonpublic users shall meet the provisions of 10.5.3.4.

Δ **10.5.3.4.1.2** Fuel dispensing indoors shall be in accordance with 10.5.3.4.

Δ **10.5.3.4.1.3** When used, deflagration venting shall be provided in exterior walls and roofs only.

Table 10.5.2.2.1.4 Separation Distances for Outdoor Gaseous Hydrogen Dispensing Systems

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

Δ **10.5.3.4.1.4** Deflagration vents shall be permitted to consist of any of the following:

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

10.5.3.4.1.5 Where applicable, snow loads shall be included in the calculations of the building deflagration venting system.

Δ **10.5.3.4.1.6** Rooms for dispensing within or attached to other buildings shall comply with all of the following:

(1) Be constructed of noncombustible or limited-combustible materials
(2) Have interior walls or partitions as follows:
    (a) Continuous from floor to ceiling
    (b) Anchored
    (c) Have a fire resistance rating of at least 2 hours
(3) Have at least one wall that is an exterior wall
(4) Be provided with explosion venting in accordance with 10.5.3.4.1.3 and 10.5.3.4.1.4
(5) Have access to the room from outside the primary structure.
(6) Be permitted to have access from within the primary structure where access to the room from outside the primary structure is not possible provided that the access is through a vapor-sealing, self-closing fire door having the appropriate rating for the location where installed.

Δ **10.5.3.4.1.7** Indoor locations shall be provided with exhaust ventilation in accordance with the requirements of Section 6.18.

Δ **10.5.3.4.1.8** Industrial and storage occupancies where storage, gas processing, and compression equipment are located outdoors shall be permitted without the ventilation of 10.5.3.4.1.7 when all of the following conditions are met:

(1) The minimum volume of the room in which a dispenser is installed is not less than 180,000 ft^3 (5000 m^3), and the maximum quantity of fuel to be dispensed per fueling event is limited to 9.2 lb (4.2 kg).
(2) The dispenser is equipped with an automatic shutoff control that conforms to all the following:
    (a) The automatic shutoff control shuts down the source of fuel when the maximum fuel quantity per dispensing event is reached or when the vehicle has been fueled to capacity, whichever is less.
    (b) The shutoff control is tested at installation and annually thereafter.
    (c) Failure of the controller shuts down the dispensing system.
(3) Where multiple dispensers are installed in a room, the minimum room volume is incrementally increased for each additional dispenser.
(4) The height of the ceiling of the room where dispensing occurs is not less than 25 ft (8 m).
(5) The maximum refueling rate is limited to not more than 2.2 lb/min (1 kg/min), and the flow limiting device is installed outdoors.
(6) All potential leak points between the dispenser cabinet and the refueling nozzle are monitored by the dispenser in accordance with 10.5.1.1.1 and 10.5.1.1.2 and activation of the monitoring system shuts down the dispensing system.
(7) Fueling hoses are as follows:
    (a) Limited to a maximum length of 25 ft (7.6 m)
    (b) Protected from mechanical damage
    (c) Protected from abrasion
    (d) Protected from being driven over by a vehicle
(8) Transfer systems are capable of depressurizing the nozzle through the dispenser vent line to facilitate disconnection.

10.5.3.4.1.9 An exhaust ventilation system for a room within or attached to another building shall be separate from any other ventilation system for the other building.

10.5.3.4.1.10 Where installed, a gas detection system shall meet all of the following:

(1) Be equipped to sound a latched alarm and visually indicate when a maximum of one-quarter of the lower flammable limit is reached
(2) Be certified by a qualified engineer with expertise in fire safety and combustible gas detection suitable for hydrogen
(3) Function during system maintenance operations

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Δ **10.5.3.4.1.11** Reactivation of the fueling system shall be by manual restart by trained personnel only.

10.5.3.4.1.12 Buildings and rooms used for compression other than that integral to the bulk storage system, gas processing, and dispensing shall be classified in accordance with 10.4.6.1.

10.5.3.4.1.13 Sources of ignition, other than electrical installations as permitted by 10.4.6.1, shall not be permitted.

Δ **10.5.3.4.1.14 Construction of Indoor Areas.** Indoor-area construction shall comply with all of the following:

(1) Indoor areas shall have walls ceilings, and floors within 15 ft (4.6 m) of the dispenser constructed as fire barriers with a fire resistance rating not less than two hours.
(2) Opening protectives shall be provided for wall openings in accordance with the requirements of the adopted building code.
(3) Through-penetrations and membrane penetrations of fire-resistance-rated construction shall be protected in accordance with the requirements of the adopted building code.
(4) A roof-ceiling assembly without the fire resistive protection required by 10.5.3.4.1.14(1) shall be permitted, provided that every part of the roof-ceiling assembly is 20 ft (6.1 m) or more above any floor immediately below.
(5) Floors without the fire resistive protection of 10.5.3.4.1.14(1) shall be permitted in dispensing areas provided that the levels below are not occupied.

10.5.3.4.2 Indoor Nonpublic Slow-Fill Fueling of Hydrogen-Powered Industrial Trucks (HPITs).

N **10.5.3.4.2.1 Indoor Nonpublic Gas Dispensing Equipment for Hydrogen-Powered Industrial Trucks (HPITs).** Gas dispensing equipment shall be listed or approved for indoor use in addition to the requirements of 10.5.3.2.1.

N **10.5.3.4.2.2 Indoor Nonpublic Slow-Fill Fueling of Hydrogen-Powered Industrial Trucks (HPITs).** Slow-fill fueling indoors shall be permitted in accordance with 10.5.3.2.2, 10.5.3.4.1, and 10.5.3.4.2.

10.5.3.4.3* Indoor Nonpublic Fast-Fill Fueling of Hydrogen-Powered Industrial Trucks (HPITs).

N **10.5.3.4.3.1** Gas dispensing equipment shall be listed or approved for indoor use in addition to the requirements of 10.5.3.2.1.

N **10.5.3.4.3.2** Fast-fill fueling indoors shall be permitted in accordance with 10.5.3.2.3, 10.5.3.4.1, and 10.5.3.4.3.

10.5.3.4.3.3 Fast-fill fueling indoors shall be permitted where storage, gas processing, and compression equipment is located outdoors in compliance with 10.5.2.2.1.

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10.5.3.4.3.4 The electrical area classification for the dispenser shall comply with all of the following:

(1) Be Class I, Division 2, Group B or Class I, Zone 2, Group IIC within 15 ft (4.6 m) of the point of transfer during filling
(2) Extend outward from the point of dispensing in the shape of a cylinder with a radius of 15 ft (4.6 m) that extends from the floor to the ceiling
(3) Not apply to vehicles

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10.5.3.4.3.5 Fire Alarm System. The dispensing area shall be equipped with automatic fire detection that meets all of the following:

(1) Designed per *NFPA 72* to cover the dispensing area
(2) Actuation of an alarm signal on the fire alarm system shuts down the gas flow from the dispenser and stops the flow of gas into the piping system located in the room where dispensing occurs.
(3) Actuation of an alarm signal on the fire alarm system initiates audible notification in the dispensing area.
(4) Manual fire alarm boxes are located as follows:
    (a) Not less than 20 ft (6.1 m) and not more than 100 ft (30.5 m) from the dispensing station
    (b) At the nearest building exit from the dispensing area
(5) The requirements of 10.5.3.4.3.5 do not require a full fire alarm system for the remainder of the building where none is required by the fire code.

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10.5.3.4.3.6 Emergency Shutdown Device (ESD). ESDs shall comply with all of the following:

(1) Be located in the dispensing area not less than 20 ft (6.1 m) and not more than 100 ft (30.5 m) in the path of egress from the dispensing area
(2) Be installed on the dispenser
(3) Shut down the dispenser, stop the flow of gas into the room, and start or continue to run the ventilation system

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Δ **10.5.3.4.3.7 Dispensing Equipment for Indoor Fast-Fill of HPITs.** In addition to the requirements of 10.5.3.2.1, 10.5.3.2.3, and 10.5.3.4.3, the following applies to dispensing equipment for indoor fast-fill of HPITS:

(1) *Protocol.*Gas dispensing equipment for indoor fast-fill of HPITs shall use the fueling protocol of SAE J2601-3, *Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks.*
(2) *Automatic Shutoff Valve.* Hydrogen gas piping used to transport GH_2 between the bulk hydrogen compressed gas storage system and a dispenser at a fast-fill station shall have a valve that closes when either of the following occurs:
    (a) The power supply to the dispenser is shut off.
    (b) Any emergency shutdown device at the refueling station is activated.
(3) *Manual Shutoff Valve.* A quarter-turn manual shutoff valve shall be provided at a fast-fill station upstream of the breakaway device, where it is readily accessible to the person dispensing hydrogen, unless one of the following occurs:
    (a) The self-closing valve referred to in 10.5.3.4.3.7(2) is located immediately upstream of the dispenser.
    (b) The dispenser is equipped with a self-closing valve that closes each time the control arm is turned to the OFF position or when the ESD is activated.
(4) *Shutdown.* Actuation or failure of the following systems shall automatically shut down the gas flow from the dispenser, stop the flow of gas to the room, and start or continue to run the mechanical ventilation system where mechanical ventilation systems are required:
    (a) Gas detection system
    (b) Fire alarm system
    (c) Fire detection system
    (d) ESD
    (e) Sensors or controls used to prevent overtemperature or overpressurization of the on-board fuel container
    (f) Required ventilation systems
    (g) Dispenser leak monitoring system
(5) *Reactivation.* Reactivation of the dispenser and gas flow into the room after system shutdown required by 10.5.3.4.3.7(2) or 10.5.3.4.3.7(4) shall be both of the following:
    (a) By manual restart and shall be
    (b) Conducted by trained personnel
(6)* *Gas Detection System.* The dispenser enclosure or housing shall be equipped with a gas detection system that shall comply with all of the following:
    (a) Actuate when a maximum of 25 percent of the lower flammable limit (LFL) is detected
    (b) Shut down the dispenser, stop the flow of gas into the room, and start or continue to run the ventilation system when mechanical ventilation systems are required
    (c) Sound a local alarm and provide visual indication where a maximum of 25 percent of the lower flammable limit (LFL) is detected
    (d) Remain functional during maintenance operations on the ventilation system.
(7) *Electrical.* Electrical equipment on dispensers shall be in accordance with 10.4.6.1.
(8) *Temperature Limits.* Dispensing systems shall be provided with a means to prevent the on-board fuel system from exceeding prescribed temperature limits during fueling operations.
(9) *Pressure Limits.* Dispensing systems shall be provided with a means to prevent the on-board fuel system from exceeding prescribed pressure limits during fueling operations.
(10) *Ignition Source Control.* The owner/operator shall not allow hot work/open flames within 15 ft (4.6 m) of the refueling location unless the dispenser is shut down, depressurized, and purged with an inert gas.
(11) *Defueling.* If GH_2 is to be removed from the vehicle storage system, GH_2 shall be discharged into a closed transfer system or vented outdoors through a vent pipe

system installed and constructed in accordance with CGA G-5.5, *Hydrogen Vent Systems*

• **10.5.4 Indoor Nonpublic Residential Fueling. (Reserved)**

10.6 Maintenance.

10.6.1 System Maintenance.

10.6.1.1 Hydrogen dispensing systems shall be maintained in accordance with the manufacturers' instructions.

10.6.1.2 The owner shall maintain a maintenance record in accordance with the manufacturers' instructions and 4.3.3.

10.6.1.3 This leak test shall be conducted following any maintenance that involves breaking a connection or, at a minimum, annually.

10.6.1.3.1 Testing shall be conducted in accordance with the manufacturer's instructions.

10.6.1.4 The detection systems shall be maintained and calibrated in accordance with Sections 6.12 and 6.22.

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

10.6.2 Hose Assembly Maintenance.

10.6.2.1 Hoses, nozzles, and breakaways shall be examined monthly or according to the manufacturers' recommendations, whichever period is shorter, and shall be maintained in accordance with the manufacturers' instructions.

Δ **10.6.2.2** Hoses shall be tested for leaks according to the manufacturer's requirements.

N **10.6.2.2.1** Leakage, surface cracks, or structural damage shall be reason for rejection and replacement.

10.6.2.3 Testing shall be carried out using an inert or nonreactive gas as the test medium or where this is not practical, with hydrogen using suitable precautions.

10.6.2.4 The owner shall maintain a record of the results (e.g., date, operator, pressure, leakage values, and visual inspection results)in accordance with 4.3.3.

10.6.3 Maintenance, Modification, and Calibration Documentation.

10.6.3.1* Pressure relief valves protecting ASME pressure vessels shall be repaired, adjusted, and tested in accordance with applicable regulations.

10.6.3.2 Pressure relief valves shall be tested at least every five years.

10.6.3.3 Pressure relief devices designed and installed in accordance with 7.1.5.5.2 shall be examined and tested in accordance with the requirements of the applicable design standard.

(A) Pressure relief valves or reclosing pressure relief devices designed in accordance with CGA S-1.3, *Pressure Relief Device Standards—Part 3—Stationary Storage Containers for Compressed Gases,* shall be examined and tested at least every 5 years or as otherwise provided by the standard.

10.6.3.4 The hydrogen dispensing system operator (e.g., station owner, contractor, station operator, and so on) shall develop a management of change (MOC) system to ensure system modifications are documented and any necessary revisions to system documents are identified and marked completed. System documents can include hazard analysis, site plans, emergency procedures, first responder pre-plans, and so on.

10.6.3.5 Each hydrogen dispensing system shall indicate the last maintenance date and date of the next scheduled maintenance.

10.6.3.6 If testing is required, each hydrogen dispensing system shall indicate the last test date and the date of the next scheduled test.

10.6.3.7 If calibration is required, each hydrogen dispensing system shall indicate expiration date of the current calibration.

(A) The calibration indicator shall be readily visible to the hydrogen dispensing system user and shall not obscure other display functions of the dispenser.

10.6.4* Maintenance personnel shall be trained in leak detection procedures.

10.6.5 Personnel performing maintenance on hydrogen installations shall be trained and wear personal protective equipment as prescribed in the safety data sheets (SDS).

10.7 Compact Hydrogen Fueling System (cHFS).

Δ **10.7.1** Section 10.7 shall apply only to the design, construction, installation, and operation of cHFSs.

N **10.7.1.1** The storage, use, and handling of GH_2 shall also comply with the requirements of Chapter 1 and 4 and Chapters 5 through 7.

N **10.7.1.2** Hydrogen dispensing systems shall comply with the requirements in Sections 10.1 through 10.4, and Section 10.6.

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Δ **10.7.2 General.**

N **10.7.2.1** cHFS shall be listed or approved.

N **10.7.2.2** The installation of cHFSs shall be in accordance with this code and the manufacturer's instructions.

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N **10.7.3 Design.**

N **10.7.3.1** Hydrogen generation, compression, and dispensing equipment shall be integrated into a single enclosure.

N **10.7.3.2** Enclosures shall be designed to allow for access, inspection, service, repair, and replacement of hardware within the enclosure without the need for a person to enter the enclosure with their full body.

N **10.7.3.3*** Enclosures shall not be treated as gas cabinets or gas rooms.

N **10.7.3.4** All cHFSs shall be provided with an ESS per the requirements in 7.1.23.13.

N **10.7.3.5** Hydrogen detection shall be provided in accordance with Section 6.13, Table 7.1.23.9.1, and 10.3.12.

N **10.7.3.6** Detection of hydrogen above 25 percent of the LFL shall result in activation of the ESS.

N **10.7.4 Hydrogen Generation Equipment.**

N **10.7.4.1** Hydrogen generation equipment shall comply with Chapter 13.

N **10.7.4.2** A cHFS shall have a hydrogen generation rate equal to or less than 500 scf/hr (14 Nm^3/hr).

N **10.7.4.3** A cHFS connected to a hydrogen pipeline or other equivalent sources shall not process hydrogen at a rate greater than 500 scf/hr (14 Nm^3/hr).

N **10.7.5 Gaseous Hydrogen Storage.**

N **10.7.5.1** Gaseous hydrogen storage systems internal to the cHFS enclosure shall have a capacity equal to or less than non-bulk storage limits.

N **10.7.5.2** Gaseous hydrogen storage systems with a capacity equal to or less than non-bulk shall be installed per Chapter 6 and Sections 7.1 and 7.2.

N **10.7.5.3** Gaseous hydrogen storage systems shall be equipped with an automatic emergency shutoff valve(s) to isolate all hydrogen storage in response to activation of the ESS.

N **10.7.6 Electrical Equipment.** Electrical systems shall be designed in accordance with the requirements in Section 6.8 and the applicable sections of Sections 7.1, 7.2, 10.3, 10.4, and 10.5.

N **10.7.6.1*** The interior of the cHFS shall be classified in accordance with Article 500 and Article 505 of *NFPA 70* or IEC 60079-10-1, *Classification Of Areas—Explosive Gas Atmospheres*.

N **10.7.6.2** Electrical equipment and wiring within the classified area shall be suitable for the area classification and protected in accordance with Article 500 and Article 501, or Article 505 of *NPFA 70*.

N **10.7.6.3** Electrical equipment and wiring shall be classified in accordance with 7.3.2.3.1.7.1, 10.4.6.1, and 10.7.7.1.

N **10.7.7 Installation.**

N **10.7.7.1*** cHFSs shall be installed in accordance with Sections 7.1 and 7.2 and Chapter 10.

N **10.7.7.2** Vehicle impact protection around the cHFS shall be provided in accordance with Section 4.14.

N **10.7.7.3** A minimum 10 lb (4.54 kg) ABC dry chemical portable fire extinguisher having an agent discharge rate of at least 1 lb/sec (0.45 kg/sec) shall be provided at the dispensing area in approved locations not more than 50 ft (15.2 m) away from the dispensing area.

N **10.7.7.3.1** Fire extinguishers shall be inspected and maintained according to NFPA 10.

N **10.7.7.4** cHFSs shall be installed on foundations with anchoring systems designed to meet the requirements of adopted building codes for the applicable seismic and wind conditions.

N **10.7.7.5** Reductions in separation distances shall be permitted based on the use of fire barrier walls where permitted in accordance with Chapters 6, 7, and 10.

Δ **10.8 Outdoor Nonpublic Home Fueling Appliances (HFA).**

Δ **10.8.1 Application.** Section 10.8 applies to the design, construction, installation, and operation of home fueling appliances.

N **10.8.1.1** HFAs shall be designed in accordance with Sections 10.1 through 10.3.

Δ **10.8.1.2** HFAs able to fuel light-duty hydrogen motor vehicles shall meet the requirements of 10.5.1 and 10.5.2.

Δ **10.8.2 General.**

N **10.8.2.1** Home fueling appliances (HFAs) shall be listed or approved.

N **10.8.2.2** The installation of HFAs shall be in accordance with this code and the manufacturer's instructions.

N **10.8.2.3** HFAs shall not use liquid hydrogen.

N **10.8.2.4** All equipment shall be designed for the pressure, temperature, and service of the system.

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N **10.8.3 Design and Construction.** The appliance shall meet the requirements of Section 10.3.

N **10.8.3.1** Equipment shall be integrated in a single enclosure.

N **10.8.3.2** Enclosures or housings shall be constructed of non-combustible or limited combustible material per Section 4.15.

N **10.8.3.3** Enclosure or housing shall be protected to minimize physical damage and vandalism.

N **10.8.3.4** The enclosure or package shall not be categorized as a gas cabinet or HEE.

N **10.8.3.5** Multiple HFAs shall not be manifolded together on the discharge side unless allowed by the equipment manufacturer and listed or approved for that purpose.

N **10.8.3.6 Piping and Hose.**

N **10.8.3.6.1** The use of a fueling hose in an installation shall be restricted to both of the following:

(1) The fueling hose is limited to a maximum length of 25 ft (7.6 m).
(2) The fueling hose is protected from mechanical damage.

N **10.8.3.6.2** Where the piping system or nozzle assembly includes means to vent hydrogen, the vented hydrogen shall be directed to a safe point of discharge.

N **10.8.3.7 Vent Systems.** Pressure relief vents shall be designed per Section 6.17 and 7.1.16.

N **10.8.3.8** HFAs shall be equipped with an emergency means to isolate all energy sources.

N **10.8.3.8.1** The emergency means to isolate all energy sources shall be located a minimum of 5 ft (1.52 m) from the HFA.

N **10.8.3.9* Buffer Capacity.** Buffer capacity to perform fueling functions shall not exceed 250 scf (7.1 Nm^3).

N **10.8.3.10** HFAs shall be provided with pressure relief devices that protect the vehicle from overpressurization in accordance with 10.3.2.

N **10.8.3.10.1** Pressure relief devices shall discharge or be vented to a safe location approved by the AHJ.

N **10.8.4 Hydrogen Supply.** HFAs shall use on-site hydrogen generation or pipeline hydrogen as the hydrogen supply.

N **10.8.4.1** Hydrogen generation equipment used by HFAs shall comply with Chapter 13.

N **10.8.5 Appliance Access.**

N **10.8.5.1** HFAs shall be located to allow access for inspection, service, repair, and replacement without removing permanent construction, other appliances, or any other piping or ducts not connected to the appliance being inspected, serviced, repaired, or replaced.

N **10.8.5.2** A level working space not less than 30 in (.76m) deep and 30 in (.76m) wide shall be provided for each service access panel of the appliance.

N **10.8.6 Installation.** Installation of HFAs shall conform to the conditions of their listing and labeling, the manufacturer instructions, Section 10.4, and local residential building code.

N **10.8.6.1** In the absence of local residential building code, equipment shall be installed per NFPA 1 or the *International Residential Code*.

N **10.8.6.2** HFAs shall be installed with clearances from unprotected combustible materials in accordance with 7.1.9.1.1 and as required by adopted residential building codes.

N **10.8.6.2.1** In the absence of hydrogen-specific residential building codes, the equipment shall be installed with clearances per the *International Residential Code*.

N **10.8.6.3** HFAs shall be located or installed to prevent hazardous operation conditions in the event of flooding.

N **10.8.6.4** Hydrogen storage, compression, and dispensing equipment shall be installed outdoors.

N **10.8.6.4.1** Hydrogen generation equipment shall be installed in accordance with Chapter 13.

N **10.8.6.5** Spacing between HFAs shall be equal to or greater than 3 ft (1 m) unless allowed by the manufacturer installation instructions and approved.

10.9 Outdoor Nonpublic Mobile Fleet Fueling.

10.9.1 Mobile fueling vehicles, mobile fueling trailers, cargo transport vehicles, and other means of providing vehicle fueling or on-site storage shall be subject to the same requirements as a permanent refueling or storage installation, with the exception of vessel requirements.

N **10.9.1.1** A mobile fueling vehicle or trailer that meets the requirements of 7.1.23 shall be allowed to be considered an HEE.

10.9.2 The dispensing of GH_2 in the open from a mobile fueling vehicle or trailer to a hydrogen vehicle located at a separate fleet fueling area in connection with commercial, industrial, governmental, or manufacturing establishments and intended for fueling vehicles used in connection with their businesses shall be allowed where all of the requirements of 10.9.2(A) through 10.9.2(L) have been met.

(A) The AHJ shall be notified before commencing operations, and permitting sought if required, under Section 10.9.

(B) The mobile fueling vehicle or trailer shall comply with US DOT requirements for the transportation of GH_2.

(C) Mobile fueling vehicles or trailers able to fuel hydrogen vehicles shall meet the applicable requirements of 10.5.1 through 10.5.2.

Δ **(D)** Deliveries or dispensing at night shall be made only in an area considered to be lighted.

(E) Smoking materials, including matches, lighters, and other sources of ignition, including torches, shall not be used within 20 ft (6.1 m) of the dispensing of GH_2 in the open from a mobile fueling vehicle or trailer to a hydrogen vehicle.

Δ **(F)** Portable fire extinguishers shall be selected, installed, inspected, and maintained in accordance with NFPA 10 and NFPA 30A.

(G) Mobile fueling vehicle or trailer brakes shall be set and chock blocks shall be in place.

(H) Persons performing dispensing operations shall be qualified to deliver and dispense GH_2 fuels.

(I) Operators of mobile fueling vehicles or trailers used for mobile fueling operations shall have access on site or be in possession of an emergency communications device to notify the authorities in the event of an emergency.

(J) The mobile fueling vehicles or trailers shall be positioned with respect to vehicles being fueled to prevent traffic from driving over the delivery hose and between the mobile fueling vehicle or trailer vehicle and hydrogen vehicle being fueled.

(K) The dispensing hose shall be properly placed on an approved reel or in an approved compartment before moving the mobile fueling vehicle or trailer.

(L) The transfer area shall meet the requirements of 10.4.1.1.

N **10.10 On-Demand Mobile Fueling.**

N **10.10.1* General.** The requirements in 10.10.2 shall apply to the on-demand mobile fueling of gaseous hydrogen into hydrogen motor vehicles.

N **10.10.1.1** The requirements in Section 10.10 shall not apply to the following:

(1) Outdoor nonpublic mobile fleet fueling at commercial, industrial, governmental, or manufacturing establishments in accordance with Section 10.9
(2) Fueling from portable containers in cases of an emergency

N **10.10.1.2** On-demand mobile fueling shall be allowed only if all of the requirements of 10.10.2 through 10.10.6 have been met.

N **10.10.2 Approvals and Mobile Fueling Locations.**

N **10.10.2.1** On-demand mobile fueling operations shall not be conducted unless approved by the AHJ and the owner or authorized person of the property on which the fueling will occur.

N **10.10.2.1.1** On-demand mobile fueling operations shall occur only at approved locations or geographic areas.

N **10.10.2.2** The distance between the exposure and the point of fueling shall meet the requirements in 7.2.2.3.2.

N **10.10.2.3** On-demand mobile fueling and parking of mobile fueling vehicles and trailers shall be prohibited in buildings, in covered parking structures, on public streets, and on public ways.

N **10.10.2.3.1** On-demand mobile fueling on the uncovered top level of parking structures are allowed where the top level can be accessed directly from the ground level without entering the structure.

N **10.10.3* Safety and Emergency Response Plan. [30A:14.2.3]**

N **10.10.3.1** A safety and emergency response plan shall be submitted for locations where on-demand mobile fueling is authorized.

N **10.10.3.2** The safety and emergency response plan shall be available on each mobile fueling vehicle.

N **10.10.3.3** Where required by the AHJ, a site plan shall be available for each approved location that shall show all existing exposures in 7.3.2.3.1.1.

N **10.10.4 Training.**

N **10.10.4.1*** Mobile fueling vehicle operators shall possess evidence of training on proper fueling procedures and the safety and emergency response plan. [**30A:**14.2.4.1]

N **10.10.4.2** The vehicle operator training shall be approved by the AHJ.

N **10.10.5 Mobile Fueling Vehicles and Equipment.**

N **10.10.5.1*** Mobile fueling vehicles shall comply with all applicable local, state, and federal requirements and shall meet the requirements of Chapters 6, 7, and 10.

N **10.10.5.2** Only storage, compression, and dispensing of gaseous hydrogen from the mobile fueling vehicle or trailer shall be allowed.

N **10.10.5.3** A mobile fueling vehicle or trailer that meets the requirements of 7.1.22 shall be permitted to be considered an HEE.

N **10.10.5.4** Hydrogen motor vehicles shall be fueled only from containers mounted on a mobile fueling vehicle or trailer.

N **10.10.5.5** A mobile fueling vehicle shall not be combined with a mobile fueling trailer.

N **10.10.5.6** Dispensing hose and hose connections shall meet the requirements of 10.3.6.

N **10.10.5.6.1** The hose shall not exceed 15 m (50 ft) in length.

N **10.10.5.7** The vehicle fueling connection for light duty hydrogen motor vehicles shall meet the requirements of 10.3.10.

N **10.10.5.8** A mobile fueling vehicle or trailer shall have emergency shutdown equipment that meets the requirements of 10.3.13.

N **10.10.5.9** Mobile fueling vehicles or trailers shall be provided with at least one portable fire extinguisher selected, installed, inspected, and maintained as required by NFPA 10.

N **10.10.5.9.1** The extinguisher shall be a minimum 10 lb (4.54 kg) ABC dry chemical agent–type and be rated with an agent discharge rate of 1 lb/sec (0.45kg/sec) or greater.

N **10.10.5.10** Signage that meets the requirement of 10.4.8 shall be prominently displayed on the mobile fueling vehicle.

N **10.10.5.11** The mobile fueling vehicles or trailers shall be fitted with 360-degree retroreflective tape or markings in compliance with 49 CFR 571.108, “Lamps, Reflective Devices, and Associated Equipment.”

N **10.10.6 Operations.**

N **10.10.6.1*** Deliveries at night shall be made only in areas deemed adequately lighted by the AHJ.

N **10.10.6.2*** The mobile fueling vehicle’s hazard warning signal and flashers shall be activated during dispensing operations.

N **10.10.6.3** Safety cones or barriers shall be employed to designate a safety perimeter and protect the vehicle fueling area.

N **10.10.6.4** The dispensing of hydrogen shall meet the requirements of Section 10.5.

N **10.10.6.5*** A means for bonding the mobile fueling vehicle or trailer to the hydrogen motor vehicle shall be provided.

N **10.10.6.5.1** Such bonding means shall be employed during fueling operations.

N **10.10.6.6** The hydrogen motor vehicle shall be turned off during fueling.

N **10.10.6.7*** Sources of ignition shall be controlled in accordance with Section 4.12.

N **10.10.6.8** Mobile fueling vehicles shall be constantly attended during fueling operations.

N **10.10.6.9** Mobile fueling vehicles shall not obstruct emergency vehicle access roads.

N **10.10.6.10** Mobile fueling vehicles shall be positioned in a manner so as to preclude traffic from driving over the dispensing hose.

N **10.10.6.10.1** The hose shall be stored in an approved manner prior to moving the mobile fueling vehicle or mobile fueling trailer.

N **10.10.6.11 Inspection Program.**

N **10.10.6.11.1** The mobile fueling operator shall have in place an approved vehicle inspection program to ensure the mobile fueling vehicle and trailer and equipment is kept in good repair.

N **10.10.6.11.2** Mobile fueling vehicles and trailers shall be inspected prior to each shift with records available to the AHJ upon request.

Chapter 11 LH_2 Fueling Facilities

11.1 Scope. This chapter applies to the design, siting, construction, installation, and operation of containers, pressure vessels, pumps, vaporization equipment, and associated equipment used for the storage or dispensing of LH_2 as an engine fuel for vehicles of all types.

11.1.1 Application. This chapter shall apply to the storage, use, and handling of LH_2 in connection with self-propelled vehicles powered by hydrogen.

11.1.1.1 The storage, use, and handling of LH_2 in connection with self-propelled vehicles powered by hydrogen shall also comply with the requirements of Chapters 1 and 4 and the applicable requirements of Chapters 5 through 8.

11.1.1.2 Chapters 4 and 6 through 8 contain fundamental requirements that shall apply to all hydrogen systems.

11.1.1.2.1 The use-specific requirements of this chapter for the storage, use, and handling of LH_2 shall apply.

11.1.1.2.2 Where there is a conflict between a fundamental requirement and a use-specific requirement, the use-specific requirement shall apply.

11.1.1.3 The requirements of Chapter 11 shall be applicable to LH_2 systems only. Where LH_2 is converted to GH_2, those portions of the system utilized for GH_2 shall be in accordance with Chapter 10.

11.2 General.

11.2.1 Risk Assessment.

11.2.1.1 All hydrogen refueling station sites shall have a completed risk assessment prior to dispensing fuel.

11.2.1.2 The risk assessment shall be updated when changes to the process affect operating limits or design specifications that were included as the basis for the original risk assessment.

11.2.2 Security. LH_2 dispensers shall be designed to be tamper resistant.

11.2.3 Operating Instructions. Operating instructions identifying the location and operation of emergency controls shall be posted conspicuously in the facility area.

11.2.4 Lighting. LH_2 dispensing areas transferring LH_2 during the night shall have permanent lighting at points of transfer and operation.

11.2.4.1 The lighting shall be designed to provide illumination of the dispensing apparatus and dispensing area, such that all controls including emergency shutdown devices are visible to the operator.

11.2.5 Personnel Protection. LH_2 refueling sites utilizing or dispensing LH_2 shall provide personnel protection barriers such as walls, cabinets, vacuum-jacketed pipe, and similar barriers to protect the fueling operator and the vehicle being fueled from contact with a release of LH_2. All facility piping other than the refueling line to the vehicle shall be behind the barrier, to deflect any LH_2 that is released due to an equipment malfunction.

Δ **11.2.6 Sources of Ignition.** Smoking materials, including matches and lighters, shall not be used within 25 ft (7.6 m) of areas used for fueling, servicing fuel systems of internal combustion engines, or receiving or dispensing of LH_2.

N **11.2.6.1** The motors of all equipment being fueled shall be shut off during the fueling operation except for emergency generators, pumps, communication devices, and so forth, where continuing operation is essential.

11.2.7 Fire Extinguishers. Portable fire extinguishers shall be selected, installed, inspected, and maintained in accordance with NFPA 10 and 11.2.7.1 through 11.2.7.3 of this code and 9.2.5.2.5 of NFPA 30A. [**30A:**9.2.5.2.1]

N **11.2.7.1** All portable fire extinguishers installed to achieve compliance with this code shall be a minimum of 4.54 kg (10 lb) ABC dry chemical having an agent discharge rate of 0.45 kg/sec (1 lb/sec) or greater. [**30A:**9.2.5.2.2]

N **11.2.7.2** The maximum travel distance from a minimum 9.1 kg (20 lb) ABC dry chemical extinguisher having an agent discharge rate of 0.45 kg/sec (1 lb/sec) or greater shall be permitted to be 30.5 m (100 ft). [**30A:**9.2.5.2.3]

N **11.2.7.3 New Fire Extinguishers.** Newly installed fire extinguishers, including replacements or exchanges, shall meet the requirements of 9.2.5.2 of NFPA 30A. [**30A:**9.2.5.2.4]

11.2.8 Piping, Tubing, and Fittings.

11.2.8.1 Pipe, tubing, and fittings shall be designed for hydrogen service and for maximum pressures and minimum and maximum temperatures.

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

11.2.8.1.2 Pipe, valves, and fittings fabricated from cast, ductile, malleable, and high-silicon iron or carbon steel shall not be used.

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

11.2.8.3 Hydrogen gas piping shall be fabricated and tested in accordance with ASME B31, *Code for Pressure Piping*.

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

11.2.8.5 Installation of Piping and Hoses on Dispensing Systems.

11.2.8.5.1 Piping and hose shall be protected from the effects of expansion, contraction, jarring, vibration, and settling.

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

11.2.8.5.3 Joints or connections shall be located in an accessible location.

11.2.8.5.4 The number of joints shall be minimized and placed in a location considering hazards to personnel safety.

11.2.8.5.5 Hydrogen shall be vented in accordance with Section 6.17.

11.2.8.6 Static protection shall be required where LH_2 cargo transport vehicles are unloaded, except where cargo transport vehicles or marine equipment are loaded or unloaded by conductive hose, flexible metallic tubing, or pipe connections through or from tight (top or bottom) outlets where both halves of metallic couplings are electrically bonded.

11.2.9 Piping Systems and Components. Piping shall be in accordance with 8.1.4.

11.2.10 Pressure Relief Devices — Vaporizers. The discharge from pressure relief devices serving the vaporizer system shall be connected to a vent pipe system.

11.2.11 Instrumentation.

11.2.11.1* Emergency Shutdown Device (ESD). All ESDs shall be of a type requiring that they be manually reset.

11.2.11.2* Pressure Instrumentation. Pressure monitoring systems or indicating devices shall be capable of reading at least

1.2 times the system maximum allowable working pressure (MAWP).

11.2.12 Electrical Equipment.

11.2.12.1 Electrical equipment and wiring shall be as specified by, and shall be installed in accordance with, *NFPA 70* and shall meet the requirements of Class I, Group B, Division or Class I, Group IIC, Zone as specified in Table 11.2.12.1.

11.2.12.2 Each interface between a flammable fluid system and an electrical conduit or wiring system, including process instrumentation connections, integral valve operators, foundation heating coils, canned pumps, and blowers, shall be sealed or isolated to prevent the passage of flammable fluids or gases to another portion of the electrical installation.

11.2.12.3 Each seal, barrier, or other means used to comply with 11.2.12.4 shall be designed to prevent the passage of flammable fluids or gases through the conduit, stranded conductors, and cables.

11.2.12.4 A primary seal shall be provided between the flammable fluid system and the electrical conduit wiring system. If the failure of the primary seal would allow the passage of flammable fluids to another portion of the conduit or wiring system, an additional approved seal, barrier, or other means shall be provided to prevent the passage of the flammable fluid beyond the additional device or means in the event that the primary seal fails.

11.2.12.5 Each primary seal shall be designed to withstand the maximum allowable service conditions to which it is expected to be exposed.

11.2.12.6 Each additional seal or barrier and interconnecting enclosure shall meet the pressure and temperature requirements of the condition to which it could be exposed in the event of failure of the primary seal, unless other approved means are provided to accomplish this purpose.

11.2.12.7 Unless specifically designed and approved for the purpose, the seals specified in 11.2.12.4 through 11.2.12.8 are not intended to replace the conduit seals required by 501.15(A) through 501.15(D) of *NFPA 70*.

11.2.12.8 Where primary seals are installed, drains, vents, or other devices shall be provided for monitoring purposes to detect flammable fluids and leakage.

11.2.13 LH_2 to GH_2 Systems. In addition to the emergency shutdown systems described in Section 11.3, the emergency shutdown system also shall shut off the liquid supply and power to the LH_2 transfer equipment necessary for producing GH_2 from LH_2.

11.2.14 Maintenance.

11.2.14.1 Maintenance shall be performed based on the OEM component manufacturer's recommendations and not less than every 6 months. Maintenance records shall be made available upon demand.

11.2.14.1.1 The refueling site shall have a written maintenance program or process safety analysis program in place. A written record of the required maintenance shall be maintained by the operator.

11.2.14.1.2 Records of required maintenance shall be provided to the authority having jurisdiction (AHJ) upon request.

11.2.14.1.3 Fueling facilities shall be free within 25 ft (7.6 m) from rubbish, debris, weeds, and other material that present a fire hazard.

11.2.14.1.4 Grass areas on the LH_2 fueling facility grounds shall be maintained in a manner that does not present a fire hazard.

11.2.14.2 A preventive maintenance program shall be in place and shall include a schedule of written procedures for test and inspection of facility systems and equipment.

11.2.14.3 Each component in service, including its support system, shall be maintained in a condition that is compatible with its operation or safety purpose by repair, replacement, or other means.

Δ Table 11.2.12.1 LH_2 Fueling Facility Electrical Area Classification

Part	Location	Class I, Group B, Division or Class I, Group IIC, Zone[a]	Extent of Classified Area[b]
A	Pits, trenches, or sumps located in or adjacent to Division 1 or 2 areas	1	Entire pit, trench, or sump
B	Discharge from relief valves, drains	1 2	Within 5 ft (1.5 m) from point of discharge Beyond 5 ft (1.5 m) but within 25 ft (7.6 m) in all directions from point of discharge
C	Vehicle/cargo transfer area Outdoors in open air at or above grade Points where connections to the hydrogen system are regularly made and disconnected[c]	 1 2	 Within 3 ft (1 m) of connection Between 3 ft (1 m) and 25 ft (7.6 m) of connection

Notes:
[a]See Article 100 of *NFPA 70* for definitions of classes, groups, divisions, Class I zones, and associated gas groups.
[b]The classified area not to extend beyond an unpierced wall, roof, or solid vaportight partition.
[c]Indoor fueling with LH_2 is not allowed. *(See 11.3.2.)*
[d]Ventilation is considered adequate when provided in accordance with the provisions of this code.

11.2.14.4 If a safety device is taken out of service for maintenance, the component being served by the device shall be taken out of service unless the same safety function is provided by an alternative means.

11.2.14.5 If the inadvertent operation of a component taken out of service could cause a hazardous condition, the system shall be shut down until the component is replaced.

11.2.14.5.1 All maintenance and servicing shall be done in accordance with 29 CFR 1910 for energy control.

11.2.14.6 Safety, gas detection, and fire protection equipment shall be tested or inspected at intervals not to exceed 6 months.

11.2.14.7 Maintenance activities on fire control equipment shall be scheduled so that a minimum of equipment is taken out of service at any one time and fire prevention safety is not compromised.

11.2.14.8 Hose Assemblies.

11.2.14.8.1 Hoses, nozzles, and breakaways shall be examined according to the manufacturers' recommendations or at least monthly and shall be maintained in accordance with the manufacturers' instructions.

11.2.14.8.2 Hose shall be tested for leaks per manufacturer's requirements, and any unsafe leakage or surface cracks shall be reason for rejection and replacement.

11.2.14.8.3 Testing shall be carried out using an inert gas as the test medium.

(A) Where this is not possible, the hose assembly shall be completely isolated from the system and tested with the flammable gas normally within the system, or with air and then purged with an inert gas.

(B) In the case of hydrogen, testing shall be carried out with helium or a helium inert gas blend (i.e., 10 percent by volume [helium] or greater) as the test gas or, if this is not possible, with hydrogen using precautions.

11.2.14.8.4 When not in use, hose shall be secured to protect it from damage.

11.2.14.8.5 Listed or approved hose assemblies shall be used to dispense fuel. Hose length at automotive motor fuel dispensing facilities shall not exceed 18 ft (5.5 m). [**30A:**12.2.4]

11.3 Dispensing.

11.3.1 General.

11.3.1.1 System Component Qualifications. The following systems and system components shall be listed or approved:

(1) Hose and hose connections
(2) Vehicle fueling connections (nozzle)
(3) Electrical equipment used with LH_2 systems
(4) Gas detection equipment and alarms
(5) Hydrogen dispensers
(6) Pressure switches
(7) Flow meters

11.3.1.2 Fail-Safe Design. LH_2 fueling facilities shall be designed so that, in the event of a power or equipment failure, the system shall go into a fail-safe condition.

11.3.1.3 Design and Construction of Containers, Cylinders, and Tanks.

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

11.3.1.3.2 Containers, cylinders, and tanks shall be designed for LH_2 service and shall be permanently marked LH_2 by the manufacturer.

11.3.1.3.3* Containers, cylinders, and tanks manufactured prior to the effective date of this code shall be allowed to be used in LH_2 service if designated for LH_2 service by the container manufacturer or if approved by the AHJ.

11.3.1.3.4 ASME Containers, Cylinders, and Tanks.

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

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

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

11.3.1.4 Dispensing Device Protection. The dispensing device shall be protected from vehicle collision damage.

11.3.1.5 Pressure Relief Devices.

11.3.1.5.1 Pressure relief valves for LH_2 service shall not be fitted with lifting devices.

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

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

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

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

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

11.3.1.5.2 Installation of Pressure Relief Devices on Dispensing Systems.

11.3.1.5.2.1 Pressure relief devices shall be in accordance with 7.1.5.5.

11.3.1.5.2.2 Pressure relief devices shall be so arranged that they discharge in accordance with Section 6.17 and 7.1.5.5.5.

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

11.3.1.5.2.4 The set pressure of the overpressure protection device for the dispensing system shall not exceed 140 percent of the service pressure of the fueling nozzle it supplies.

Δ **11.3.1.5.3** Pressure relief valves shall be installed where liquid or cold gas can be trapped between shutoff valves in the piping system.

11.3.1.5.4* The discharge from pressure relief devices serving the fueling system shall be connected to a vent system in accordance with Section 6.17.

11.3.1.6 Hose and Hose Connections.

11.3.1.6.1 Hose shall be constructed of or lined with materials that are resistant to corrosion and exposure to LH_2.

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

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

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

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

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

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

11.3.1.6.5.2 The individual component and manufacturer's identification shall be retained in each section and throughout the system.

11.3.1.6.5.3 The hose shall be approved or listed for hydrogen service.

11.3.1.7 Valves.

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

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

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

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

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

11.3.1.7.3.1 Container valves incorporating integral pressure relief devices complying with Section 8.1.4 shall not require additional marking.

11.3.1.8 Emergency Shutdown System. An emergency shutdown system (ESD) shall be provided that includes a shut-off valve, which shall be provided within 10 ft (3.1 m) of the dispenser, for stopping liquid supply and shutting down transfer equipment. An actuator for the valve, distinctly marked for easy recognition with a permanently affixed, legible sign, shall be provided with a shutdown control point located near the dispenser and another shutdown control point located at a safe, remote location.

11.3.1.9 Maximum Delivery Pressure. The maximum delivery pressure at the vehicle tank inlet shall not exceed the maximum allowable pressure of the vehicle fuel tanks.

11.3.1.10 System Testing.

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

11.3.1.10.2 This leak test shall be in addition to the ASME B31, *Code for Pressure Piping,* testing required by 11.2.8.3.

11.3.1.10.3 The assembly shall be leak tested using hydrogen or helium.

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

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

11.3.1.10.6 At fueling stations, gas used for calibration and testing shall be vented to a vent pipe in accordance with Section 6.17.

11.3.1.11 Shutoff Valve and Breakaway Device. Hose and arms shall be equipped with a shut-off valve at the fuel end and a breakaway device to minimize release of liquid and vapor in the event that a vehicle pulls away while the hose remains connected. Such a device shall be installed and maintained in accordance with the manufacturer's instructions.

11.3.1.12 Emergency Shutoff Valve. Where a hose or arm of nominal 3 in. (76 mm) diameter or larger is used for liquid transfer or where one of nominal 4 in. (100 mm) diameter or larger is used for vapor transfer, an emergency shutoff valve shall be installed in the piping of the transfer system within 10 ft (3.0 m) from the nearest end of the hose or arm.

11.3.1.12.1 Where the flow is away from the hose, a check valve shall be permitted to be used as the shut-off valve.

11.3.1.12.2 Where either a liquid or vapor line has two or more legs, an emergency shut-off valve shall be installed either in each leg or in the feed line before the legs.

11.3.1.13 Bleed or Vent Connections. Bleed or vent connections shall be provided so that loading arms and hose can be drained and depressurized prior to disconnection, if necessary, and lead to a safe point of discharge.

11.3.1.14 Fueling Connections. A fueling connector and mating vehicle receptacle shall be used for reliable, safe, and secure transfer of LH_2 or gas vapor to or from the vehicle with minimal leakage.

11.3.1.14.1 The fueling connector either shall be equipped with an interlock device that prevents release while the line is open or shall have self-closing ends that automatically close upon disconnection.

11.3.1.15 Transfer of LH_2. The transfer of LH_2 into vehicular onboard fuel supply containers shall be performed in accordance with the manufacturer's instructions, which shall be posted at the dispensing device.

11.3.1.16 Signs.

11.3.1.16.1 A warning sign with the following words shall be posted at dispensing stations and compressor or pumping areas:

STOP MOTOR, NO SMOKING, NO CELL PHONES, FLAMMABLE GAS

11.3.1.16.1.1 The following wording shall be added to the warning sign:

HYDROGEN DOES NOT HAVE A DISTINCTIVE ODOR AND IS EXTREMELY COLD

11.3.1.16.1.2 The location of signs shall be determined by local conditions.

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

11.3.1.17 Dispenser Installations Beneath Canopies. Where LH_2 dispensers are installed beneath a canopy or enclosure, either the canopy or enclosure shall be designed to prevent accumulation or entrapment of ignitible vapors or all electrical equipment installed beneath the canopy or enclosure shall be suitable for Class I, Division 2 hazardous (classified) locations.

11.3.1.18 Dispenser Connections. A means shall be provided that connects to the dispenser supply piping and that prevents flow in the event that the dispenser is displaced from its mounting. [**30A:**12.2.2]

11.3.1.19 Dispensing Devices. Dispensing devices for LH_2 shall be listed or approved.

Δ **11.3.2 Dispensing to the Public.** Indoor LH_2 fueling shall be prohibited.

11.3.2.1 Outdoors. A facility in which LH_2 pumping, gas processing, hydrogen generation equipment, storage, and dispensing equipment are sheltered by an enclosure that is constructed as weather protection in accordance with Section 6.7 with a roof designed for ventilation and dispersal of escaped gas shall be considered to be located outdoors.

11.3.3 Outdoor Public Fueling.

11.3.3.1 General.

11.3.3.1.1 Dispensing devices, including points of transfer from dispensers installed at outdoor motor fuel dispensing stations, shall be located as follows:

(1) Not less than 25 ft (7.6 m) from the nearest important building not associated with the LH_2 facility
(2) Not less than 25 ft (7.6 m) from the line of adjoining property that can be built upon
(3) Not less than 25 ft (7.6 m) from fixed sources of ignition
(4) Such that all parts of the vehicle being served will be on the premises of the service station
(5) Such that the nozzle, when the hose is fully extended, will not reach within 10 ft (3 m) of building openings, as adopted in 10.5.3.4.1.5

11.3.3.1.1.1 Points of transfer shall include the maximum length of the refueling hose serving the dispenser.

11.3.3.1.2 Dispensing devices shall be mounted on a concrete island or shall otherwise be protected against collision damage by means acceptable to the AHJ. Dispensing devices shall be securely bolted in place. [-] Dispensing devices shall also be located in a position where they cannot be struck by a vehicle that is out of control descending a ramp or other slope. Dispensing devices shall be installed in accordance with the manufacturer's instructions. [**30A:**6.3.4]

11.3.3.1.3 Motor vehicle traffic patterns at motor fuel dispensing facilities shall be designed to inhibit movement of vehicles that are not being fueled from passing through the dispensing area. [**30A:**6.3.7]

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

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

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

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

11.3.3.1.5 A vehicle fueling pad shall be provided in the area where vehicles are to be refueled.

11.3.3.1.5.1 The pad shall be constructed with a length and width to accommodate the types of vehicles to be fueled and to provide a surface under the fueling hose.

11.3.3.1.5.2 The vehicle fueling pad shall be of concrete construction.

(A) Combustible materials, including asphalt, shall not be used for the construction of or surfacing of the fueling pad. *(See 8.3.2.3.1.5.)*

11.3.3.2 Outdoor Public Full-Service Attended Fueling.

11.3.3.2.1 Operating Requirements for Full-Service Motor Fuel Dispensing Facilities. Each motor fuel dispensing facility shall have an attendant or supervisor on duty whenever the facility is open for business. The attendant or supervisor shall dispense liquids into fuel tanks or into containers, except as covered in 11.3.3.3 and 11.3.3.4. [**30A:**9.3]

11.3.3.3 Outdoor Public Attended-Self Service Fueling.

11.3.3.3.1 There shall be at least one attendant on duty while the self-service facility is open for business. The attendant's primary function shall be to supervise, observe, and control the dispensing of motor fuels. [**30A:**9.4.2]

Δ **11.3.3.3.2** The responsibility of the attendant shall be as follows:

(1) Control sources of ignition

(2) Immediately activate emergency controls and notify the fire department of any fire or other emergency

11.3.3.3.3 The attendant or supervisor on duty shall be mentally and physically capable of performing the functions and assuming the responsibility prescribed in 11.3.3.3. [**30A:** 9.4.3.1]

11.3.3.3.4 Operating instructions shall be conspicuously posted in the dispensing area. [**30A:**9.4.4]

11.3.3.4 Outdoor Public Unattended Self-Service Fueling.

11.3.3.4.1 Unattended self-service facilities shall be permitted, where approved by the AHJ. [**30A:**9.5.1]

11.3.3.4.2 At unattended self-serve motor fuel dispensing facilities, coin–and currency–type devices shall be permitted only with the approval of the AHJ. [**30A:**6.3.8]

11.3.3.4.3 Operating instructions shall be conspicuously posted in the dispensing area. The instructions shall include location of emergency controls and a requirement that the user stay outside of his/her vehicle and in view of the fueling nozzle during dispensing. [**30A:**9.5.2]

11.3.3.4.4 In addition to the warning signs specified in 11.3.1.16.1, emergency instructions shall be conspicuously posted in the dispenser area. The instructions shall incorporate the following or equivalent wording:

Emergency Instructions

In case of fire or spill

(1) Use emergency stop button.

(2) Report accident by calling (*specify local fire number*).
Report location.

[**30A:**9.5.3]

11.3.3.4.5 A telephone or other approved, clearly identified means to notify the fire department shall be provided on the site in a location approved by the AHJ. [**30A:**9.5.5]

11.3.3.4.6* Additional fire protection shall be provided where required by the AHJ. [**30A:**9.5.6]

Δ **11.3.3.4.7*** Fuel dispensing systems shall be provided with one or more clearly identified emergency shutoff devices or electrical disconnects. Such devices or disconnects shall be installed in approved locations but not less than 20 ft (6 m) or more than 100 ft (30 m) from the fuel dispensing devices that they serve. Emergency shutoff devices or electrical disconnects shall disconnect power to all dispensing devices; to all remote pumps serving the dispensing devices; to all associated power, control, and signal circuits; and to all other electrical equipment in the hazardous (classified) locations surrounding the fuel dispensing devices. When more than one emergency shutoff device or electrical disconnect is provided, all devices shall be interconnected. Resetting from an emergency shutoff condition shall require manual intervention and the manner of resetting shall be approved by the authority having jurisdiction. The emergency shutoff device shall disconnect simultaneously from the source of supply, all conductors of the circuits, including the grounded conductor, if any. Equipment grounding conductors shall remain connected. [**70:**514.11(A)]

*Exception: Intrinsically safe electrical equipment need not meet this requirement. [**70:**514.11(A)]*

11.3.4 Outdoor Nonpublic Fueling.

11.3.4.1 General. (Reserved)

11.3.4.2 Outdoor Nonpublic Full-Service Fueling. (Reserved)

11.3.4.3 Outdoor Nonpublic Attended Self-Service Fueling. (Reserved)

11.3.4.4 Outdoor Nonpublic Unattended Self-Service Fueling. (Reserved)

11.3.4.5 Outdoor Nonpublic Residential Fueling. (Reserved)

11.3.4.6 Refueling from Transport Vehicles. Mobile refueling vehicles, temporary trailers (with or without tractors), and other means of providing vehicle refueling or onsite storage shall be subject to the same requirements as a permanent refueling or storage installation.

11.3.4.6.1 The dispensing of LH_2 in the open from a transport vehicle to a motor vehicle located at a separate fleet fueling area in connection with commercial, industrial, governmental, or manufacturing establishments and intended for fueling vehicles used in connection with their businesses shall be allowed if all of the requirements of 11.3.4.6.1 through 11.3.4.6.9 have been met.

11.3.4.6.2 The AHJ shall be notified before commencing operations, and permitting sought if required, under 11.3.4.6.1.

11.3.4.6.3 The transport vehicle shall comply with U.S. DOT requirements for the transportation of LH_2.

11.3.4.6.4 Smoking materials, including matches, lighters, and other sources of ignition, including torches, shall not be used within 25 ft (7.6 m) of the dispensing of LH_2 in the open from a transport vehicle to a motor vehicle.

11.3.4.6.5 Each area where dispensing of LH_2 in the open from a transport vehicle to a motor vehicle shall be provided with one or more listed fire extinguishers that have a minimum capability of 40-B:C.

11.3.4.6.5.1 The fire extinguishers shall be within the dispensing operation.

11.3.4.6.5.2 Fire extinguishers shall be inspected and maintained under NFPA 10.

11.3.4.6.6 Transport vehicle brakes shall be set, and chock blocks shall be in place.

11.3.4.6.7 Persons performing dispensing operations shall be qualified to deliver and dispense LH_2 fuels. Operators of transport vehicles used for mobile fueling operations shall have access on site or be in possession of an emergency communications device to notify the authorities in the event of an emergency.

11.3.4.6.8 The transport vehicles shall be positioned with respect to vehicles being fueled to prevent traffic from driving over the delivery hose and between the transport vehicle and the motor vehicle being fueled. The dispensing hose shall be properly placed on an approved reel or in an approved compartment before the transport vehicle is moved.

11.3.4.6.9 The transfer area shall meet the requirements of 10.4.1.1.

11.3.4.7 Refueling from Vehicle-Mounted Tank at Commercial and Industrial Facilities. Dispensing from vehicle-mounted tanks located at commercial and industrial facilities used in connection with their business shall be allowed where the following conditions are met:

(1) An inspection of the premises and operations shall be made and approved by the AHJ.
(2) All dispensing of LH_2, including mobile refueling, into vehicle onboard fuel systems shall be compliant with the requirements of a permanent LH_2 refueling installation at the point of dispensing fuel
(3) The vehicle-mounted container shall comply with the requirements of the DOT.
(4) The dispensing hose shall not exceed 50 ft (15 m) in length.
(5) Nighttime deliveries shall be made only in lighted areas.
(6) Mobile refueling units shall meet the site requirements of a permanent refueling station at the point of dispensing and if left on site.

11.4 Storage.

11.4.1 General. The storage of LH_2 in bulk and non-bulk LH_2 installations shall be in accordance with the applicable requirements of Chapters 6 and 8.

Δ **11.4.2 Indoor Storage.** Indoor storage of LH_2 to be used for vehicle fueling purposes shall be prohibited.

11.4.3 Outdoor Storage.

11.4.3.1 Ullage Space. All cryogenic containers, vessels, and tanks shall provide and maintain ullage space to prevent overfilling of the vessel.

11.4.3.2 Stationary Storage Tanks.

11.4.3.2.1 Points of transfer shall be located not less than 25 ft (7.6 m) from the nearest important building not associated with the LH_2 facility, from the line of adjoining property that can be built upon, or from fixed sources of ignition.

11.4.3.2.2 Points of transfer shall include the maximum length of the off-loading LH_2 bulk supply tanker, and off-loading hoses. *(See also 8.3.4.5.)*

11.4.4 Underground Storage. (Reserved)

N **11.4.5 Cargo Transport Unloading.**

N **11.4.5.1** Cargo transport unloading shall comply with 7.3.4.2 and 8.3.4.5.

N **11.4.5.2** The delivery vehicle shall be located so that all parts of the vehicle are on the premises when delivery is made. [**30A:** 9.2.2.4]

N **11.4.5.3** The hydrogen site shall be designed with a traffic pattern for the cargo transport vehicle.

Chapter 12 Hydrogen Fuel Cell Power Systems

12.1 Scope. This chapter shall apply to the design, construction, and installation of fuel cell power systems.

12.1.1 Application. The requirements of this chapter shall apply to stationary, portable, hydrogen vehicle, and micro–fuel cell power generation systems.

12.1.1.1 The storage, use, and handling of hydrogen in any quantity shall also comply with the requirements of Chapters 1 and 4 and the applicable requirements of Chapters 5 through 8.

12.1.1.2 Chapters 4 and 6 through 8 contain fundamental requirements that shall apply to all hydrogen systems.

12.1.1.2.1 The use-specific requirements of this chapter for hydrogen fuel cell power systems shall apply.

12.1.1.2.2 Where there is a conflict between a fundamental requirement and a use-specific requirement, the use-specific requirement shall apply.

12.2* General.

12.2.1* Listed and Approved Equipment.

12.2.1.1 Listed and approved hydrogen fuel cell equipment shall be installed in accordance with the listing requirements and manufacturers' instructions.

12.2.1.2 Listed and approved hydrogen fuel cell equipment shall not be required to meet the requirements of Chapter 7.

N **12.2.1.3** Fuel processing equipment integral to listed fuel cell power system appliances installed in accordance with NFPA 853 shall not be required to meet the requirements of Chapter 13.

12.3 Specific Requirements.

12.3.1 Stationary Fuel Cells.

Δ **12.3.1.1 General.**

Δ **12.3.1.1.1 Prepackaged, Self-Contained, Fuel Cell Power Systems.**

Δ **12.3.1.1.1.1** Prepackaged, self-contained fuel cell power systems shall be designed, tested, and listed in accordance with ANSI/CSA FC1, *Fuel cell technologies — Part 3-100: Stationary fuel cell power systems — Safety*. [**853:**4.2]

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Δ **12.3.1.1.2 Pre-Engineered and Matched Modular Fuel Cell Power Systems.** Pre-engineered fuel cell power systems and matched modular components (which are assembled on site) shall be designed, tested, and listed in accordance with ANSI/CSA FC1, *Fuel cell technologies — Part 3-100: Stationary fuel cell power systems — Safety.* [**853:**4.3]

Δ **12.3.1.1.2.1** Proprietary equipment or materials for which no generally recognized codes or standards exist shall be evaluated based on data from operational experience in the same or comparable service or test records covering the performance of the equipment or materials.

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Δ **12.3.1.1.3 Engineered and Field-Constructed Fuel Cell Power Systems.**

12.3.1.1.3.1 Documentation for engineered and field-constructed fuel cell power systems shall be provided. [**853:**4.4.1]

12.3.1.1.3.2 Documentation shall include a fire risk evaluation prepared by a registered engineer or third party acceptable to the AHJ. [**853:**4.4.2]

12.3.1.2 Siting and Installation. Stationary fuel cell power system(s) and associated equipment, components, and controls shall be sited and installed in accordance with NFPA 853.

12.3.2 Portable Fuel Cells.

Δ **12.3.2.1* General.** Prepackaged, self-contained, portable fuel cell power systems shall be designed, tested, and listed in accordance with ANSI/CSA America FC 3, *Portable Fuel Cell Power Systems.*

12.3.2.2 Indoor Portable Fuel Cells. (Reserved)

12.3.2.3 Outdoor Portable Fuel Cells. (Reserved)

12.3.3 Micro–Fuel Cell Power Systems.

12.3.3.1 Listed or Approved Systems. Prepackaged, self-contained micro–fuel cell power systems shall be listed or approved for the application.

12.3.3.2 Indoor Micro Fuel Cells. (Reserved)

12.3.3.3 Outdoor Micro Fuel Cells. (Reserved)

12.3.4* Hydrogen Vehicle Fuel Cell–Powered Systems.

12.3.4.1 The temporary use of a dwelling unit owner's or an occupant's fuel cell–powered system integrated into a hydrogen vehicle to provide power to one- and two-family dwellings and townhouse units while parked outside or in an attached or detached garage shall comply with the vehicle manufacturer's instructions and *NFPA 70*.

N **12.3.4.2** The temporary use of the dwelling unit owner's or occupant's fuel cell–powered system integrated into a hydrogen vehicle to power the dwelling while parked in an attached or detached garage or outside shall not exceed 30 days.

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12.4 Storage.

12.4.1 Requirements for Hydrogen Storage Systems Serving Portable Fuel Cell Power Systems.

12.4.1.1 General.

12.4.1.1.1 Fuel Cell Cartridges.

12.4.1.1.1.1 Fuel cell cartridges shall be listed or approved for the application.

12.4.1.1.1.2 Fuel cell cartridge refilling equipment shall be listed or approved for the application, and refill shall be in accordance with the manufacturer's published instructions and the listing.

12.4.1.2 Indoor Storage. (Reserved)

12.4.1.3 Outdoor Storage. (Reserved)

12.4.2 Requirements for Hydrogen Storage Systems Serving Micro–Fuel Cell Power Systems.

12.4.2.1 General.

12.4.2.1.1 Fuel Cell Cartridges.

12.4.2.1.1.1 Fuel cell cartridges shall be listed or approved for the application.

12.4.2.1.1.2 Fuel cell cartridge refilling equipment shall be listed or approved for the application, and refill shall be in accordance with the manufacturer's published instructions and the listing.

12.4.2.2 Indoor Storage. (Reserved)

12.4.2.3 Outdoor Storage. (Reserved)

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Chapter 13 Hydrogen Generation Systems

13.1 Scope. This chapter shall apply to equipment used to generate hydrogen.

13.1.1 Application.

13.1.1.1 This chapter shall apply to permanently installed hydrogen generation systems with rated capacity to generate greater than 1.3 oz/hr (36 g/hr) but less than 220 lb/hr (100 kg/hr).

13.1.1.1.1 Systems that generate hydrogen in excess of the quantity indicated in 13.1.1.1 shall be constructed, installed, and operated in accordance with nationally recognized standards.

13.1.1.2 The storage, use, and handling of GH_2 or LH_2 shall also comply with the requirements of Chapters 1 and 4 and the applicable requirements of Chapters 5 through 8.

13.1.1.3 Chapters 4 and 6 through 8 contain fundamental requirements that shall apply to all hydrogen systems.

13.1.1.3.1 The use-specific requirements of this chapter for hydrogen generation systems shall apply.

13.1.1.3.2 Where there is a conflict between a fundamental requirement and a use-specific requirement, the use-specific requirement shall apply.

13.2 General.

13.2.1* Listed or Approved Equipment. Listed or approved hydrogen-generating equipment shall be installed in accordance with the listing or approval requirements and manufacturers' instructions.

N **13.2.1.1** Listed or approved hydrogen generators shall not be required to meet the requirements of Chapter 7 except as noted in this chapter.

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Δ **13.2.2 Siting.** Hydrogen generation system(s) shall be installed in accordance with the manufacturer's instructions.

N **13.2.2.1** All safety-related controls for the installation of the hydrogen generator shall comply with NFPA 79.

13.2.3 Indoor Installations.

Δ **13.2.3.1** In addition to the requirements of 13.2.2, indoor hydrogen generation system(s) shall be installed in accordance with 13.2.3.1.1 through 13.2.3.1.3.

N **13.2.3.1.1** Indoor, non-bulk, hydrogen generation systems equipment with internal hydrogen volumes exceeding the maximum allowable quantity (MAQ) defined in 6.4.1.1 shall be separated from exposures in accordance with the lesser of 7.3.2.2 or 7.3.2.3. *(See 3.3.169, Non-Bulk Hydrogen Compressed Gas.)*

N **13.2.3.1.2** Indoor hydrogen generation system equipment with internal hydrogen volumes exceeding the limits for non-bulk shall be installed in accordance with 7.3.2.2. *(See 3.3.169, Non-Bulk Hydrogen Compressed Gas.)*

N **13.2.3.1.3** A hydrogen generation system and associated hydrogen storage with internal volumes less than or equal to the MAQ defined in 6.4.1.1 shall be permitted without fire-rated separation.

Δ **13.2.4 Outdoor Installations.**

Δ **13.2.4.1** In addition to the requirements of 13.2.2, outdoor hydrogen generation system(s) shall be installed in accordance with 13.2.4.1.1 through 13.2.4.1.4:

N **13.2.4.1.1** The system shall be anchored, located, and protected so that the system and equipment will not be affected by rain, snow, ice, wind, and lightning.

N **13.2.4.1.2** Outdoor, non-bulk hydrogen generation system equipment with internal hydrogen volumes exceeding the MAQ defined in 6.4.1.1 shall be separated from exposures in accordance with the lesser of 7.2.2.3.2 or 7.3.2.3. *(See 3.3.169, Non-Bulk Hydrogen Compressed Gas.)*

N **13.2.4.1.3** Outdoor hydrogen generation system equipment with internal hydrogen volumes exceeding the limits for non-bulk systems shall be separated from exposures in accordance with 7.3.2.3. *(See 3.3.169, Non-Bulk Hydrogen Compressed Gas.)*

N **13.2.4.1.4** A hydrogen generation system and associated hydrogen storage with internal volumes less than or equal to the MAQ defined in 6.4.1.1 shall be permitted without fire-rated separation.

13.2.4.2 For outdoor or rooftop installations, a hydrogen generation system and related components shall be designed and constructed for outdoor installation.

13.2.4.3 The area classification around hydrogen generation system outlets that exhaust flammable gas in concentrations greater than 25 percent lower flammable limit (LFL) shall be in accordance with Article 500.5 or Article 505.5 of *NFPA 70*.

13.2.5 Rooftop Installations. For units installed on rooftops, the roofing material under and within 12 in. (305 mm) horizontally of a hydrogen generation system or component thereof shall comply with one of the following:

(1) Be noncombustible
(2) Have a Class A fire rating in accordance with the adopted building code

13.3 Electrolyzers.

13.3.1* General. Water electrolyzers shall be listed to ISO 22734, *Hydrogen generators using water electrolysis process—Industrial, commercial, and residential applications*,or approved.

N **13.3.1.1*** Small electrolyzers shall be permitted to be listed to UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements,* or approved for laboratory and similar uses.

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Δ **13.3.2 Siting.** Siting of electrolyzers shall be in accordance with the requirements of Section 13.2 and 13.3.2.1 through 13.3.2.5.

N **13.3.2.1** The system shall be placed on a firm foundation that is capable of supporting the equipment or components in accordance with ASCE-7, *Minimum Design Loads For Buildings and Other Structures.*

N **13.3.2.2** The system shall be anchored, located, and protected so that the system and equipment will not be affected by freezing temperatures and seismic events.

N **13.3.2.3 Access.**

N **13.3.2.3.1** The system shall be protected against access by unauthorized persons commensurate with the location and installation environment.

N **13.3.2.3.2** Fire department access shall be provided.

N **13.3.2.4** The system shall be located outside potentially hazardous (i.e., classified) areas defined by Article 500.5 or Article 505.5 of *NFPA 70* unless listed and approved for such areas.

N **13.3.2.5** Vent terminations from hydrogen generation systems shall be in accordance with Section 6.17.

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13.3.3* Indoor Installations of Electrolyzers. Electrolyzers listed or approved for residential occupancies compliant with the GH_2 content limit of 6.4.1.5.1.1 shall be permitted in residences.

13.3.3.1 A hydrogen generation system installed indoors shall be located in a ventilated area in accordance with the provisions of Section 6.18.

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13.4 Catalytic-Reforming-Based Hydrogen Generation Systems.

13.4.1* General. Reforming-based hydrogen generators shall be listed or approved to ISO 16110-1, *Hydrogen Generators Using Fuel Processing Technologies – Part 1: Safety.*

13.4.2* Siting and Installation. Siting and installation of catalytic-reformer-type hydrogen generation systems shall be in accordance with Chapters 5 through 8 of NFPA 853.

N **13.4.2.1** Small reformers with internal hydrogen volumes not exceeding the maximum allowable quantity (MAQ) defined in 6.4.1.1 shall be permitted to be sited and installed in accordance with Chapter 9 of NFPA 853.

Δ **13.4.2.2** Catalytic reforming systems using a flammable liquid as a fuel with outdoor bulk fuel storage located at an elevation above the catalytic reforming system shall be equipped with an automatic isolation valve at the tank.

Δ **13.4.2.3** Catalytic reforming systems that store hydrogen shall be installed in accordance with the manufacturer's instructions and 7.2.2.2 for non-bulk storage or 7.3.2.2 for bulk storage.

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Δ **13.4.2.4** Reformer burner exhausts shall be located and installed in accordance with Chapter 12 of NFPA 54.

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13.5 Gasifiers.

13.5.1 General. (Reserved)

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N **13.5.2 Siting.** Gasifiers shall be installed in accordance with the requirements of Section 13.2 and 13.5.2.1 through 13.5.2.5.

N **13.5.2.1** The system shall be placed on a firm foundation that is capable of supporting the equipment or components in accordance with ASCE-7, *Minimum Design Loads for Buildings and Other Structures.*

N **13.5.2.2** The system shall be anchored, located, and protected so that the system and equipment will not be affected by freezing temperatures and seismic events.

N **13.5.2.3* Access.**

N **13.5.2.3.1** The system shall be protected against access by unauthorized persons commensurate with the location and installation environment.

N **13.5.2.3.2** Fire department access shall be provided.

N **13.5.2.4** Vent terminations from gasifiers shall be in accordance with Section 6.17.

N **13.5.2.4.1** Venting to a flare stack shall be permitted in accordance with 13.5.3.9.4.3.

N **13.5.2.5** All safety-related controls shall comply with NFPA 79.

13.5.3* Installation of Gasifier Equipment.

13.5.3.1* Conditioning Equipment. Gasification systems contain conditioning equipment to cool and scrub the gas prior to delivery as a fuel; the conditioning equipment shall comply with 13.5.3.1.1 and 13.5.3.1.2.

13.5.3.1.1 Materials for conditioning equipment shall be selected based on both the temperature and the chemical composition of the gas.

13.5.3.1.2 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. *(See 13.5.3.1.3.)*

N **13.5.3.1.3** Where the output stated in 13.5.3.1.2 contains residual toxic content that exceeds applicable OSHA exposure limits in the event of a leak, the requirements 13.5.3 shall apply.

13.5.3.2 Area Classification. The area classification around the gasification equipment shall be in accordance with Article 500.5 or Article 505.5 of *NFPA 70*.

Δ **13.5.3.3 Public Access.** Gasifier systems shall be isolated from public access areas based on a risk assessment of potential exposure to all of the following:

(1) Atmospheres containing flammable gas in excess of 25 percent of the LFL in the event of a leak
(2) Thermal radiation from flare stacks
(3) Toxic constituents in the fuel should a leak event occur

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N **13.5.3.4 Gasifier Hazard Area.** The gasifier hazard area shall be determined in accordance with 13.5.3.2. *(See 3.3.114, Gasifier Hazard Area.)*

N **13.5.3.4.1** The gasifier hazard area shall not be less than the distance specified in 7.1.9.

Δ **13.5.3.5 Air Intakes.** Air intakes to the gasifier systems shall be located so the equipment is not affected by other exhausts, gases, or contaminants.

13.5.3.6 Gasifier Hazard Area Security. Security barriers, fences, landscaping, or other obstacles shall be provided to define the gasifier hazard area and prevent access by unauthorized persons.

13.5.3.7* Warning Signals. Warning signals shall be provided at all gasifier hazard area access points.

13.5.3.7.1 These signals shall be tied to the detection systems outlined in 13.5.3.10 to warn of hazardous conditions.

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13.5.3.8 Controller Location for Gasifiers. The controller for the gasifier process control system shall be located in an area not accessible to the general public and isolated from the gasifier hazard area.

13.5.3.9 Process Systems for Gasifiers. Process systems for gasifiers shall comply with 13.5.3.9.1 through 13.5.3.9.4.

13.5.3.9.1 Piping, valves, and fittings from the gasifier chamber to the end use or storage system shall conform to ASME B31, *Code for Pressure Piping*.

13.5.3.9.2 Backflow prevention shall be provided to preclude inducing external atmospheres into the gasifier systems.

Δ **13.5.3.9.3*** Manual shutoff valves shall conform to 13.5.3.9.3.1 and 13.5.3.9.3.2.

N **13.5.3.9.3.1** 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.

N **13.5.3.9.3.2** The manual flow shutoff valve shall be monitored by the gasifier process control system.

N **13.5.3.9.3.3** The manual flow shutoff valve shall trigger an emergency shutdown of the gasifier process when moved from the full open position

Δ **13.5.3.9.4** Emergency stops shall conform to 13.5.3.9.4.1 through 13.5.3.9.4.4.

N **13.5.3.9.4.1** 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.

N **13.5.3.9.4.2** Activation of the emergency stop system shall do all 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.

N **13.5.3.9.4.3** Vented gas from all gasifier process elements that can contain toxic constituents in excess of that allowed under 13.5.3.10.2 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 Section 6.17 and 7.1.16.

N **13.5.3.9.4.4** The emergency stop capability shall be provided by an independent controller from the main process controller.

13.5.3.10 Hazard Detection and Fire Protection for Gasifiers.

Δ **13.5.3.10.1 Flammable Gas Detection.** Flammable gas detection shall be provided in the vicinity of major gasifier components.

N **13.5.3.10.1.1** For indoor installations, detection shall also be provided in areas where hydrogen could collect in the event of a leak.

N **13.5.3.10.1.2** 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.

Δ **13.5.3.10.2 Toxic Gas Detection.** Toxic gas detection shall be provided in the gasifier hazard area or building for all gas constituents that, when released, could reach the OSHA permissible exposure limit (PEL), OSHA ceiling limit, or short-term exposure limit (STEL).

N 13.5.3.10.2.1* This detection capability shall include detection of carbon monoxide as a minimum.

Δ 13.5.3.10.3* **Thermal Detectors.** Thermal detectors shall shall be provided throughout the gasifier area to detect fires and activate the fire suppression system and initiate a gasifier shutdown.

N 13.5.3.10.3.1 The detection system shall comply with *NFPA 72.*

N 13.5.3.10.3.2 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.

Δ **13.5.3.10.4 Detection Devices and Visual Warning System.**

N 13.5.3.10.4.1 Detection devices shall be tied to visual warning devices.

N 13.5.3.10.4.2 Activation of emergency stop for detected hazards other than fire shall be as recommended by the manufacturer or as required by local regulatory requirements.

13.5.3.10.5* Fire Suppression System. 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.

13.5.4 Indoor Installations of Gasifiers.

N 13.5.4.1 In addition to the requirements of 13.2.3, indoor-located gasifier system equipment shall be installed in accordance with 13.5.4.1.1 through 13.5.4.1.3.

N 13.5.4.1.1 Separation distances of gasifier system equipment with internal volumes exceeding the maximum allowable quantity (MAQ) defined in 6.4.1.1 from exposures shall be in accordance with the lesser of 7.3.2.2.2.2 or 7.3.2.3.

N 13.5.4.1.2 Separation distances of gasifier system equipment with internal volumes less than or equal to the MAQ defined in 6.4.1.1 from exposures shall be in accordance with the lesser of 7.2.2.2 or 7.3.2.3.

N 13.5.4.1.3 Gasification system equipment and associated hydrogen storage shall be permitted without fire-rated separation provided that the internal volumes are less than or equal to the MAQ defined in 6.4.1.1.

13.5.4.2* Buildings for gasifier equipment shall be ventilated and include pressure relief panels to prevent overpressure from deflagrations.

13.5.4.3 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.

13.5.4.4 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

13.5.4.5 Gasifiers that occupy a portion of a building shall be separated from other occupancies in accordance with 7.1.9.

13.5.5 Outdoor Installations of Gasifiers. 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

13.5.6 Rooftop Installation of Gasifiers. Hydrogen gasifiers shall not be installed on rooftops or in penthouse areas of occupied structures.

13.5.6.1 The installation of listed or approved gasifiers shall be permitted provided the listing or approval is specific to rooftop installations.

13.6 Storage.

13.6.1 Requirements for Hydrogen Storage Systems Serving Electrolyzer Installations. The requirements of this section addressing hydrogen storage systems serving electrolyzer installations are supplemental to those specified by Sections 13.2 and 13.3.

13.6.1.1 In residential applications, the electrolyzer installation shall be in accordance with the equipment listing and the manufacturer's instructions.

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Chapter 14 Combustion Applications

14.1 Scope. This chapter shall apply to equipment that uses hydrogen as a fuel source for combustion fuel to provide heat used for the processing of materials and related equipment.

14.1.1* Applicability The requirements of this chapter shall apply to the use of GH_2 as part of a manufacturing process using thermal spraying or as a fuel in heating applications.

14.1.1.1 This chapter also shall apply to new installations and to alterations or extensions to existing equipment.

14.1.1.2 The storage, use, and handling of GH_2 in any quantity shall also comply with the requirements of Chapters 1 and 4 and the applicable requirements of Chapters 5 through 8.

14.1.1.3 The requirements of Chapters 4 and 6 through 8 shall be applicable to all hydrogen systems.

14.1.1.4 Use-specific requirements for hydrogen or hydrogen mixtures used as a fuel for thermal spray equipment and for heating applications shall apply.

14.1.1.5 Where there is a conflict between a fundamental requirement and a use-specific requirement, the use-specific requirement shall be applicable.

14.2 General. (Reserved)

14.3 Use.

14.3.1 Thermal Spraying Equipment.

14.3.1.1 General. Thermal spraying equipment shall meet the requirements of 14.3.1.

14.3.1.2* Indoor Installations of Thermal Spraying Equipment.

14.3.1.2.1* Thermal spray equipment shall be installed, inspected, and maintained in accordance with the manufacturer's instructions to minimize the potential for leaks of the gas delivery system.

14.3.1.2.2* The area in which the thermal spray equipment is installed shall be classified in accordance with Article 500 or Article 505 of *NFPA 70*.

14.3.1.2.2.1 Electrical equipment shall comply with the requirements of *NFPA 70* for the electrical classification of the area in which it is installed.

14.3.1.2.3 Ventilation.

14.3.1.2.3.1 The area containing the thermal spray equipment shall be ventilated to prevent flammable gas buildup from potential system leaks.

14.3.1.2.3.2 Mechanical exhaust ventilation systems required by Section 6.18 or for operation of the equipment shall be interlocked with the thermal spraying equipment to prevent the flow of gases without the ventilation system operating.

14.3.1.2.4* The ceiling of rooms in which thermal spray equipment is installed shall be constructed in a manner to prevent the accumulation of hydrogen gas.

14.3.1.2.5 Venting systems discharging hydrogen to the atmosphere shall be piped to a designated point outside the building in accordance with Section 6.17.

14.3.1.2.6 Gas Detection System.

14.3.1.2.6.1* A hydrogen gas detection system shall be installed in the room or area where thermal spray equipment utilizing hydrogen gas is installed.

14.3.1.2.6.2 Activation of the gas detection system shall result in the following:

(1) The thermal spray system shall be prevented from starting if hydrogen is detected at a concentration exceeding 25 percent of the lower flammable limit (LFL).
(2) The thermal spray system shall be shut down upon detection of hydrogen during operation at a concentration exceeding 25 percent of the LFL.

14.3.1.2.7 Emergency Shutoff.

14.3.1.2.7.1 Automatic emergency shutoff valves shall be provided on the piping used to supply hydrogen gas to the thermal spraying equipment.

14.3.1.2.7.2 Activation of the valves shall shut off the flow of hydrogen in the event of the following:

(1) Loss of ventilation systems required by 14.3.1.2.3.2
(2) Detection of hydrogen at a concentration exceeding 25 percent of the LFL
(3) Activation of emergency stop functions provided with the manufacturer's equipment

14.3.1.3 Outdoor Installations of Thermal Spray Equipment. (Reserved)

Chapter 15 Special Atmosphere Applications

15.1 Scope. This chapter shall apply to equipment that uses hydrogen as an atmosphere for use in the following applications:

(1) Furnaces regulated by NFPA 86 using hydrogen in special atmosphere applications
(2) Hydrogen used as a heat exchange medium for hydrogen-cooled electrical generators

15.1.1 The storage, use, and handling of GH_2 in any quantity shall also comply with the requirements of Chapters 1 and 4 and the requirements of Chapters 6 through 8, as applicable.

15.1.2 In addition to the requirements of this code, furnaces using hydrogen in the form of a special atmosphere shall be in accordance with NFPA 86.

15.1.3 Where there is a conflict between a fundamental requirement and a use-specific requirement, the use-specific requirement shall apply.

15.2 General. (Reserved)

15.3 Use.

15.3.1 Furnaces.

15.3.1.1 General.

15.3.1.1.1* Subsection 15.3.1 shall apply to the production and use of special atmospheres either by blending (or mixing) pure hydrogen gas with other gases, such as nitrogen or the use of pure hydrogen as the sole constituent of the special atmospheres in furnaces.

15.3.1.1.1.1 Subsection 15.3.1 shall apply to special atmospheres containing hydrogen used in Class C or Class D furnaces.

15.3.1.1.1.2 All furnace installations shall also comply with the requirements of NFPA 86.

15.3.1.1.2 Before new equipment is installed or existing equipment is remodeled, complete plans, sequence of operations, and specifications shall be submitted for approval to the authority having jurisdiction. [**86:**4.1.1]

15.3.1.1.2.1* Plans shall be drawn that show all essential details with regard to location, construction, ventilation, piping, and electrical safety equipment. A list of all combustion, control, and safety equipment giving manufacturer and type number shall be included. [**86:**4.1.1.1]

15.3.1.1.2.2* Wiring diagrams and sequence of operations for all safety controls shall be provided. [**86:**4.1.1.2]

N **15.3.1.1.2.3** Plans shall include the furnace class (e.g., Class A, B, C, or D.) [**86:**4.1.1.3]

Δ **15.3.1.1.2.4** Any deviation from this code shall require approval from the authority having jurisdiction. [**86:**4.1.2]

15.3.1.1.3 Venting.

15.3.1.1.3.1* Unwanted, normal operating, and emergency releases of fluids (gases or liquids) from special [hydrogen] atmosphere generators, storage tanks, gas cylinders, and flow control units shall be disposed of to an approved location. [**86:**13.5.1.3]

15.3.1.1.3.2 Venting of unwanted flammable [hydrogen] atmosphere gas shall be done by controlled venting to an approved location outside the building or by completely burning the atmosphere gas and venting the products of combustion to an approved location. [**86:**13.5.1.4]

15.3.1.1.3.3 Nonflammable and nontoxic gases shall be vented to an approved location outside the building at a rate that does not pose a hazard of asphyxiation. [**86:**13.5.1.5]

15.3.1.1.4 Flow Control of Special [Hydrogen] Atmospheres. [86:13.5.7]

15.3.1.1.4.1* Processes and equipment for controlling flows of special [hydrogen] atmospheres shall be designed, installed, and operated to maintain a positive pressure within connected furnaces. [**86:**13.5.7.1]

15.3.1.1.4.2 When furnace chamber door operation or workload quenching causes atmosphere contractions, the flow rates used shall restore positive internal pressure before air infiltration would cause a transition into the flammability range. [**86:**13.5.7.2]

15.3.1.1.4.3* Where the atmosphere is flammable, its flow rate shall be sufficient to provide stable burn-off flames at vent ports. [**86:**13.5.7.3]

15.3.1.1.4.4 Means shall be provided for metering and controlling the flow rates of all fluids comprising the special [hydrogen] atmosphere for a furnace. [**86:**13.5.7.4]

(A) Devices with visible indication of flow shall be used to meter the flows of carrier gases, carrier gas component fluids, inert purge gases, enrichment gases, or air. [**86:**13.5.7.4.1]

(B) The installation of flow control equipment shall meet the following criteria: [**86:**13.5.7.4.3]

(1) It shall be installed at the furnace, at the generator, or in a separate flow control unit. [**86:**13.5.7.4.3(1)]
(2) It shall be accessible and located in an illuminated area so that its operation can be monitored. [**86:**13.5.7.4.3(2)]

15.3.1.1.5* Special Processing Hydrogen Atmosphere Gas Mixing Systems. Where [hydrogen atmospheres are prepared using] gas mixing systems that incorporate a surge tank mixing scheme that cycles between upper and lower set pressure limits, the following shall apply:

(1)* Pipes feeding [hydrogen] atmosphere mixing systems shall contain manual isolation valves.
(2) The effluents from the relief devices used to protect a [hydrogen] atmosphere mixing system shall be piped to an approved location.
(3)* Piping and components shall be in accordance with ASME B31.3, *Process Piping*.
(4) The use of liquids shall not be permitted in [hydrogen] atmosphere mixing systems.
(5) Means shall be provided for metering and controlling the flow rates of all gases.
(6) Flow control of the blended atmosphere gas shall be in compliance with each furnace's applicable special [hydrogen] atmosphere flow requirements and protective equipment.
(7) Atmosphere gas mixers that create nonflammable or indeterminate gas mixtures shall be provided with the following:
    (a) Gas analyzers or other equipment for continuously monitoring and displaying the flammable gas composition
    (b) Automatic controls to shut off the flammable gas flow when the [hydrogen] concentration rises above the operating limit
(8) If the creation of a gas mixture with a [hydrogen] content that is higher than intended results in the risk of explosions where none existed, controls shall be provided to shut off the [hydrogen] flow automatically when the [-] concentration rises above the operating limit.
(9) When the [hydrogen] concentration in a mixed gas exceeds the established high limit, an alarm shall be actuated to alert personnel in the area.
(10) Restart of [hydrogen] flow after a high concentration limit interruption shall require manual intervention at the site of the gas mixer.
(11) Safety shutoff valves used to admit combustible gases to the gas mixer shall be normally closed and capable of closing against maximum supply pressure.
(12) Atmosphere gas mixers installed outdoors shall be selected for outdoor service or placed in a shelter that provides weather protection.
(13) Where a gas mixer is sited in a shelter, the temperature within shall be maintained in accordance with the manufacturer's recommendations.

[**86:**13.5.6]

15.3.1.1.6 Synthetic Atmosphere Flow Control. Synthetic atmosphere flow control units shall have the additional capabilities specified in 15.3.1.1.6.1 through 15.3.1.1.6.9. [**86:**13.5.8]

15.3.1.1.6.1 An atmosphere flow control unit equipped with an inert purge mode shall have a manually operated switch on the face of the unit that actuates the purge. [**86:**13.5.8.1]

Δ **15.3.1.1.6.2** A safety interlock shall be provided for preventing the initial introduction of [any] flammable fluids into a furnace before the furnace temperature has risen to 1400°F (760°C). [**86:**13.5.8.2]

N **(A)** Open circuit failure of the temperature-sensing components shall cause the same response as an operating temperature less than 1400°F (760°C). [**86:**8.16.2]

N **(B)*** The 1400°F (760°C) bypass interlock shall be equipped with temperature indication. [**86:**8.16.3]

N **(C)*** The temperature-sensing components of the 1400°F (760°C) bypass interlock shall be rated for the temperature and the atmosphere to which they are exposed. [**86:**8.16.4]

N **(D)** The temperature-sensing element of the 1400°F (760°C) bypass interlock shall be located so that unsupervised burners are not allowed to operate at temperatures below 1400°F (760°C). [**86:**8.16.5]

N **(E)*** The temperature-sensing element of the [1400°F (760°C) bypass] interlock shall be located where recommended by the [furnace] manufacturer or designer. [**86:**8.15.8]

N **(F)*** The 1400°F (760°C) bypass interlock set point shall not be set below 1400°F (760°C) and shall indicate its set point in units of temperature (degrees Fahrenheit or degrees Celsius) that are consistent with the primary temperature-indicating controller. [**86:**8.16.6]

N **(G)** Visual indication shall be provided to indicate when the 1400°F (760°C) bypass interlock is in the bypass mode. [**86:**8.16.7]

N **(H)*** The operating temperature controller and its temperature-sensing element shall not be used as the 1400°F (760°C) bypass interlock. [**86:**8.16.8]

15.3.1.1.6.3 Resumption of [hydrogen atmosphere] flow following a power failure shall require manual intervention (reset) by an operator after power is restored. [**86:**13.5.8.5]

15.3.1.1.6.4 Where the flammable fluid flow is interrupted, one of the following shall apply:

(1) The flow control unit shall automatically admit a flow of inert gas that restores positive pressure and shall initiate an audible and visual alarm, unless otherwise permitted by 15.3.1.1.6.4(2).
(2) Manual inert gas purge shall be provided for furnaces where operators are present and able to effect timely shutdown procedures subject to the authority having jurisdiction.

[**86:**13.5.8.6]

15.3.1.1.6.5 Means shall be provided to test for leakfree operation of safety shutoff valves for flammable or toxic fluids. [**86:**13.5.8.7]

Δ **15.3.1.1.6.6*** Safety relief valves to prevent overpressurizing of glass tube flowmeters and all other system components shall be in accordance with ASME B31.3, *Process Piping*. [**86:**13.5.8.8]

15.3.1.1.6.7 The effluents from relief valves used to protect control unit components containing flammable or toxic fluids shall be piped to an approved disposal location. [**86:**13.5.8.9]

15.3.1.1.6.8 Alternative valves meeting the following criteria shall be provided for manually shutting off the flow of flammable fluids into a furnace: [**86:**13.5.8.10]

(1) They shall be separate from the atmosphere control unit. [**86:**13.5.8.10(1)]
(2) They shall be accessible to operators. [**86:**13.5.8.10(2)]
(3) They shall be located remotely from the furnace and control unit. [**86:**13.5.8.10(3)]
(4) They shall be listed or approved for the service.

15.3.1.1.6.9* Pipes feeding atmosphere flow control units shall contain isolation valves. [**86:**13.5.8.11]

15.3.1.1.6.10 Low melting point solder shall not be used with piping supplying hydrogen to furnaces or to special [hydrogen] atmosphere blending systems of flow control manifolds.

15.3.1.1.7 Piping Systems for Hydrogen Atmospheres.

15.3.1.1.7.1 Piping shall be sized for the full flow of [hydrogen] atmospheres to all connected furnaces at maximum demand rates. [**86:**13.5.9.1]

15.3.1.1.7.2* Pressure vessels and receivers shall be constructed of materials compatible with the lowest possible temperature of [hydrogen] processing atmospheres, or controls shall be provided to stop the flow of gas when the minimum temperature is reached. [**86:**13.5.9.2]

(A) A low temperature shutoff device used as prescribed in 15.3.1.1.7.2 shall not be installed so that closure of the device can interrupt the main flow of inert safety purge gas to connected furnaces containing indeterminate special processing atmospheres. [**86:**13.5.9.2.1]

(B) If closure of a low temperature shutoff device creates any other hazard, an alarm shall be provided to alert furnace operators or other affected persons of this condition. [**86:**13.5.9.2.2]

(C) The user shall consult with the industrial gas supplier to select the low temperature shutoff device, its placement, and a shutoff set point temperature. [**86:**13.5.9.2.3]

15.3.1.1.8 Inspection, Testing, and Maintenance.

15.3.1.1.8.1 All safety interlocks shall be tested for function at least annually. [**86:**7.4.4]

15.3.1.1.8.2* The safety interlock set point of temperature, pressure, or flow safety devices shall be both of the following:

(1) Verified
(2) Documented at least annually

[**86:**7.4.5]

N **15.3.1.1.8.3** Safety devices that can be configured or programmed shall comply with both of the following:

(1) Have documented configurations
(2) Be verified at least annually

[**86:**7.4.6]

15.3.1.1.8.4 Safety device testing shall be documented at least annually. [**86:**7.4.7]

15.3.1.1.8.5 Whenever any safety interlock is replaced, it shall be tested for function. [**86:**7.4.18]

15.3.1.1.8.6 Whenever any temperature, pressure, or flow device used as a safety interlock is replaced, the set point setting shall be verified. [**86:**7.4.19]

15.3.1.1.9 Fire Protection.

15.3.1.1.9.1* General. A study shall be conducted to determine the need for fixed or portable fire protection systems for ovens, furnaces, or related equipment. [**86:**9.1]

(A) The determination of the need for fire protection systems shall be based on a review of the fire hazards associated with the equipment. [**86:**9.1.1]

(B) Where determined to be necessary, fixed or portable fire protection systems shall be provided. [**86:**9.1.3]

15.3.1.1.10* Special Atmospheres and Furnaces.

15.3.1.1.10.1 Indeterminate Atmospheres. Indeterminate atmospheres shall be treated as flammable atmospheres with the following considerations:

(1) Where one special atmosphere is replaced with another special atmosphere (e.g., flammable [hydrogen] replaced with nonflammable) that can cause the atmosphere to become indeterminate at some stage, burn-in or burn-out procedures shall not be used.
(2) In the case of any indeterminate atmosphere, inert gas purge procedures alone shall be used for introduction and removal of special processing atmospheres.

[**86:**13.5.10.1]

15.3.1.1.10.2 Automatic Cycling. Automatic cycling of a furnace (e.g., quenching, load transfer from a heated zone to a cold vestibule) shall not be permitted where the special atmosphere has become indeterminate during the replacement of a flammable [hydrogen] atmosphere with a nonflammable or an inert atmosphere (or vice versa) until the special atmosphere in all furnace chambers has been verified as either flammable, nonflammable, or inert. [**86:**13.5.10.2]

15.3.1.1.10.3* Furnace Type. The type of furnace shall be determined in accordance with Table 15.3.1.1.10.3. [**86:**13.5.10.3]

15.3.1.1.11 Design Requirements for the Introduction, Use, and Removal of Flammable and Indeterminate Special Atmospheres from Furnaces. [86:13.5.11]

15.3.1.1.11.1 General.

(A) Flammable and indeterminate atmosphere gases shall be introduced, used, and removed from furnaces without creating an uncontrolled fire, deflagration, or explosion. [**86:**13.5.11.1.1]

(B)* Special atmosphere furnaces that use flammable [hydrogen] or indeterminate special atmospheres shall be designed and maintained to minimize the unintended infiltration of air into the furnace. [**86:**13.5.11.1.2]

(C)* Operating instructions for introducing, using, and removing flammable special [hydrogen] atmosphere gases shall comply with Chapter 13 and Section 7.3 of NFPA 86. [**86:**13.5.11.1.3]

(D)* Where present, the liquid level in manometers or bubbler bottles on vent lines shall be checked and maintained at the required operating range as necessary. [**86:**13.5.11.1.4]

(E)* Discharge from effluent vents of furnaces using special [hydrogen] atmospheres shall be piped or captured by hoods and discharged to an approved location. [**86:**13.5.11.1.5]

(F)* Process control air or burnout air shall be supplied from an air blower. [**86:**13.5.11.1.6]

(G)* Where a furnace uses an atmosphere oil seal, means shall be provided so that furnace pressure is maintained below the static head pressure of the seal oil. [**86:**13.5.11.1.7]

Δ **15.3.1.1.11.2 Burn-Off Pilots and Other Ignition Sources.** This section applies to burn-off pilots and other ignition sources provided for the purpose of igniting flammable special [hydrogen] atmosphere gases at effluent stacks, open ends, or doors when a flammable atmosphere is present in the furnace. [**86:**13.5.11.2]

(A) A burn-off pilot, glow plug, flame screen, or other source of ignition shall be provided and located at the gas–air interface and sized to reliably ignite the flammable special [hydrogen] atmosphere gas that is released at effluents, open ends or doors. [**86:**13.5.11.2.1]

Table 15.3.1.1.10.3 Types of Class C Furnaces

Furnace Type	Feature	Operating Temperature	Example
Type I	The chamber(s) <1400°F are separated by doors from those operating at >1400°F	One or more zones always >1400°F	Pusher tray (cold chambers at each end, inner and outer doors with and without integral quench)
Type II		Can be <1400°F after introduction of a cold load	Batch integral quench (1 or more cold chambers, integral quench)
Type III	Both inlet and outlet ends of furnace are open and no external doors or covers	At least one zone >1400°F and have no inner doors separating zones > and <1400°F	Belt (both ends open)
Type IV	Only one end of the furnace is open and there are no external doors or covers		Belt (with integral quench, entry end open)
Type V	Outer doors or covers are provided		Box (exterior door)
Type VI		>1400°F before introduction and removal of special [hydrogen] atmosphere gas	
Type VII		Never >1400°F	
Type VIII	A heating cover furnace with an inner cover	A heating cover and inner cover are separated from a base that supports the work being processed	Bell (with or without retort)
Type IX	A heating cover furnace without an inner cover or with a nonsealed inner cover		Car tip-up

For SI units, 1400°F = 760°C.
[**86:**Table 13.5.10.3]

(B)* Burn-off pilots that are exposed to inert purge gas or special [hydrogen] atmosphere gas under either normal or emergency conditions shall be of a type that will remain in service to ignite flammable effluent gases. [**86:**13.5.11.2.2]

(C)* Burn-off pilots igniting effluent from vent pipes shall not require flame supervision. [**86:**13.5.11.2.3]

(D) Where burn-off pilots are the primary ignition source for effluent from open furnace ends, at least one burn-off pilot shall have flame supervision at each open end. [**86:**13.5.11.2.4]

(E)* Where one or more burn-off pilots are the primary ignition source at a door, at least one burn-off pilot shall have flame supervision interlocked to prevent automatic door opening in the event of flame failure. [**86:**13.5.11.2.5]

(F) Burn-off pilots that have flame supervision shall accomplish the following:

(1) Provide an audible and visual alarm to alert the operator to the failure
(2) Not shut off the burn-off pilot gas in the event of flame failure

[**86:**13.5.11.2.6]

(G)* Burn-off pilot gas shall not shut off in the event of power failure. [**86:**13.5.11.2.7]

(H)* Burn-off pilots shall be located and sized to reliably ignite the effluent stream. [**86:**13.5.11.2.8]

(I) Each burn-off pilot shall be equipped with an individual manual shutoff valve. [**86:**13.5.11.2.9]

(J)* Burn-off pilots gas supply source shall be located downstream of the equipment main manual isolation valve and upstream of any other shutoff devices that can close automatically, including safety shutoff valves. [**86:**13.5.11.2.10]

Δ **15.3.1.1.11.3* Flame Curtains.** Where a flame curtain is used, the following features shall be provided and in service:

(1) One or more flame curtain pilots shall be positioned to reliably ignite the flame curtain.
(2)* At least one flame curtain pilot at a flame curtain shall have flame supervision interlocked to prevent the opening of a closed door served and interlocked to prevent initial operation of the flame curtain at the door served.
(3) At least one safety shutoff valve upstream of all flame curtains on a furnace shall be interlocked to close upon the following conditions:
    (a) Low fuel gas pressure on the flame curtain fuel gas supply
    (b) High fuel gas pressure on the flame curtain fuel gas supply where a high gas pressure issue would create a safety concern
(4) For flame curtains equipped with flame supervision independent of the flame curtain pilot flame supervision, it shall be permissible to bypass the safety shutoff valve interlocks in 15.3.1.1.11.3(3)(a) and 15.3.1.1.11.3(3)(b) once the door served is open provided that flame curtain flame is sensed by the flame curtain flame supervision system.
(5) An automatic control valve shall be provided ahead of each flame curtain arranged to open when the door served is not closed.
(6) When the safety shutoff valve in item 15.3.1.1.11.3(3) is closed, any doors served by that safety shutoff valve shall be interlocked so they cannot open.
(7)* A manual means of overriding the door interlock in 15.3.1.1.11.3(6) shall be provided.

[**86:**13.5.11.3]

15.3.1.1.11.4 Flammable Special Atmosphere Introduction. Flammable special [hydrogen] atmospheres shall be introduced into a furnace using one of the following methods:

(1) Purge-in
(2) With the exception of Type VIII furnaces, burn-in

[**86:**13.5.11.4]

15.3.1.1.11.5 Flammable Special Atmosphere Removal. Flammable special [hydrogen] atmospheres shall be removed from a furnace using one of the following methods:

(1) Purge-out
(2) With the exception of Type VIII furnaces, burn-out

[**86:**13.5.11.5]

15.3.1.1.11.6 Purge-in Requirements.

(A) Written purge-in instructions shall be provided for each furnace. [**86:**13.5.11.6.1]

(1)* Purge effectiveness shall not be compromised during the purge process. [**86:**13.5.11.6.1.1]
(2) Furnace doors and covers shall be positioned in accordance with the operating instructions before purge-in begins. The inner and outer covers of Type VIII and Type IX furnaces shall not be placed in position onto the furnace base unless the workload and base are at least 50°F (28°C) below the auto-ignition temperature of any flammable gas mixture that can be present in the cover. [**86:**13.5.11.6.1.2]

(B) Purge-in shall reduce the oxygen content of the furnace to less than 1 percent by displacement with an inert gas or before introduction of the flammable special [hydrogen] atmosphere gas. [**86:**13.5.11.6.2]

(C) Positive Furnace Pressure.

(1) A positive furnace pressure shall be maintained during the purge-in process and continue through the transition from the inert gas purge to the introduction of special [hydrogen] atmosphere gas. [**86:**13.5.11.6.3.1]
(2) Positive pressure for Type VIII or Type IX heating-cover (retort) type furnaces shall be indicated by a bubbler, vent manometer, or similar device. [**86:**13.5.11.6.3.2]

(D)* During the inert gas purge, flammable special [hydrogen] atmosphere safety shutoff valves shall remain closed. [**86:**13.5.11.6.4]

Δ **(E)** Purging of the furnace shall continue until the purge has been verified as complete using one of the following methods:

(1) Time-flow purge method in accordance with 13.5.12 of NFPA 86.
(2) Two consecutive analyses of all chambers indicating that the oxygen content is less than 1 percent

[**86:**13.5.11.6.5]

(F) Furnaces shall not be required to be at any specific temperature when the inert gas is displaced by the flammable special [hydrogen] atmosphere gases. [**86:**13.5.11.6.6]

(G)* Active sources of ignition shall be provided at interfaces between air and flammable or indeterminate special [hydrogen] atmosphere gases at furnace openings and doors. Effluent vents terminating inside a building shall also be provided with an active source of ignition. [**86:**13.5.11.6.7]

(H)* All furnace and vestibule volumes that will contain a flammable special [hydrogen] atmosphere gas shall be purged with inert gas prior to the special [hydrogen] atmosphere gas being admitted. [**86:**13.5.11.6.8]

(I) During the inert gas purge, all flame curtain fuel gas valves shall be closed. [**86:**13.5.11.6.9]

(J) During the inert gas purge, all circulating and recirculating fans shall be operating as required by the operating instructions. [**86:**13.5.11.6.10]

(K) Flammable special [hydrogen] atmosphere gases shall not be introduced unless the following conditions exist:

(1) Burn-off pilots at open ends, doors, and effluent lines are ignited.
(2) All manual valves to flame curtains (where provided) are open.
(3) All automatic valves to flame curtain are in service.
(4)* All required quench fluid levels are at the correct level.
(5) Purging of the furnace has been completed as defined by 15.3.1.1.11.6(E)
(6) Operation of flame curtains (where provided) is verified.

[**86:**13.5.11.6.11]

(L)* After the introduction of the flammable special [hydrogen] atmosphere, the purge-in atmosphere introduction process is considered complete when flame appears at furnace doors, open ends, or effluent lines in accordance with the specific design features and operating instructions for the furnace. [**86:**13.5.11.6.12]

15.3.1.1.11.7 Burn-in Requirements.

(A) For Type VIII furnaces, burn-in procedures shall not be used. [**86:**13.5.11.7.2.1]

(B) Written burn-in instructions shall be provided for each furnace. [**86:**13.5.11.7.2]

(1)* Burn-in effectiveness shall not be compromised by taking any action that deviates from the written operating instructions for burn-in. [**86:**13.5.11.7.2.1]
(2) The position of inner and outer furnace doors and the placement of manual torches shall be as directed in the operating instructions during each stage of the burn-in procedure. [**86:**13.5.11.7.2.2]

(C)* Burn-in shall reduce the oxygen content of the furnace by consuming the oxygen in the air through combustion with a flammable atmosphere gas that will reliably ignite at the gas–air interfaces. [**86:**13.5.11.7.3]

(D)* To begin the burn-in process, the flammable special [hydrogen] atmosphere gas shall be introduced at a location in the furnace that is at or above 1400°F (760°C). [**86:**13.5.11.7.4]

(E)* Where a stable flame front propagating through a chamber under 1400°F (760°C) cannot be maintained, the burn-in process shall not be used. [**86:**13.5.11.7.5]

(F)* For zones under 1400°F (760°C), stable flames of burning gas shall be maintained in the zones as the special [hydrogen] atmosphere gas is burned-in. [**86:**13.5.11.7.6]

(G)* For a Type II furnace (batch integral quench furnace) with heating chamber fan, the fan shall not be operating during burn-in while the inner heating chamber door is open. [**86:**13.5.11.7.7]

(H)* For Types I through VII furnaces, recirculating fans in cooling zones shall be turned off during burn-in. [**86:**13.5.11.7.8]

(I) Special Requirements for Type IX Furnaces. [86:13.5.11.7.9]

(1) Circulating base fans, where provided, shall be turned on. [**86:**13.5.11.7.9.1]
(2)* The cover shall be sealed to the furnace base before flammable or indeterminate special [hydrogen] atmospheres are introduced. [**86:**13.5.11.7.9.2]

(J) For Type VIII furnaces, burn-out procedures shall not be used. [**86:**13.5.11.9.1]

(K)* After the introduction of the flammable special [hydrogen] atmosphere, the burn-in atmosphere introduction process shall be considered complete when flame appears at the furnace doors, open ends, or effluent lines, where present, in accordance with the specific design features and operating instructions for the furnace. [**86:**13.5.11.7.11]

15.3.1.1.11.8 Purge-out Requirements.

(A) Written purge-out instructions shall be provided for each furnace. [**86:**13.5.11.8.1]

(1)* Purge effectiveness shall not be compromised during the purge process. [**86:**13.5.11.8.1.1]
(2) Furnace doors and covers shall be positioned in accordance with the manufacturer's instructions before purge-out begins. [**86:**13.5.11.8.1.2]

(B) Positive Furnace Pressure.

(1) A positive furnace pressure shall be maintained at all times during purge-out, including the transition from the special [hydrogen] atmosphere gas operation to the inert gas purge. [**86:**13.5.11.8.2.1]
(2) For Types VIII and IX furnaces, an indication of positive furnace pressure shall be provided by an indicating manometer or similar device. [**86:**13.5.11.8.2.2]

(C)* Once the inert purge gas flow has been established for purge-out, the flow of all flammable special [hydrogen] atmosphere gases shall be stopped. [**86:**13.5.11.8.3]

(D)* Purging shall include all of the furnace volume that contains a flammable or indeterminate special [hydrogen] atmosphere gas. [**86:**13.5.11.8.4]

Δ **(E)*** Purge-out shall be considered complete when all chambers that would create a hazard are below 50 percent of LFL and shall be determined by one of the following two methods:

(1) Time-flow purge method in accordance with 13.5.12 of NFPA 86 as it applies to the purge-out process

(2) Two consecutive analyses of all chambers indicating that the flammable level within the furnace is below 50 percent of LFL

[**86:**13.5.11.8.5]

(F) When purge-out is complete, the following shall be permitted to be turned off:

(1) Burn-off pilots
(2) Circulation and recirculation fans required for purge-out
(3) Inert purge gas supply to the furnace
(4) Flame curtains

[**86:**13.5.11.8.6]

15.3.1.1.11.9 Burn-Out Requirements.

(A) For Type VIII furnaces, burn-out procedures shall not be used. [**86:**13.5.11.9.1]

(B) Written burn-out instructions shall be provided for each furnace. [**86:**13.5.11.9.2]

(1)* Burn-out effectiveness shall not be compromised by taking any action that deviates from the written operating instructions for burn-out. [**86:**13.5.11.9.2.1]
(2)* Inner and outer furnace doors, where provided, shall be placed in the appropriate position as directed in the operating instructions during each stage of the burn-out procedure. [**86:**13.5.11.9.2.2]

(C)* Through the controlled admission of air to a furnace, burn-out shall reduce the flammable content within all heating chambers and vestibules through combustion with the oxygen in the air. [**86:**13.5.11.9.3]

(D)* To initiate the burn-out process, one of the following conditions shall be met:

(1) Air is introduced into the furnace at a point that is at or above 1400°F (760°C).
(2) Where air is introduced into a furnace at a point below 1400°F (760°C), the following shall apply:
    (a)* The furnace is under positive pressure.
    (b) A source of ignition is provided at the interface between the flammable atmosphere and the point of air introduction.

[**86:**13.5.11.9.4]

(E) Burn-out shall include turning off all special [hydrogen] atmosphere gases and admitting air in a sequence outlined in the written burn-out instructions. [**86:**13.5.11.9.5]

(F) Burnout air shall be admitted by any of the following arrangements:

(1) Through furnace doors
(2) Through independent piping and furnace gas inlets
(3) Through sections of piping and furnace inlets that are common to both flammable special [hydrogen] atmosphere and burnout air when the systems are designed to prevent the flow of air and flammable special [hydrogen] atmosphere at the same time

[**86:**13.5.11.9.6]

(G)* During burn-out, recirculating fans shall be turned off in furnace zones under 1400°F (760°C) and in zones at or above 1400°F (760°C) that can cause turbulence in zones under 1400°F (760°C). [**86:**13.5.11.9.7]

(H) Burn-out shall be considered complete when one of the following conditions is satisfied:

(1) For furnaces that do not contain soot, all visible flame in the furnace and at all effluents are observed to be extinguished.
(2) For furnaces that contain soot that cannot re-form a flammable atmosphere gas, all visible flames in the furnace and at all effluents are observed to be extinguished.
(3) For furnaces that contain soot that re-form flammable atmosphere gas, all visible flames in the furnace and at effluents are observed to be extinguished after burn-out procedures are performed that include the introduction of additional air to effect the burn-out of the re-formed flammable atmosphere gas.

[**86:**13.5.11.9.8]

(I) When burn-out is complete, the following shall be permitted to be turned off:

(1) Burn-off pilots
(2) Circulation and recirculation fans required for burn-out
(3) Flame curtains

[**86:**13.5.11.9.9]

15.3.1.1.11.10* Special Atmosphere Equipment Piping System. [86:13.5.11.10]

(A) General. The special [hydrogen] atmosphere equipment piping system shall be that piping starting at the equipment manual isolation valve that includes the components for the delivery of special [hydrogen] atmosphere fluids to a furnace. [**86:**13.5.11.10.1]

Δ **(B) Manual Shutoff Valves and Equipment Isolation.**

(1)* An equipment isolation manual shutoff valve shall be provided for each special [hydrogen] atmosphere fluid, shall be located upstream of all devices on the special [hydrogen] atmosphere equipment piping, and shall be lockable. [**86:**13.5.11.10.2.1]
    (a) Where fuel gas is used as a special [hydrogen] atmosphere gas, a separate manual shutoff valve shall be provided for the special [hydrogen] atmosphere feed. This valve shall not be required to be lockable where the fuel gas main isolation manual shutoff valve is lockable. [**86:**13.5.11.10.2.1(A)]
    (b) Equipment isolation manual shutoff valves for each special [hydrogen] atmosphere fluid shall be accessible from the normal operator working level without the use of ladders or portable equipment. [**86:**13.5.11.10.2.1(B)]
(2) The position of any manual shutoff valve that can interrupt the supply of inert gas to an automatic inert purge gas line shall be electrically supervised and cause a visual and audible alarm to alert the operator whenever this valve is not in the open position and the automatic inert purge is required to be in service. [**86:**13.5.11.10.2.2]
(3) A bypass manual shutoff valve shall be provided to bypass each normally open emergency inert gas purge valve, and be arranged as follows:
    (a) Be accessible to the operator for use in accordance with written operating instructions

(b) Have a port area equal to or larger than the bypassed normally open emergency inert gas purge valve

[**86:**13.5.11.10.2.3]

(4) Each manual shutoff valve shall have a tag that identifies the valve and the special [hydrogen] atmosphere it controls. [**86:**13.5.11.10.2.4]

(5) The operating instructions required by Section 7.3.3 of NFPA 86 shall reference the valve tag identifications required by 15.3.1.1.11.10(B)(4). [**86:**13.5.11.10.2.5]

(6) Each manual shutoff valve shall be in accordance with the following: [**86:**13.5.11.10.2.6]

(a) They shall be provided for each piece of equipment. [**86:**6.2.4.1(1)]

(b) They shall have permanently affixed visual indication of the valve position. [**86:**6.2.4.1(2)]

(c) They shall be quarter-turn valves with stops. [**86:**6.2.4.1(3)]

(d) Wrenches or handles shall remain affixed to valves and shall be oriented with respect to the valve port to indicate the following:

i. An open valve when the handle is parallel to the pipe

ii. A closed valve when the handle is perpendicular to the pipe

[**86:**6.2.4.1(4)]

(e)* They shall be readily accessible.

(f) Valves with removable wrenches shall not allow the wrench handle to be installed perpendicular to the fuel gas line when the valve is open. [**86:**6.2.4.1(6)]

(g) They shall be able to be operated from full open to full close and return without the use of tools. [**86:**6.2.4.1(7)]

(7) Manual valves that are not used for shutoff shall not be required to comply with 15.3.1.1.11.10(B) other than 15.3.1.1.11.10(B)(4). [**86:**13.5.11.10.2.7]

(C) Regulators.

(1) Regulators shall be provided on each special [hydrogen] atmosphere gas line where the gas supply pressure exceeds the operating or design parameters of equipment piping and components in the equipment piping. [**86:**13.5.11.10.3.1]

(2)* Regulator atmospheric vents shall be vented to an approved location. [**86:**13.5.11.10.3.2]

(3) Regulator vents shall not be manifolded with the following:

(a) Vents from other furnaces

(b) Vents downstream of the safety shutoff valves

(c) Relief valve vents

[**86:**13.5.11.10.3.3]

(4)* Where a regulator vent is manifolded with other vents, the area of the vent manifold shall equal or exceed the sum of the individual vent line areas of each vent line served from its point of connection. [**86:**13.5.11.10.3.4]

(5) The regulator vent termination shall be designed to prevent the entry of water and insects without restricting the flow capacity of the vent. [**86:**13.5.11.10.3.5]

Δ **(D) Relief Valves.**

(1)* Relief valves shall be provided downstream of any regulator where a regulator failure could expose downstream piping, components, or furnace to pressures exceeding their maximum design pressure. [**86:**13.5.11.10.4.1]

(2)* Relief valve(s) or other means of controlling pressure shall be provided for each liquid special atmosphere piping system where there is a potential to overpressurize the liquid special atmosphere piping. This specifically includes each section of liquid-filled special atmosphere piping that can be isolated by valves. [**86:**13.5.11.10.4.2]

(3)* Relief valves shall be piped to an approved location. [**86:**13.5.11.10.4.3]

(4) Relief valve piping shall not be manifolded with either of the following:

(a) Vents from other furnaces

(b) Vents from regulators

[**86:**13.5.11.10.4.4]

(5) Relief valve piping shall not be manifolded with other relief valve piping where either of the following could occur:

(a) Mixing of liquids and gases

(b) Mixing of fluids (liquids or gases) that could result in corrosion to relief valves or relief valve piping

[**86:**13.5.11.10.4.5]

(E) Filters.

(1) A filter shall be provided upstream of each liquid flow sensor. [**86:**13.5.11.10.5.1]

(2) A filter shall have a particle size rating that will not allow particles of a size that can foul liquid flow sensors or liquid flowmeters to pass the filter. [**86:**13.5.11.10.5.2]

(F) Flowmeters. One flowmeter shall be provided on each special [hydrogen] atmosphere equipment supply line. [**86:**13.5.11.10.6]

(G) Pressure Gauges. Pressure gauges shall be provided at points in the special [hydrogen] atmosphere equipment piping where the operator must be provided visual pressure information to verify the furnace is being maintained within safe operating limits. These points shall be determined as part of the furnace design. [**86:**13.5.11.10.7]

(H)* Atmosphere Inlets. Atmosphere inlets shall not be located in such a way that atmosphere flow will directly impinge on temperature control or over temperature control thermocouples. [**86:**13.5.11.10.8]

15.3.1.1.12 Special Atmosphere Safety Equipment. Paragraphs 15.3.1.1.12.1 through 15.3.1.1.12.17 shall apply to the safety equipment and its application to the furnace special [hydrogen] atmosphere system. [**86:**13.5.11.11]

15.3.1.1.12.1 All safety devices, with the exception of flow sensors, shall be one of the following:

(1) Listed for the service intended

(2) Approved where listed devices are not available

(3) Programmable controllers applied in accordance with Section 8.3 of NFPA 86

[**86:**13.5.11.11.1]

15.3.1.1.12.2 Electric relays and safety shutoff valves shall not be used as substitutes for electrical disconnects and manual shutoff valves. [**86:**13.5.11.11.2]

15.3.1.1.12.3 Regularly scheduled inspection, testing, and maintenance of all safety devices shall be performed. *[See 15.3.1.1.8.]* [**86:**13.5.11.11.3]

15.3.1.1.12.4 Safety devices shall be installed, used, and maintained in accordance with this code and manufacturers' instructions. [**86:**13.5.11.11.4]

15.3.1.1.12.5 Where a device is used with a flammable special [hydrogen] atmosphere gas and the device manufacturer's instructions require conduit seals or a cable type that will not permit transfer of gas, the required seals or cable type shall be installed. [**86:**13.5.11.11.5]

15.3.1.1.12.6 Safety devices shall be located or guarded to protect them from physical damage. [**86:**13.5.11.11.6]

15.3.1.1.12.7 Safety devices shall not be bypassed electrically or mechanically. [**86:**13.5.11.11.7]

(A) The requirement in 15.3.1.1.12.7 shall not prohibit safety device testing and maintenance in accordance with Chapter 7. Where a system includes a built-in test mechanism that bypasses any safety device, it shall be interlocked to prevent operation of the system while the device is in test mode, unless listed for that purpose. [**86:**13.5.11.11.7.1]

(B) The requirement in 15.3.1.1.12.7 shall not prohibit a time delay applied to the action of pressure proving or flow proving, where the following conditions exist:

(1) There is an operational need demonstrated for the time delay.
(2) The use of a time delay is approved.
(3) The time delay feature is not adjustable beyond 5 seconds.
(4) A single time delay does not serve more than one pressure-proving or flow-proving safety device.
(5) The time from an abnormal pressure or flow condition until the holding medium is removed from the safety shutoff valves does not exceed 5 seconds.

[**86:**13.5.11.11.7.2]

15.3.1.1.12.8* A manual emergency means shall be provided for the removal of the furnace special [hydrogen] atmosphere using the method, either purge-out or burn-out, that is the basis of the furnace design. [**86:**13.5.11.11.8]

15.3.1.1.12.9 The activation of any carrier gas or furnace pressure safety interlock required in 15.3.1.1.12 shall initiate the appropriate action to bring the furnace to a safe state. The action shall be manual or automatic in accordance with the furnace design and operating instructions. [**86:**13.5.11.11.9]

15.3.1.1.12.10 Removal of Flammable Special Atmospheres. [86:13.5.11.11.10]

(A)* Removal of flammable special [hydrogen] atmospheres by burn-out, purge-out, or emergency purge-out shall be initiated under the following conditions:

(1) Normal furnace atmosphere burn-out initiated
(2) Normal furnace atmosphere purge-out initiated
(3) Low flow of carrier gas(es) that will not maintain a positive pressure in chambers below 1400°F (760°C) and positive pressure not restored by the automatic transfer to another source of gas
(4) A furnace temperature below which any liquid carrier gas used will not reliably dissociate
(5) Automatic emergency inert gas purge initiated
(6) Manual operator emergency inert gas purge initiated

[**86:**13.5.11.11.10.1]

(B) When removal of flammable special [hydrogen] atmospheres is initiated in response to the conditions listed in 15.3.1.1.12.10(A)(3) through 15.3.1.1.12.10(A)(6), one of the following shall occur based upon chamber temperature:

(1) For chambers below 1400°F (760°C), one of the following actions shall occur, and the selected action shall be implemented as part of the furnace design:
    (a) Automatically burned-out where burn-out is an acceptable option
    (b) Purged-out by normal means where burn-out is not an acceptable option
    (c) Automatically purged-out by emergency inert gas purge
    (d) Manual burn-out or purge-out by manual emergency inert gas purge where furnace design allows the time needed for manual action
(2) For chambers at or above 1400°F (760°C), the chamber shall be manually or automatically burned-out or purged-out.

[**86:**13.5.11.11.10.2]

15.3.1.1.12.11 Flammable Special Atmosphere Safety Shutoff Valves — General. [86:13.5.11.11.11]

(A) One safety shutoff valve shall be provided in the supply line of each flammable special [hydrogen] atmosphere gas or liquid. [**86:**13.5.11.11.11.1]

(B)* Exothermic generated special [hydrogen] atmosphere gas supplies used for both purging and process shall not require safety shutoff valves. [**86:**13.5.11.11.11.2]

(C) Safety shutoff valve components shall be of materials selected for compatibility with the gas or liquid handled and for ambient conditions. [**86:**13.5.11.11.11.3]

(D) Means for testing all gas safety shutoff valves for valve seat leakage shall be installed. [**86:**13.5.11.11.11.4]

(E)* A test of seat leakage of gas safety shutoff valves shall be completed at least annually. [**86:**13.5.11.11.11.5]

15.3.1.1.12.12 Flammable Special Atmosphere Safety Shutoff Valves. [86:13.5.11.11.12]

(A) For furnaces using burn-in procedures for introducing flammable special [hydrogen] atmosphere carrier gases, it shall be permissible to admit flammable special [hydrogen] atmosphere carrier gas when the following conditions exist:

(1) The furnace temperature exceeds 1400°F (760°C) at the point where the flammable special [hydrogen] atmosphere carrier gas is introduced.
(2) If the furnace is designed to operate with an automatic inert gas purge, the presence of the required inert gas pressure shall be verified manually or automatically.
(3) Operator action opens the valve.

[**86:**13.5.11.11.12.1]

Δ **(B)** For furnaces using purge-in procedures for introducing flammable special [hydrogen] atmosphere carrier gases, it shall be permissible to admit flammable special [hydrogen] atmosphere carrier gas when both of the following conditions exist:

(1) The inert gas purge is complete.

(2) If the furnace is designed to operate with an emergency inert gas purge, the presence of the required inert gas pressure shall be verified manually or automatically.

[**86:**13.5.11.11.12.2]

(C) For furnaces using burn-in or purge-in procedures for introducing flammable special [hydrogen] atmosphere gases that are not carrier gases, the safety shutoff valves for the noncarrier gases shall open only when the carrier gas flow has been established. [**86:**13.5.11.11.12.3]

(D)* Safety shutoff valves shall automatically close upon occurrence of the following conditions:

(1) Normal furnace atmosphere burn-out initiated
(2) Normal furnace atmosphere purge-out initiated
(3) Low flow of carrier gas(es) that will not maintain a positive pressure in chambers below 1400°F (760°C) and positive pressure not restored by the automatic transfer to another source of gas
(4) A furnace temperature below which any liquid carrier gas used will not reliably dissociate
(5) Automatic emergency inert gas purge initiated
(6) Manual operator emergency inert gas purge initiated
(7) Power failure
(8) Liquid carrier gas excess flow

[**86:**13.5.11.11.12.4]

15.3.1.1.12.13 Emergency Inert Gas Purge. [86:13.5.11.11.13]

N **15.3.1.1.12.13.1** A minimum supply of inert purge gas equal to five times the total vacuum system volume shall be available during operation with flammable atmospheres. [**86:**14.5.3.115.1]

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15.3.1.1.12.14 Special Atmosphere Flow Interlocks. [86:13.5.11.11.14]

(A) Minimum carrier gas flow(s) required by this code shall be proved by either:

(1) A flow switch for each special atmosphere that is considered a carrier gas
(2) Furnace pressure switch(s)

[**86:**13.5.11.11.14.1]

(B) If minimum carrier gas flow is not proven, the following shall be applied:

(1) Actions listed in 15.3.1.1.12.10(B) shall be initiated.
(2) Visual and audible alarms shall alert the operator of loss of minimum carrier gas flow.

[**86:**13.5.11.11.14.2]

(C) Inert purge gas equipment piping shall be equipped with:

(1) A pressure switch that will audibly and visually alert the operator of a low purge pressure condition.
(2) A flow switch that will audibly and visually alert the operator of a low purge flow condition.

[**86:**13.5.11.11.14.3]

15.3.1.1.12.15* Furnace vestibules shall be equipped with means for explosion relief. [**86:**13.5.11.11.15]

15.3.1.1.12.16* The flow of noncarrier special atmosphere gases that are nonflammable shall not be permitted until minimum carrier gas flow has been proven. [**86:**13.5.11.11.16]

15.3.1.1.12.17 Operating Precautions for Heating Cover–Type Furnaces. The rate of separating a heating cover from or rejoining a heating cover to the inner cover shall not exceed a rate that causes rapid expansion or contraction of the atmosphere gas inside the inner cover. [**86:**13.5.11.11.17]

Δ **15.3.1.1.13* Burner Management System Logic.**

Δ **(A)** Purge and ignition trials shall be performed using either devices listed for such service or programmable controllers used in accordance with Section 8.3 of NFPA 86. [**86:**8.2.11]

Δ **(B)** The activation of any safety interlock required in Chapter 8 of NFPA 86 shall result in a safety shutdown. [**86:**8.2.12]

N **(C)** Loss of power or signal from a safety interlock shall result in a safety shutdown. [**86:**8.2.13]

Δ **(D)** Safety interlocks shall meet one or more of the following criteria:

(1) Be hardwired without relays in series and ahead of the controlled device
(2) Be connected to an input of a programmable controller logic system complying with Section8.3 of NFPA 86
(3) Be connected to a relay that represents a single safety interlock that is configured to initiate safety shutdown
(4)* Be connected to a listed safety relay with monitoring that represents one or more safety interlocks and initiates safety shutdown

[**86:**8.2.14]

(E)* All safety function sensors and final elements shall be independent of operating sensors and final elements. [**86:**8.2.15]

(F)* Electrical power for safety control circuits shall be dc or single-phase ac, 250 volt maximum, one-side grounded, with all breaking contacts in the ungrounded, fuse-protected, or circuit breaker–protected line. [**86:**8.2.16]

15.3.1.1.14 Programmable Logic Controller Systems. Programmable logic controller systems shall be in accordance with Section 8.3 of NFPA 86.

15.3.1.1.15* Inert Gas for Furnace Purge. NFPA 86 identifies several specific situations where inert gas purge is required and shall be referenced to identify the appropriate requirements.

15.3.1.1.15.1 Where inert purge gas is required by NFPA 86 or used as a safety purge media, the following shall apply:

(1) It shall be available at all times and be sufficient for five volume changes of all connected atmosphere furnaces.
(2) If the inert gas has a flammable gas component, it shall be analyzed on a continuous basis to verify that the oxygen content is less than 1 percent and the combined combustible gas concentration remains less than 25 percent of the LFL.

[**86:**13.5.5.1.4]

15.3.1.1.16 Storage Systems for Special Atmospheres. Tanks containing purge media shall be provided with a low-level audible and visual alarm that meets the following criteria:

(1) The alarm is situated in the area normally occupied by furnace operators.
(2) The low-level alarm set point is established to provide time for an orderly shutdown of the affected furnace(s).

(3) The minimum contents of a tank containing a purge medium at the low-level alarm set point is sufficient to purge all connected atmosphere furnaces with at least five volume changes.

[**86:**13.5.5.2]

15.3.1.2 Special Atmospheres in Class D Furnaces.

N **15.3.1.2.1** Class D furnaces shall be further subdivided into four subclasses as shown in Table 15.3.1.2.1. [**86:**Table 14.1.2]

N **15.3.1.2.1.1** Class D furnaces that are capable of operating in more than one of the modes in Table 15.3.1.2.1 shall be equipped with all the necessary hardware and instrumentation features required by this chapter for each operating mode it employs. [**86:**14.1.2.1]

N **15.3.1.2.1.2** At a minimum, all Class D furnaces shall meet the hardware and instrumentation requirements for Mode D-1. [**86:**14.1.2.1.1]

N **15.3.1.2.1.3** Mode D-3 shall comprise an operation at a negative gauge pressure with a flammable special atmosphere. [**86:**14.1.2.4]

N **15.3.1.2.1.4** Mode D-4 shall comprise an operation at a positive gauge pressure with a flammable special atmosphere. [**86:**14.1.2.5]

N **15.3.1.2.2* Gas Hazards.** Where the potential for the release of hazardous gases from a vacuum furnace exists, such gases shall be directed to an approved location. [**86:**14.2.2]

15.3.1.2.3 Safety Controls and Equipment. The requirements of 15.3.1.2 shall apply to any vacuum chamber or vacuum furnace in which [hydrogen] gas is used at pressures equal to or greater than the fuel's partial pressure at 50 percent of its LFL when mixed with air at standard temperature and pressure (i.e., 1.0 atm and 25°C). [**86:**14.5.3.1]

N **15.3.1.2.3.1** Processes and equipment upstream of interconnected furnaces that are used for controlling flows of special atmospheres shall be designed, installed, and operated to maintain positive pressure at all times. [**86:**14.5.3.1.1]

N **15.3.1.2.3.2** When furnace chamber door operation or workload quenching causes atmosphere contractions, the flow rates used shall restore positive internal pressure before air infiltration would cause a transition into the flammability range. [**86:**14.5.3.1.2]

N **15.3.1.2.3.3** Where the atmosphere is flammable, its flow rate shall be sufficient to provide stable burn-off flames at vent ports. [**86:**14.5.3.1.3]

N **Table 15.3.1.2.1 Operating Modes of Class D Vacuum Furnaces [86:Table 4.1.2]**

Mode	Operating Pressure	Special Atmosphere
D-1	Vacuum or negative gauge pressure	None or nonflammable
D-2	Positive gauge pressure	None or nonflammable
D-3	Vacuum or negative gauge pressure	Flammable [Hydrogen]
D-4	Positive gauge pressure	Flammable [Hydrogen]

N **(A)** Indeterminant atmospheres shall be treated as flammable atmospheres. [**86:**14.5.3.1.3.1]

15.3.1.2.3.4 Flammable Gas Supply. [86:14.5.3.1.4]

(A) The flammable gas supply shall be connected to the vacuum chamber through a normally closed automatic safety shutoff valve. [**86:**14.5.3.1.4.1]

(B) Vacuum furnaces that rely on a partial vacuum to hold the door closed shall have the flammable gas supply connected to the vacuum chamber through two normally closed automatic safety shutoff valves. [**86:**14.5.3.1.4.2]

(C) A manual shutoff valve shall be provided in all flammable atmosphere supply pipe(s). [**86:**14.5.3.1.4.3]

15.3.1.2.3.5 The flammable gas supply system shall be interlocked with the vacuum system to prevent the introduction of any flammable atmosphere until the furnace has been evacuated to a level of 1×10^{-1} torr (13.3 Pa) or less. [**86:**14.5.3.1.5]

N **15.3.1.2.3.6** High- and low-pressure switches shall be installed on the flammable gas line. [**86:**14.5.3.1.6]

Δ **15.3.1.2.3.7** High- and low-pressure switches installed on the flammable gas line shall be interlocked to shut off the supply of gas when its pressure deviates from the design operating range. [**86:**14.5.3.1.7]

15.3.1.2.3.8* In the case of a multiple-chamber-type or continuous-type vacuum furnace, the following criteria shall apply:

(1) Each chamber shall be regarded as a separate system.
(2) Interlocks shall be provided that prevent the valves from opening between adjacent interconnecting chambers once a flammable atmosphere has been introduced into any of them.

[**86:**14.5.3.1.8]

15.3.1.2.3.9 The vacuum pumping system shall be interlocked with the supply gas system so that mechanical pumps continue to operate while flammable gas is in the vacuum chamber, to prevent the backflow of air through nonoperating pumps. [**86:**14.5.3.1.9]

15.3.1.2.3.10 The following shall be piped to a source of inert gas:

(1) Mechanical pump gas ballast valves
(2) Vacuum air release valves on roughing or forelines

[**86:**14.5.3.1.10]

N **15.3.1.2.3.10.1** A minimum supply of inert purge gas equal to five times the total vacuum system volume shall be available during operation with flammable atmospheres. [**86:**14.5.3.1.1]

N **15.3.1.2.3.10.2** The purge gas supply shall be connected to the vacuum chamber through a normally open valve. [**86:**14.5.3.15.2]

(A) A pressure sensor shall monitor the purge gas line pressure and shall stop the supply of flammable gas if the pressure becomes too low to allow purging in accordance with 15.3.1.2.3.10.1.[**86:**14.5.3.1.2.1]

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N **(B)** Any manual inert purge gas shutoff valves shall be proved open through the use of a position monitoring switch and

interlocked to prevent the introduction of flammable gas. [**86:**14.5.3.15.2.2]

15.3.1.2.3.11 Manual air release valves shall not be permitted. [**86:**14.5.3.1.11]

15.3.1.2.3.12 Vacuum furnaces that rely on a partial vacuum to hold the door closed shall incorporate a pressure switch, independent of the chamber pressure control device, to terminate flammable gas addition before the backfill pressure rises to a point where door clamping is lost. [**86:**14.5.3.1.12]

15.3.1.2.3.13 Vacuum furnaces that are backfilled with flammable gases to pressures greater than that required to hold the door closed shall incorporate clamps and seals to ensure the door is tightly and positively sealed. [**86:**14.5.3.1.13]

15.3.1.2.3.14* Sight glasses, where provided, shall be valved off before operation with flammable gases, except for sight glasses used solely for pyrometers. [**86:**14.5.3.1.14]

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15.3.1.2.4 Processing of Flammable Gases for Class D-3 Furnaces. [86:14.5.3.2]

Δ **15.3.1.2.4.1** During processing, flammable gases shall be exhausted from vacuum furnaces by pumping them through the vacuum pumps. [**86:**14.5.3.2.1]

15.3.1.2.4.2 If the flammable gas is exhausted through a vacuum pump, the system shall be designed to prevent air backflow if the pump stops. [**86:**14.5.3.2.2]

Δ **15.3.1.2.4.3** Venting of the vacuum pump shall be in accordance with 14.2.8 of NFPA 86, and one of the following actions shall be taken during flammable gas operation:

(1) The pump discharge shall be diluted with inert gas to lower the combustible level of the mixture below the LFL.
(2) The pump discharge shall be passed through a burner.

[**86:**14.5.3.2.3]

N **15.3.1.2.5 Processing of Flammable Gases for Class D-4 Furnaces. [86:14.5.3.3]**

N **15.3.1.2.5.1** During processing, flammable gases shall be exhausted from vacuum furnaces by venting in continuous flow to the atmosphere. [**86:**14.5.3.3.1]

15.3.1.2.5.2 If the flammable gas is vented to the atmosphere directly without passing through the vacuum pumps, the vent line shall be provided with a means of preventing air from entering the furnace chamber. [**86:**14.5.3.3.2]

15.3.1.2.5.3 If the flammable gas is vented to the atmosphere through a burner, all of the following shall apply:

(1) The vent line shall be provided with a means of preventing air from entering the furnace chamber.
(2) The existence of the burner ignition source shall be monitored independently.
(3) Interlocks shall be provided to shut off the flammable gas supply and initiate inert gas purge if the flame is not sensed.

[**86:**14.5.3.3.3]

15.3.1.2.5.4 For Mode D-4 operations, the following criteria shall be met:

(1) A pressure switch shall be interlocked to close the flammable gas supply if the chamber pressure exceeds the maximum operating pressure.
(2) The pressure switch shall be independent of the chamber pressure control device.
(3) A pressure switch shall be interlocked to close the flammable gas supply and initiate purge if the chamber pressure drops below the minimum operating pressure.

[**86:**14.5.3.3.4]

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15.3.1.2.5.5 Where flammable gas is exhausted through a vent (not through the pump), the vent valve shall not open until a pressure above atmosphere is attained in the chamber. [**86:**14.5.3.3.5]

15.3.1.2.6 Purge-out Requirements. [86:14.5.3.4]

N **15.3.1.2.6.1** Written purge-out instructions shall be provided for each furnace. [**86:**14.5.3.4.1]

N **(A)** Purge effectiveness shall not be compromised during the purge process. [**86:**14.5.3.4.1.1]

N **(B)** Furnace doors and covers shall be positioned in accordance with the manufacturer's instructions before purge-out begins. [**86:**14.5.3.4.1.2]

(C) When purge is initiated, the flammable gas valve(s) shall be closed. [**86:**14.5.3.4.1.3]

Δ **15.3.1.2.6.2** Purging shall be complete when any of the following criteria is satisfied:

(1) Two consecutive analyses of the vent gas from the furnace indicate that less than 50 percent of the LFL has been reached.
(2) Five furnace volume changes with inert gas have occurred.
(3) The furnace is pumped down to a minimum vacuum level of 1×10^{-1} torr (13.3 Pa) prior to inert gas backfill.

[**86:**14.5.3.4.2]

N **15.3.1.2.7 Removal of Flammable Special Atmospheres by Purge-out. [86:14.5.3.12]**

N **15.3.1.2.7.1** Where utilized, the removal of flammable special atmospheres by purge-out or emergency purge-out shall be initiated under the following conditions:

(1) Normal furnace purge-out initiated
(2) For vacuum furnaces operating in Mode D-4, low flow of flammable gas(es) that will not maintain a positive pressure and positive pressure not restored by the automatic transfer to another source of gas
(3) A furnace temperature below which any volatile, flammable liquids injected into the furnace will not vaporize
(4) Automatic emergency inert gas purge initiated
(5) Manual operator emergency inert gas purge initiated

[**86:**14.5.3.12.1]

N **15.3.1.2.7.2** When purge is initiated, all special atmosphere safety shutoff valves shall automatically close, and remain closed for the entire purge duration. [**86:**14.5.3.12.2]

N **15.3.1.2.8 Flammable Special Atmosphere Safety Shutoff Valves — General. [86:14.5.3.13]**

N **15.3.1.2.8.1** The flammable gas supply shall be connected to the vacuum chamber through a normally closed automatic safety shutoff valve. [**86:**14.5.3.13.1]

N **15.3.1.2.8.2** Vacuum furnaces operating in Mode D-3 that rely on a partial vacuum to hold the door closed shall have the flammable gas supply connected to the vacuum chamber through two normally closed automatic safety shutoff valves. [**86:**14.5.3.13.2]

N **15.3.1.2.8.3** Safety shutoff valve components shall be of materials selected for compatibility with the gas or liquid handled and for ambient conditions. [**86:**14.5.3.13.3]

N **15.3.1.2.8.4** Means for testing all gas safety shutoff valves for valve seat leakage shall be installed. [**86:**14.5.3.13.4]

N **15.3.1.2.8.5** A test of seat leakage of gas safety shutoff valves shall be completed at least annually. *[See A.15.3.1.1.12.11(E)].* [**86:**14.5.3.13.5]

N **15.3.1.2.9 Flammable Special Atmosphere Safety Shutoff Valves. [86:14.5.3.14]**

N **15.3.1.2.9.1** For furnaces using purge-in procedures to introduce flammable special atmosphere gases, the furnace shall be designed to operate with an automatic inert gas purge that automatically verifies the presence of the required inert gas pressure. [**86:**14.5.3.14.1]

N **15.3.1.2.9.2** For furnaces complying with 15.3.1.2.9.1, one of the following shall be required:

(1) Flammable special atmosphere gases shall not be permitted to enter the furnace until the purge-in process is complete.
(2) Operator action shall be required to open the flammable special atmosphere safety shutoff valve.

[**86:**14.5.3.14.2]

N **15.3.1.2.9.3** For Class D-4 furnaces that introduce special atmosphere gases that are not carrier gases, the safety shutoff valves for the noncarrier gases shall open only when the carrier gas flow has been established. [**86:**14.5.3.14.3]

N **15.3.1.2.9.4** Flammable special atmosphere safety shutoff valves shall automatically close upon occurrence of any of the following conditions:

(1) Emergency purge pressure becomes too low to allow purging in accordance with 15.3.1.2.10.1
(2) Normal furnace atmosphere purge-out initiated
(3) Low flow of Mode D-4 carrier gas(es) that will not maintain a positive pressure and the positive pressure is not restored by the automatic transfer to another source of gas
(4) A furnace temperature below which any volatile flammable liquids injected into the furnace will not vaporize
(5) Automatic emergency inert gas purge initiated
(6) Manual operator emergency inert gas purge initiated
(7) Power failure
(8) Liquid carrier gas excess flow

[**86:**14.5.3.14.4]

N **15.3.1.2.10 Emergency Inert Gas Purge. [86:14.5.3.15]**

N **15.3.1.2.10.1** A minimum supply of inert purge gas equal to five times the total vacuum system volume shall be available during operation with flammable atmospheres. [**86:**14.5.3.15.1]

N **15.3.1.2.10.2** The purge gas supply shall be connected to the vacuum chamber through a normally open valve. [**86:**14.5.3.15.2]

N **(A)** A pressure sensor shall monitor the purge gas line pressure and shall stop the supply of flammable gas if the pressure becomes too low to allow purging in accordance with 15.3.1.2.10.1.[**86:**14.5.3.15.2.1]

N **(B)** Any manual inert purge gas shutoff valves shall be proved open through the use of a position monitoring switch and interlocked to prevent the introduction of flammable gas. [**86:**14.5.3.15.2.2]

N **(C)** The emergency inert gas purge shall be initiated upon any of the following conditions:

(1) For Class D-4 vacuum furnaces, low flow of flammable gas(es) that will not maintain a positive pressure and positive pressure not restored by the automatic transfer to another source of gas
(2) A furnace temperature below which any volatile flammable liquids injected into the furnace will not vaporize
(3) Manual operator emergency inert gas purge initiated
(4) Power failure

[**86:**14.5.3.15.3]

15.3.1.2.11* Emergency Shutdown Procedure. In the event of an electrical power failure or flammable gas failure, the system shall be purged in accordance with 15.3.1.2.6. [**86:**14.5.3.16]

15.3.2* Hydrogen Cooled Generators.

15.3.2.1 General.

15.3.2.1.1 Subsection 15.3.2 shall apply to electric power-generating equipment that employs a hydrogen atmosphere to provide cooling of the equipment or power-generation efficiency gains or both.

15.3.2.1.1.1 The storage and delivery piping systems and equipment for hydrogen-cooled generators shall comply with the applicable requirements of Chapters 1 and 4 and Chapters 6 through 8 and the modifications identified herein.

15.3.2.1.1.2 If the hydrogen supply is an active gas-generation device, such as an electrolyzer or a reformer, the applicable provisions of Chapter 13 shall apply.

15.3.2.1.2 Monitoring of Hydrogen Atmosphere.

15.3.2.1.2.1 The internal atmosphere of the generator shall be monitored to ensure maintenance of hydrogen purity at 85 percent or better.

15.3.2.1.2.2 Warnings of low purity shall be provided to the operator(s).

15.3.2.1.3 Ignition Sources.

15.3.2.1.3.1* The area classification around hydrogen-cooled generators shall, at a minimum, be in accordance with ANSI/IEEE C2, *National Electrical Safety Code*.

15.3.2.1.3.2 Installations in which the generator is coupled to the exhaust end of a gas turbine, or in which the high-pressure section of a steam turbine results in the generator being in the proximity of hot surfaces that might exceed 1000°F (538°C), shall require risk mitigations for potentially hazardous areas associated with the generator intersecting such hot surfaces.

15.3.2.1.3.3 As a function of necessary design, generators might contain electrical ignition sources in close proximity (i.e., field excitation brushes, shaft grounding brushes, and various high-current electrical devices necessary for control of the generator output).

15.3.2.1.3.4 The presence of potential ignition sources shall be considered when providing risk mitigation.

15.3.2.1.4 Seal Oil Systems.

15.3.2.1.4.1 Where seal oil systems are used, the oil pressure shall be monitored to detect system failure.

(A) Where automatic shutdown capability exists, system failure shall automatically shut the unit down.

(B) If there is no automatic shutdown capability, an operator alarm shall be provided to enable timely operator action to shut the unit down.

15.3.2.1.4.2 The seal oil system shall include a secondary system capable of providing full seal oil pressure for the time required to reduce the speed to the manufacturer's recommended RPM to purge the generator of hydrogen.

15.3.2.1.4.3 Where an automatic purge capability is available, loss of seal oil pressure shall initiate the automatic purge of the generator hydrogen once the unit RPM has been reduced to the manufacturer's recommended purge speed.

15.3.2.1.4.4 Warnings of loss of seal oil pressure shall be provided to the operator(s).

15.3.2.2 Indoor Installations.

15.3.2.2.1* Buildings that enclose hydrogen-cooled generator installations shall be ventilated to avoid flammable gas buildup from potential system leaks.

15.3.2.2.2 The building ceiling shall avoid features that could trap hydrogen gas, such as solid beams that form a tight fit with the roof deck.

15.3.2.2.3 The building designer shall consider the use of redundant fans and hydrogen detection systems in the design of the ventilation system.

15.3.2.2.4* All hydrogen system vents shall be routed to an appropriate area outside the building and meet the requirements of Chapters 5 through 8, as applicable.

15.3.2.3 Outdoor Installations.

15.3.2.3.1 The potentially hazardous area surrounding a hydrogen-cooled generator and associated equipment shall not intersect with heating, ventilating, and air-conditioning (HVAC) air intakes and windows, doors, and other openings into occupied spaces (e.g., control rooms and break rooms).

15.3.2.3.2* All hydrogen system vents shall be routed to an appropriate point above other equipment and buildings and meet the requirements of Chapters 5 through 8 as applicable.

15.4 Storage.

15.4.1 Requirements for Hydrogen Storage Systems Serving Furnace Installations.

15.4.1.1* General. The storage of GH_2 or LH_2 serving furnace installations shall be in accordance with Chapters 6 through 8, as applicable.

15.4.1.2 Indoor Storage. (Reserved)

15.4.1.3 Outdoor Storage. (Reserved)

15.4.2 Requirements for Hydrogen Storage Systems Serving Hydrogen-Cooled Generators.

15.4.2.1 General. The storage of GH_2 or LH_2 serving hydrogen-cooled generators shall be in accordance with Chapters 6 through 8, as applicable.

15.4.2.2 Indoor Storage. (Reserved)

15.4.2.3 Outdoor Storage. (Reserved)

Chapter 16 Laboratory Operations

16.1 Scope. The requirements of this chapter shall apply to the storage, use, and handling of GH_2 and LH_2 in laboratories, laboratory buildings, laboratory units, or laboratory work areas as defined by Chapter 3.

16.1.1 Application.

16.1.1.1 The requirements of this chapter shall apply to the storage, use, handling, or dispensing of GH_2 in laboratory buildings, laboratory units, and laboratory work areas, whether located above or below grade, where the amount of GH_2 exceeds 75 scf (2.2 standard m^3) or the amount of LH_2 exceeds 1 gal (3.8 L).

16.1.1.2 The storage, use, and handling of GH_2 in any quantity shall also comply with the requirements of Chapters 1 and 4 and the requirements of Chapters 5 through 8, as applicable.

16.1.1.3 Chapters 4 and 6 through 8 contain fundamental requirements that shall apply to all hydrogen systems.

16.1.1.4 The use-specific requirements of this chapter for hydrogen in laboratory operations shall apply.

16.1.1.5 Where there is a conflict between a fundamental requirement and a use-specific requirement, the use-specific requirement shall apply.

16.1.2 This chapter shall not apply to the following:

(1) Laboratory units that contain less than 75 scf (2.2 standard m^3) of GH_2 or 1 gal (3.8 L) of LH_2
(2)* Laboratories that are pilot plants
(3) Laboratories that are primarily manufacturing plants
(4) Incidental testing facilities

16.2 General.

16.2.1 Means of Access to an Exit.

16.2.1.1* A second means of access to an exit shall be provided from a laboratory work area if any of the following situations exist: [**45:**5.3.1]

(1) A laboratory work area contains an explosion hazard located so that an incident would block escape from or access to the laboratory work area. [**45:**5.3.1(1)]
(2) A hood in a laboratory work area is located adjacent to the primary means of exit access. [**45:**5.3.1(4)]
(3) A compressed gas cylinder larger than lecture bottle size [approximately 2 in. × 13 in. (5 cm × 33 cm)] is located such that it could prevent safe egress in the event of accidental release of cylinder contents. [**45:**5.3.1(5)]
(4) A cryogenic container is located such that it could prevent safe egress in the event of accidental release of container contents. [**45:**5.3.1(6)]

16.2.1.2 Emergency lighting shall be provided for laboratory work areas. [**45:**5.5.3.1]

16.2.1.3 Emergency lighting shall be installed in accordance with Section 7.9 of NFPA *101.* [**45:**5.3.2]

16.2.2 Electrical Installation. All electrical installations, including wiring and appurtenances, apparatus, lighting, signal systems, alarm systems, remote control systems, or parts thereof, shall comply with *NFPA 70.* [**45:**5.5]

16.2.2.1* Laboratory work areas, laboratory units, and chemical fume hood interiors shall be considered as unclassified electrically with respect to Article 500 [or Article 505] of *NFPA 70*, unless operations are determined to cause a hazardous atmosphere. [**45:**5.5.2]

16.2.3 Fire Protection.

16.2.3.1 Automatic Fire Extinguishing Systems.

16.2.3.1.1 Automatic Sprinkler Systems.

16.2.3.1.1.1 A fire protection system shall be provided for laboratories in accordance with Chapter 6.

16.2.3.1.1.2* Fire sprinklers in laboratory units shall be the quick-response (QR) sprinkler type installed in accordance with NFPA 13. [**45:**6.1.1.2]

16.2.3.1.1.3 Automatic sprinkler systems shall be regularly inspected, tested, and maintained in accordance with NFPA 25. [**45:**6.1.1.3]

16.2.3.2 Fire Alarm Systems.

16.2.3.2.1 A fire alarm system shall be provided for laboratories in accordance with Chapter 6.

16.2.3.2.2 The fire alarm system shall activate fire alarm notification appliances and notify the fire department. [**45:**6.4.3]

16.2.3.3 Standpipe and Hose Systems.

16.2.3.3.1* Class I wet standpipe systems shall be installed in laboratory buildings where the floor of the highest story is located more than 30 ft (9.14 m) above the lowest level of fire department vehicle access, or where the floor level of the lowest story is located more than 30 ft (9.14 m) below the highest level of fire department vehicle access in accordance with NFPA 14. [**45:**6.2.1]

16.2.3.3.2* Standpipe systems shall be regularly inspected, tested, and maintained in accordance with NFPA 25. [**45:**6.2 2]

16.2.3.4 Portable Fire Extinguishers. Portable fire extinguishers shall be installed, located, and maintained in accordance with NFPA 10. [**45:**6.3.1]

16.2.4 Explosion Hazard Protection. A laboratory work area shall be considered to contain an explosion hazard if an explosion involving hydrogen could result in significant damage to a facility or serious injuries to personnel within that laboratory work area.

16.2.5 Fire Prevention.

16.2.5.1 Fire Prevention Procedures.

16.2.5.1.1 Fire prevention procedures shall be established for all new and existing laboratories. [**45:**6.5.1.1]

16.2.5.1.2 Fire prevention procedures shall include, but not be limited to, the following:

(1) Handling and storage of [GH_2 and LH_2]
(2) Open flame and spark-producing equipment work permit system
(3) Arrangements and use of portable electric cords
(4) Smoking area controls

[**45:**6.5.1.2]

16.2.5.2* Maintenance Procedures. Maintenance procedures shall be established for all new and established laboratories. [**45:**6.5.2]

16.2.5.3* Emergency Plans.

Δ **16.2.5.3.1** The emergency action plan shall include the following procedures in the event of a chemical emergency, fire, or explosion:

(1) Procedures for sounding the alarm
(2) Procedures for notifying and coordinating with the fire department, governmental agencies, or other emergency responders or contacts, as required
(3) Procedures for evacuating and accounting for personnel, as applicable
(4) Procedures for establishing requirements for rescue and medical duties for those requiring or performing these duties
(5) Procedures and schedules for conducting drills
(6) Procedures for shutting down and isolating equipment under emergency conditions to include the assignment of personnel responsible for maintaining critical plant functions or for shutdown of process operations
(7) Appointment and training of personnel to carry out assigned duties, including steps to be taken at the time of initial assignment, as responsibilities or response actions change, and at the time anticipated duties change
(8) Alternative measures for occupant safety, when applicable
(9) Aisles designated as necessary for movement of personnel and emergency response
(10) Maintenance of fire protection equipment
(11) Safe procedures for startup to be taken following the abatement of an emergency

[**400:**7.2.3.2]

16.2.5.3.2* Procedures for extinguishing clothing fires shall be established for all new and existing laboratories. [**45:**6.5.3.2]

16.2.5.3.3 All laboratory users, including, but not limited to, instructors and students, shall be trained prior to laboratory use and at least annually thereafter on the emergency plan. [**45:**6.5.3.3]

16.3 Use.

16.3.1 General.

16.3.1.1 Instructional Laboratories. Experiments and tests conducted in educational and instructional laboratory units shall be under the direct supervision of an instructor.

16.3.1.2 Cylinders in Use.

16.3.1.2.1 Cylinders, when in use, shall be connected to gas delivery systems designed by a qualified person. [**45:**10.1.6.1]

16.3.1.2.2 Cylinders shall be attached to an instrument for use by means of a regulator. [**45:**10.1.6.2]

16.3.1.2.3 A compressed gas cylinder shall be considered to be "in use" if it is in compliance with one of the following:

(1) Connected through a regulator to deliver gas to a laboratory operation
(2) Connected to a manifold being used to deliver gas to a laboratory operation
(3) A single cylinder secured alongside the cylinder described in 16.3.1.2.3(1) as the reserve cylinder for the cylinder described in 16.3.1.2.3(1).

[**45:**10.1.6.3]

16.3.1.2.4 Cylinders not "in use" shall not be stored in the laboratory unit. [**45:**10.1.6.4]

16.3.2 Indoor Use.

16.3.2.1 Laboratory Ventilating Systems and Hood Requirements.

16.3.2.1.1* General.

16.3.2.1.1.1 This chapter shall apply to laboratory exhaust systems, including chemical fume hoods, local ventilated enclosures, fume arms, special local exhaust devices, and other systems for exhausting air from laboratory work areas in which [GH_2 or LH_2] are released. [**45:**7.1.1]

16.3.2.1.1.2 This chapter shall apply to laboratory air supply systems and shall provide requirements for identification, inspection, and maintenance of laboratory ventilation systems and hoods. [**45:**7.1.2]

16.3.2.1.2 Basic Requirements.

16.3.2.1.2.1* Laboratory ventilation systems shall be designed to ensure that fire hazards and risks are minimized. [**45:**7.2.1]

16.3.2.1.2.2* Laboratory units and laboratory hoods in which [GH_2 or LH_2] are present shall be continuously ventilated under normal operating conditions. [**45:**7.2.2]

16.3.2.1.2.3* Chemical fume hoods shall not be relied upon to provide explosion (blast) protection unless specifically designed to do so. *(See also H.6.4 and H.6.5 for further information on explosion-resistant hoods and shields.)* [**45:**7.2.3]

16.3.2.1.2.4 Exhaust and supply systems shall be designed to prevent a pressure differential that would impede egress or ingress when either system fails or during a fire or emergency scenario. This design includes reduced operational modes or shutdown of either the supply or exhaust ventilation systems. [**45:**7.2.5]

16.3.2.1.2.5 The release of [GH_2] into the laboratory shall be controlled by enclosure(s) or captured to prevent any flammable concentrations of vapors from reaching any source of ignition. [**45:**7.2.6]

16.3.2.1.3 Supply Systems.

16.3.2.1.3.1 Laboratory ventilation systems shall be designed to ensure that [GH_2] originating from the laboratory shall not be recirculated. [**45:**7.3.1]

16.3.2.1.3.2* The location and configuration of fresh air intakes shall be chosen so as to avoid drawing in [GH_2] or products of combustion coming either from the laboratory building itself or from other structures and devices. [**45:**7.3.2]

16.3.2.1.3.3 The air pressure in the laboratory work areas shall be negative with respect to corridors and non-laboratory areas of the laboratory unit except in the following instances:

(1) Where operations such as those requiring clean rooms preclude a negative pressure relative to surrounding areas, alternate means shall be provided to prevent escape of the atmosphere in the laboratory work area or unit to the surrounding spaces.
(2) The desired static pressure level with respect to corridors and non-laboratory areas shall be permitted to undergo momentary variations as the ventilation system components respond to door openings, changes in chemical fume hood sash positions, and other activities that can for a short term affect the static pressure level and its negative relationship.
(3) Laboratory work areas located within a designated electrically classified hazardous area with a positive air pressure system as described in NFPA 496, Chapter 7, Pressurized Control Rooms, shall be permitted to be positive with respect to adjacent corridors.

[**45:**7.3.3]

16.3.2.1.3.4* The location of air supply diffusion devices shall be chosen so as to avoid air currents that would adversely affect the performance of chemical fume hoods, exhaust systems, and fire detection or extinguishing systems. *(See 16.2.3.1, 16.2.3.2, and 16.3.2.1.8.1.)* [**45:**7.3.4]

16.3.2.1.4 Exhaust Air Discharge.

16.3.2.1.4.1* Air exhausted from chemical fume hoods and other special local exhaust systems shall not be recirculated. *(See also 16.3.2.1.3.1.)* [**45:**7.4.1]

16.3.2.1.4.2* Energy Conservation Devices.

(A) If energy conservation devices are used, they shall be designed in accordance with 16.3.2.1.3.1 and 16.3.2.1.3.3. [**45:**7.4.2.1]

(B) Energy conservation devices shall only be used in a laboratory ventilation system when evaluated and approved by a qualified person. These systems must meet, or exceed, the criteria established by Section 5.4.7 and Section 5.4.7.1 of ANSI/AIHA Z9.5, *Laboratory Ventilation*. Systems that recirculate within their respective laboratory area, such as fan coil units for sensible heat loads, are exempt from these requirements. [**45:**7.4.2.2]

(C) Energy conservation devices shall be designed and installed in a manner that safely facilitates anticipated service and maintenance requirements and does not adversely impact the proper operation of the exhaust system. [**45:**7.4.2.3]

16.3.2.1.4.3 Air exhausted from laboratory work areas shall not pass unducted through other areas. [**45:**7.4.3]

16.3.2.1.4.4* Air from laboratory units and laboratory work areas in which [GH_2] is present shall be continuously discharged through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building. [**45:**7.4.4]

16.3.2.1.4.5 Positive pressure portions of the lab hood exhaust systems (e.g., fans, coils, flexible connections, and ductwork) located within the laboratory building shall be sealed airtight or located in a continuously mechanically ventilated room. [**45:**7.4.5]

16.3.2.1.4.6 Chemical fume hood face velocities and exhaust volumes shall be sufficient to contain [GH_2] generated within the hood and exhaust them outside of the laboratory building. [**45:**7.4.6]

16.3.2.1.4.7* The hood shall provide containment of the possible hazards and protection for personnel at all times when [GH_2 is] present in the hood. [**45:**7.4.7]

16.3.2.1.4.8 Special local exhaust systems, such as snorkels or "elephant trunks," shall have sufficient capture velocities to entrain the [GH_2] being released. [**45:**7.4.8]

16.3.2.1.4.9* Canopy hoods, laminar flow cabinets, and ductless enclosures shall not be used in lieu of chemical fume hoods. [**45:**7.4.9]

16.3.2.1.4.10 Laminar flow cabinets shall not be used in lieu of chemical fume hoods.

16.3.2.1.4.11* Air exhausted from chemical fume hoods and special exhaust systems shall be discharged above the roof at a location, height, and velocity sufficient to prevent re-entry of chemicals and to prevent exposures to personnel. [**45:**7.4.11]

16.3.2.1.5 Duct Construction for Hoods and Local Exhaust Systems.

16.3.2.1.5.1 Ducts from chemical fume hoods and from local exhaust systems shall be constructed entirely of noncombustible materials except in the following cases:

(1) Flexible ducts of combustible construction shall be permitted to be used for special local exhaust systems within a laboratory work area. *(See 16.3.2.1.5.2.)*
(2) Combustible ducts shall be permitted to be used if enclosed in a shaft of noncombustible or limited-combustible construction where they pass through nonlaboratory areas or through laboratory units other than the one they serve. *(See 16.3.2.1.5.2.)*
(3) Combustible ducts shall be permitted to be used if all areas through which they pass are protected with an approved automatic fire extinguishing system, as described in 16.2.3. *(See 16.3.2.1.5.2.)*

[**45:**7.5.1]

16.3.2.1.5.2 Combustible ducts or duct linings shall have a flame spread index of 25 or less when tested in accordance with ASTM E84 *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials.* Test specimens shall be of the minimum thickness used in the construction of the duct or duct lining. [**45:**7.5.2]

16.3.2.1.5.3 Ducts shall be of adequate strength and rigidity to meet the conditions of service and installation requirements and shall be protected against mechanical damage. [**45:**7.5.5]

16.3.2.1.5.4 Materials used for vibration isolation connectors shall comply with 16.3.2.1.5.2. [**45:**7.5.6]

16.3.2.1.5.5 Controls and dampers, where required for balancing or control of the exhaust system, shall be of a type that, in event of failure, will fail open to ensure continuous draft. *(See 16.3.2.1.9.3 through 16.3.2.1.9.5.)* [**45:**7.5.10.1.1]

16.3.2.1.5.6 Hand holes, where installed for damper, sprinkler, or fusible link inspection or resetting and for residue clean-out purposes, shall be equipped with tight-fitting covers provided with substantial fasteners. [**45:**7.5.8]

16.3.2.1.5.7 Manifolding of Chemical Fume Hood and Ducts.

(A) Exhaust ducts from each laboratory unit shall be separately ducted to a point outside the building, to a mechanical room, or to a shaft. [**45:**7.5.9.1]

(B) Connection to a common chemical fume hood exhaust duct system shall be permitted to occur within a building only in any of the following locations:

(1) A mechanical room, not connected to a shaft, shall be protected in accordance with Table 5.1.1 of NFPA 45.
(2) A shaft or a mechanical room connected to a shaft, shall be protected in accordance with the chapter on protection of vertical openings of NFPA *101*
(3) A point outside the building

[**45:**7.5.9.2]

(C) Exhaust ducts from chemical fume hoods and other exhaust systems within the same laboratory unit shall be permitted to be combined within that laboratory unit. *(See 16.3.2.1.4.1.)* [**45:**7.5.9.3]

16.3.2.1.6 Exhausters (Fans), Controls, Velocities, and Discharge.

16.3.2.1.6.1 Fans shall be selected to meet requirements for fire, explosion, and corrosion. [**45:**7.7.1]

16.3.2.1.6.2 Fans conveying both corrosive and flammable or combustible materials shall be permitted to be lined with or constructed of corrosion-resistant materials having a flame spread index of 25 or less when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials.* [**45:**7.7.2]

16.3.2.1.6.3 Fans shall be located and arranged so as to afford ready access for repairs, cleaning, inspection, and maintenance. [**45:**7.7.3]

16.3.2.1.6.4* Where [GH_2 is] passed through the fans, the rotating element shall be of nonferrous or spark-resistant construction; alternatively, the casing shall be constructed of or lined with such material. [**45:**7.7.4]

(A) Nonferrous or spark-resistant materials shall have a flame spread index of 25 or less when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials.* [**45:**7.7.4.2]

16.3.2.1.6.5 Motors and their controls shall be located outside the location where [GH_2 is] generated or conveyed, unless specifically approved for that location and use. [**45:**7.7.5]

16.3.2.1.6.6* Fans shall be marked with an arrow or other means to indicate direction of rotation and with the location of chemical fume hoods and exhaust systems served. [**45:**7.7.6]

16.3.2.1.7 Chemical Fume Hood Requirements. *(See also 16.3.2.1.2.2.)* [**45:**7.8]

16.3.2.1.7.1 Chemical Fume Hood Interiors.

(A)* Materials of construction used for the interiors of new chemical fume hoods or for the modification of the interiors of existing chemical fume hoods shall have a flame spread index of 25 or less when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*, unless the interior of the hood is provided with automatic fire protection in accordance with 16.3.2.1.9.2. [**45:**7.8.1.1]

(B)* Baffles shall be constructed so that they are unable to be adjusted to materially restrict the volume of air exhausted through the chemical fume hood. [**45:**7.8.1.3]

(C)* Chemical fume hoods shall be provided with a means of preventing overflow of a spill of 0.5 gal (2 L) of liquid. [**45:**7.8.1.4]

16.3.2.1.7.2* Chemical Fume Hood Sash Glazing. The sash, if provided, shall be glazed with material that will provide protection to the operator against the hazards associated with the use of the hood. *(See also Annex H.)* [**45:**7.8.2]

16.3.2.1.7.3* Chemical Fume Hood Sash Closure.

(A) Chemical fume hood sashes shall be kept closed whenever possible. [**45:**7.8.3.1]

(B) When a fume hood is unattended, its sash shall remain fully closed. [**45:**7.8.3.2]

16.3.2.1.7.4* Electrical Devices.

(A) In installations where services and controls are within the hood, additional electrical disconnects shall be located within 50 ft (15 m) of the hood and shall be accessible and clearly marked. [**45:**7.8.4.1]

(B) If electrical receptacles are located external to the hood, no additional electrical disconnect shall be required. [**45:**7.8.4.2]

16.3.2.1.7.5 Other Hood Services.

(A) For new installations or modifications of existing installations, controls for chemical fume hood services (gas, air, water, etc.) shall be located external to the hood and within easy reach. [**45:**7.8.5.1]

(B) In existing installations where service controls are within the hood, additional shutoffs shall be located within 50 ft (15 m) of the hood and shall be accessible and clearly marked. [**45:**7.8.5.2]

16.3.2.1.7.6 Auxiliary Air. For auxiliary air hoods, auxiliary air shall be introduced exterior to the hood face in such a manner that the airflow does not compromise the protection provided by the hood and so that an imbalance of auxiliary air to exhaust air will not pressurize the hood interior. [**45:**7.8.6]

16.3.2.1.7.7 Hood Proper Function Alarm.

(A)* A measuring device for indicating that the hood airflow remains within safe design limits shall be provided on each chemical fume hood. [**45:**7.8.7.1]

(B)* The measuring device for hood airflow shall be a permanently installed device and shall provide continuous indication to the hood user of adequate airflow and alert inadequate hood airflow by a combination of an audible and visual alarm. Where an audible alarm could compromise the safety of the user or the research, alternative means of alarm shall be considered. [**45:**7.8.7.2]

16.3.2.1.8 Chemical Fume Hood Location.

16.3.2.1.8.1* Chemical fume hoods shall be located in areas of minimum air turbulence. [**45:**7.9.1]

16.3.2.1.8.2 Chemical fume hoods shall not be located adjacent to a single means of access to an exit or to high-traffic areas. [**45:**7.9.2]

16.3.2.1.8.3* Work stations not directly related to the chemical fume hood activity shall not be located directly in front of chemical fume hood openings. [**45:**7.9.3]

16.3.2.1.9 Chemical Fume Hood Fire Protection.

16.3.2.1.9.1 Automatic Fire Protection.

(A)* Automatic fire protection systems shall be provided in chemical fume hoods as provided in 16.3.2.1.9.1(B). [**45:**7.10.1]

(B) If a hazard assessment shows that an automatic extinguishing system is required for the chemical fume hood, then the applicable automatic fire protection system standard shall be followed. [**45:**7.10.2.1]

16.3.2.1.9.2 Automatic fire protection systems, where provided, shall comply with the following standards, as applicable:

(1) NFPA 11
(2) NFPA 12
(3) NFPA 12A
(4) NFPA 13
(5) NFPA 15
(6) NFPA 17
(7) NFPA 17A
(8) NFPA 69
(9) NFPA 750
(10)* NFPA 2001

[**45:**7.10.2.1]

(A) The fire extinguishing system shall be designed to extinguish fires within the chemical fume hood under the anticipated conditions of use. [**45:**7.10.2.2]

16.3.2.1.9.3* The design and installation of laboratory exhaust ducts shall be in accordance with NFPA 91, except that the requirements of 7.5.10.1 through 7.5.12 in NFPA 45 shall take precedence. [**45:**7.5.10]

(A)* Automatic fire dampers shall not be used in laboratory exhaust systems. [**45:**7.5.10.1.2]

(B) A duct conveying laboratory exhaust that passes through a fire barrier shall provide an alternative means of protection equal to or greater than the rating through which the duct passes by one of the following or in accordance with 16.3.2.1.9.3(C): [**45:**7.5.10.2.1]

(1) Wrapped or encased with listed or approved materials having a fire-resistance rating equal to the fire barrier for 3.05 m (10 ft.) of the duct on each side of the barrier including duct supports within this span [**45:**7.5.10.2.1(1)]

(2) Constructed of materials and supports having a minimum fire resistance rating equal to the fire barrier [**45:**7.5.10.2.1(2)]
(3) Enclosed with a shaft that is constructed of material having a fire resistance rating equal to the fire barrier for 3.05 m (10 ft.) of the duct on each side of the fire barrier with no inlets to the duct within this distance, and the duct entry into and exit from the shaft is protected in accordance with 4.2.13 of NFPA 91. [**45:**7.5.10.2.1(3)]

(C) If not protected in accordance with 16.3.2.1.9.3(B), when an exhaust duct enters an exhaust shaft, the penetration shall be protected by all of the following:

(1) Branch ducts connect to enclosed exhaust risers meeting the requirements of 5.3.4.1 or 5.3.4.4 of NFPA 90A.
(2) The airflow moves upward.
(3)* Steel subducts at least 560 mm (22 in.) in length are carried up inside the riser from each inlet.
(4) The riser is appropriately sized to accommodate the flow restriction created by the subduct.

[**45:**7.5.10.2.2]

16.3.2.1.9.4 Fire detection and alarm systems shall not be interlocked to automatically shut down laboratory exhaust fans. [**45:**5.11]

16.3.2.1.9.5 Door operation for egress shall be maintained when the supply system shuts down and the lab exhaust system operates, creating a pressure differential. [**45:**7.5.12]

16.3.2.1.9.6 Chemical fume hoods equipped with control systems that vary the hood exhaust airflow as the sash opening varies and/or in conjunction with whether the laboratory room is in use (occupied or unoccupied) shall be equipped with a user-accessible means to attain maximum exhaust hood airflow regardless of sash position when necessary or desirable to ensure containment and removal of a potential hazard within the hood. [**45:**7.10.3]

16.3.2.1.9.7* Chemical fume hoods shall be installed in a manner that prevents fire or smoke from a fire in the chemical fume hood from spreading into the voids above the ceiling. [**45:**7.10.4]

16.3.2.1.10 Identification of Chemical Fume Hood Systems.

16.3.2.1.10.1* Special-use chemical fume hoods and special-use local exhaust systems shall be identified to indicate their intended use. [**45:**7.13.1]

16.3.2.1.10.2 A sign containing the following information from the last inspection shall be affixed to each hood, or a properly maintained log of all hoods providing the following information shall be maintained:

(1) Inspection interval
(2) Last inspection date
(3) Average face velocity
(4) Location of fan that serves hood
(5) Inspector's name

[**45:**7.13.2]

16.3.2.1.11 Inspection, Testing, and Maintenance.

16.3.2.1.11.1* When installed or modified and at least annually thereafter, chemical fume hoods, chemical fume hood exhaust systems, and laboratory special exhaust systems shall be inspected and tested as applicable, as follows:

(1) Visual inspection of the physical condition of the hood interior, sash, and ductwork
(2) Measuring device for hood airflow
(3) Low airflow and loss-of-airflow alarms at each alarm location
(4) Face velocity
(5) Verification of inward airflow over the entire hood face
(6) Changes in work area conditions that might affect hood performance

[**45:**7.14.1]

16.3.2.1.11.2 Deficiencies in hood performance shall result in immediate suspension of all activities in the hood until the deficiencies can be corrected.

[**45:**7.14.2]

16.3.2.1.11.3 Chemical fume hood face velocity profile or hood exhaust air quantity shall be checked after any adjustment to the ventilation system balance. [**45:**7.14.3]

16.3.2.1.11.4 Detectors and Alarms. Air system flow detectors, if installed, shall be inspected and tested annually. [**45:**7.13.4.1]

16.3.2.1.11.5 Fans and Motors.

(A)* Air supply and exhaust fans, motors, and components shall be inspected at least annually. [**45:**7.14.5.1]

(B) Where airflow detectors are not provided or airflow-rate tests are not made, fan belts shall be inspected quarterly; double sheaves and belts shall be permitted to be inspected semiannually. [**45:**7.14.5.2]

(C) Frayed or broken belts shall be replaced promptly. [**45:**7.14.5.3]

16.3.2.2 Laboratory Operations and Apparatus.

16.3.2.2.1 Operations. This chapter shall apply to new and existing laboratories [**45:**11.1]

16.3.2.2.1.1* Hazards of Chemicals and Chemical Reactions.

(A) Before laboratory tests or chemical reactions are begun, evaluations shall be made for hazards that can be encountered or generated during the course of the work. [**45:**11.2.1.1]

(B) Evaluations shall include the hazards associated with the properties and the reactivity of the materials used and any intermediate and end products that can be formed, hazards associated with the operation of the equipment at the operating conditions, and hazards associated with the proposed reactions — for example, oxidation and polymerization. *[See also 16.3.2.2.1.1(D).]* [**45:**11.2.1.2]

(C) Regular reviews of laboratory operations and procedures shall be conducted with special attention given to any change in materials, operations, or personnel. [**45:**11.2.1.3]

(D)* Where reactions are being performed to synthesize materials, the hazard characteristics of which have not yet been determined by test, precautions shall be employed to control the highest possible hazard based on a known hazard of similar material. [**45:**11.2.1.4]

(E)* Where use of a new material or the premixing of flammable and oxidizing materials might present an explosion potential, initial experiments or tests shall be conducted in an enclosure that is designed to protect people and property from potential explosion damage. *(See 16.2.4.)* [**45:**11.2.1.5]

(F) Unattended or automatic laboratory operations involving hazardous chemicals shall be provided with regular surveillance for abnormal conditions. [**45:**11.2.1.6]

(1) All heating operations whether attended or unattended shall be provided with an independent high-temperature alarm and an automatic shutdown with manual reset to prevent system failure that can result in fire or explosion. [**45:**11.3.3.4]
(2) Electrically heated constant temperature baths shall be equipped with over-temperature shutoff switches in addition to normal temperature controls, if overheating could result in a fire or an explosion. [**45:**11.3.4.1]

16.3.2.2.1.2 Other Operations.

(A) Other laboratory operations, such as reactions at temperatures and pressures either above or below ambient conditions, shall be conducted in a manner that minimizes hazards. [**45:**11.2.7.1]

(B) Shielding shall be used whenever there is a reasonable probability of explosion or vigorous chemical reaction and associated hazards during charging, sampling, venting, and discharge of products. *(See 16.2.4 and 16.3.2.2.2.3.)* [**45:**11.2.7.2]

(C) Glass apparatus containing gas or vapors under vacuum or above ambient pressure shall be shielded, wrapped with tape, or otherwise protected from shattering (such as engineering controls or by apparatus design) during use. [**45:**11.2.7.3]

(D)* Quantities of reactants shall be limited and procedures shall be developed to control or isolate vigorous or exothermic reactions. [**45:**11.2.7.4]

(E) [GH_2] evolved during drying operations shall be condensed, trapped, or vented to avoid ignition. [**45:**11.2.7.5]

16.3.2.2.2 Apparatus.

16.3.2.2.2.1 General.

(A) Apparatus shall be installed in compliance with applicable requirements of NFPA standards, including *NFPA 70*. [**45:**11.3.1.1]

(B) Operating controls shall be accessible under normal and emergency conditions. [**45:**11.3.1.2]

16.3.2.2.2.2 Heating Equipment and Heating Operations.

(A) All heating of flammable liquids, combustible liquids, or flammable gases shall be conducted so as to minimize fire hazards. [**45:**11.3.3.1]

(B) Provisions shall be made to contain liquid that might be accidentally released from glass apparatus containing more than 8.45 oz (.25 L) of flammable liquid or combustible liquid heated to its flash point. [**45:**11.3.3.2]

(C) Supplementary fire-extinguishing equipment shall be provided, if necessary. [**45:**11.3.3.3]

(D) All heating operations whether attended or unattended shall be provided with a high-temperature alarm and an automatic shutdown with manual reset to prevent system failure that can result in fire or explosion. [**45:**11.3.3.4]

(E) Strong oxidizing materials, such as perchloric acid, shall not be heated by gas flames or oil baths. [**45:**11.3.3.5]

(F) Heating equipment with circulation fans or water cooling shall be equipped with an interlock arranged to disconnect current to the heating elements if the fan fails or the water supply is interrupted. [**45:**11.3.3.6]

(G) Burners, induction heaters, ovens, furnaces, and other heat-producing equipment shall be located a safe distance from areas where temperature-sensitive and flammable materials and [GH_2] are handled. [**45:**11.3.3.7]

(H) Oven and furnace installations shall comply with NFPA 86. [**45:**11.3.3.8]

16.3.2.2.2.3 Pressure Equipment.

(A)* Equipment used at pressures above 15 psi (103 kPa gauge) shall be designed and constructed by qualified individuals for use at the expected temperature, pressure, and other operating conditions affecting safety. [**45:**11.3.5.1]

(B) Pressure equipment shall be fitted with a pressure relief device, such as a rupture disc or a relief valve. The pressure relief device shall be vented to a safe location. [**45:**11.3.5.2]

(C) Equipment operated at pressures above 15 psi (103 kPa gauge), such as autoclaves, steam sterilizers, reactors, and calorimeters, shall be operated and maintained according to manufacturers' instructions, the design limitations of the equipment, and applicable codes and regulations. [**45:**11.3.5.3]

(1) Such equipment shall be inspected on a regular basis. [**45:**11.3.5.3.1]
(2) Any significant change in the condition of the equipment, such as corrosion, cracks, distortion, scale formation, or general chemical attack, or any weakening of the closure, or any inability of the equipment to maintain pressure, shall be documented and removed from service immediately and shall not be returned to service until approved by a qualified person. [**45:**11.3.5.3.2]

(D) Any pressure equipment that has been found to be degraded shall be derated or discarded, whichever is appropriate. [**45:**11.3.5.4]

16.3.2.2.2.4 Analytical Instruments.

(A) Analytical instruments, such as infrared, ultraviolet, atomic absorption, x-ray, mass spectrometers, chromatographs, and thermal analyzers, shall be installed in accordance with the manufacturers' instructions and applicable standards and codes. [**45:**11.3.6.1]

(B)* Analytical instruments shall be operated in accordance with manufacturers' instructions or approved recommended operating procedures. [**45:**11.3.6.2]

16.3.2.3 Hazard Identification. This chapter shall apply to new and existing laboratories. [**45:**13.1]

16.3.2.3.1* Exhaust Systems. Exhaust systems used for the removal of hazardous materials shall be identified to warn personnel of the possible hazards. [**45:**13.3]

16.3.2.3.2 Identification Systems. Graphic systems used to identify hazards shall comply with ANSI Z535.1, *Safety Colors*; ANSI Z535.2, *Environmental and Facility Safety Signs*; ANSI Z535.3, *Criteria for Safety Symbols*; and ANSI Z535.4, *Product Safety Signs and Labels*; or other approved graphic systems. [**45:**13.5]

16.3.3 Outdoor Dispensing. (Reserved)

16.4 Storage.

16.4.1 General.

16.4.1.1 GH_2 and LH_2 in Cylinders.

16.4.1.1.1 Cylinders shall be handled only by trained personnel. *(See Annex I.)*

16.4.1.1.2 Cylinder Safety.

16.4.1.1.2.1 Cylinders shall be secured in accordance with 7.1.7.4.

16.4.1.1.2.2 Cylinders in the laboratory shall be equipped with a pressure regulator designed for the specific gas and marked for its maximum cylinder pressure. [**45:**10.1.5.2]

(A) The regulator system shall be equipped with two gauges, either on the regulator or remote from the regulator, installed so as to show both the cylinder pressure and the outlet pressure. [**45:**10.1.5.2.1]

(B) Where the source cylinder is outside of the laboratory work area, a station regulator and inlet pressure gauge shall be installed at the point of use. [**45:**10.1.5.2.2]

(C) Cylinders shall have a manual shutoff valve. A quick connect shall not be used in place of a shutoff valve. [**45:**10.1.5.3]

16.4.1.2 Storage and Piping Systems.

16.4.1.2.1* The method of storage and piping systems for compressed and liquefied gases shall comply with Chapters 4, 6, 7, and 8.

16.4.1.2.2* Each point of use shall have an accessible manual shutoff valve. [**45:**10.2.3]

16.4.1.2.2.1 The manual shutoff valve at the point of use shall be located away from the potential hazards and be located within 6 ft (1.8 m) of the point of use. [**45:**10.2.3.1]

16.4.1.2.2.2 Where the cylinder valve is located within 6 ft (1.8 m), a separate point-of-use shutoff valve shall not be required. [**45:**10.2.3.2]

16.4.1.2.2.3 Line regulators that have their source away from the point of use shall have a manual shutoff valve on the high-pressure side of the regulator. [**45:**10.2.3.3]

16.4.1.2.2.4 Educational and instructional laboratory work areas that have flammable gas piped in from an external source shall have an emergency gas shutoff device in an accessible location near one of the egress doors from the laboratory work area in addition to valves required elsewhere. [**45:**10.2.3.4]

16.4.1.2.3* Every portion of a piping system shall be rated for a pressure equal to or greater than the maximum system pressure that can develop or shall have uninterruptible and adequately sized pressure relief. [**45:**10.2.4.1]

16.4.1.2.3.1* A pressure relief system shall be designed to provide a discharge rate sufficient to avoid further pressure increase and shall vent to a safe location. [**45:**10.2.4.2]

16.4.1.2.4* Permanent piping shall be identified at the supply point and at each discharge point with the name of the material being transported. [**45:**10.2.5]

16.4.1.2.5* Piping systems, including regulators, shall not be used for gases other than those for which they are designed and identified unless a thorough review of the design specifications, materials of construction, and service compatibility is made by a qualified person and any appropriate modifications have been made. [**45:**10.2.6]

16.4.1.3 LH_2.

16.4.1.3.1 All system components used for cryogenic fluids shall be selected and designed for such service. [**45:**10.4.1]

16.4.1.3.1.1 Design pressure for vessels and piping shall be not less than 150 percent of maximum pressure relief. [**45:**10.4.1.1]

16.4.1.3.1.2* Systems or apparatus handling a cryogenic fluid that can cause freezing or liquefaction of the surrounding atmosphere shall be designed to prevent contact of the condensed air with organic materials. [**45:**10.4.1.2]

16.4.1.3.2 Pressure relief of vessels and piping handling cryogenic fluids shall comply with the applicable requirements of 16.4.1.2. [**45:**10.4.2]

16.4.1.3.3 The space in which cryogenic systems are located shall be ventilated commensurate with the properties of [LH_2]. [**45:**10.4.3]

16.4.2 Indoor Storage. Cylinders [-]that are not necessary for current laboratory requirements shall be stored outside the laboratory unit in accordance with Chapters 7 and 9. [**45:**10.1.2]

16.4.3 Outdoor Storage.

16.4.3.1 [GH_2] cylinders installed or stored outside of laboratory buildings shall be installed and operated in accordance with Chapters 1 through 7. [**45:**10.3.1]

16.4.3.2 Compressed gas delivery systems shall be designed in accordance with Chapters 1 through 7. [**45:**10.3.2]

Chapter 17 Parking Garages

17.1 Scope.

17.1.1 This chapter shall apply to open and enclosed parking garages used to store self-propelled vehicles powered by GH_2 or LH_2.

17.1.2 This chapter also shall apply to storage of self-propelled vehicles powered by GH_2 or LH_2 within the residential garages of one- and two-family dwellings.

17.2 Application.

17.2.1 This chapter shall apply to buildings and parking structures that store self-propelled vehicles powered by GH_2 or LH_2.

17.2.2 This chapter shall not apply to dispensing of GH_2 or LH_2 or to storage or use of GH_2 or LH_2 in parking garages.

17.2.3 Storage or use of GH_2 or LH_2 other than within the fuel and propulsion systems of vehicles being stored shall not be allowed unless specifically approved by the authority having jurisdiction (AHJ).

17.3* Parking Garages. The storage of self-propelled vehicles powered by GH_2 or LH_2 in parking garages or residential garages associated with one- or two-family dwellings shall be subject to the same requirements applicable to vehicles powered by traditional fuels.

Chapter 18 Repair Garage

18.1 Scope.

18.1.1 This chapter shall apply to buildings and structures used for service and repair operations in connection with vehicles in which GH_2 is used.

18.1.2 This chapter does not apply to service and repair operations in connection with self-propelled vehicles that store LH_2 onboard.

18.2 Applicability.

18.2.1 This chapter shall apply to service and repair operations in connection with self-propelled vehicles powered by GH_2.

18.2.2 The storage, use, and handling of GH_2 in any quantity shall comply with the requirements of Chapters 1 and 4 and the applicable requirements of Chapters 5 through 7.

18.2.3 Dispensing of GH_2 shall comply with Chapter 10.

18.2.4 Major repair facilities that also repair vehicles powered by flammable and combustible liquids, CNG, LNG, or LP-Gas shall also meet the requirements of NFPA 30A.

18.2.5 Major Repair Garages.

18.2.5.1 Hydrogen Motor Vehicles Repair Garages.

18.2.5.1.1 Major repair garages for hydrogen motor vehicles shall meet the requirements of Sections 18.3 and 18.4.

18.2.5.1.2 Repairs that would be required to be performed in a major repair garage shall be permitted to be performed in a minor repair garage if the vehicle is defueled in accordance with 18.3.2 to less than 400 scf (11.4 Nm^3) and the fuel supply container is sealed and not damaged.

18.2.5.1.3 Movement of the fuel supply container or a subassembly upon which the fuel supply container remains mounted to allow access to other parts of the vehicle that are not a portion of the fuel system shall be permitted to be performed in a minor repair garage if it is defueled to less than 400 scf (11.4Nm^3) and the fuel supply container is sealed and not damaged.

18.2.5.2 Hydrogen-Powered Industrial Trucks Repair Garages. Major repair garages for hydrogen-powered industrial trucks shall meet the requirements of Sections 18.3 and 18.6.

18.2.6 Minor Repair Garages.

18.2.6.1 Minor repair garages for hydrogen motor vehicles shall only meet the requirements of NFPA 30A and not the requirements of Sections 18.3, 18.4, and 18.6.

18.2.6.2 Minor repair garages for hydrogen-powered industrial trucks shall meet the requirements of Section 18.6 and NFPA 505, and not the requirements of Sections 18.3 and 18.4.

18.3 General.

18.3.1 Repair Areas. Repairing of hydrogen vehicles shall be restricted to areas specifically provided for such purposes.

Δ **18.3.1.1 Repair Rooms, Booths, and Areas.** Requirements for major repair garages used for service and repair of hydrogen vehicles shall be limited to rooms, booths, or areas constructed in accordance with the applicable requirements of 18.3.1.1 through 18.3.1.7.

18.3.1.2 Walls and Ceilings.

18.3.1.2.1 Walls, doors, and ceilings that intersect or enclose a repair area shall be constructed of noncombustible or limited-combustible materials or assemblies and shall be securely and rigidly mounted or fastened.

18.3.1.2.2 The interior surfaces of the repair area shall be smooth, and designed and installed to facilitate ventilation.

18.3.1.3 If walls or ceiling assemblies are constructed of sheet metal, single-skin assemblies shall be no thinner than 1.2 mm (0.0478 in.), and each sheet of double-skin assemblies shall be no thinner than 0.9 mm (0.0359 in.).

18.3.1.4 Structural sections of repair booths shall be permitted to be sealed with a caulk or sealant to minimize air leakage.

18.3.1.5 Repair rooms shall be constructed of and separated from surrounding areas of the building by construction assemblies that have a fire resistance rating of one hour.

18.3.1.6 Enclosed repair booths and repair rooms shall be provided with means of egress that meet the applicable requirements of Chapter 40 of NFPA *101*.

18.3.1.7 Separation from Other Operations.

18.3.1.7.1 Repair booths shall be separated from other operations by a minimum distance of 915 mm (3 ft) or by a partition, wall, or floor/ceiling assembly having a minimum fire resistance rating of one hour. Multiple connected repair booths shall not be considered as other operations.

18.3.1.7.1.1 A clear space of not less than 915 mm (3 ft) shall be maintained on all sides and above the repair booth.

18.3.1.7.1.2 This clear space shall be kept free of any storage or combustible construction.

18.3.1.7.2 Paragraph 18.3.1.7 shall not prohibit locating a repair booth closer than 915 mm (3 ft) to or directly against an interior partition, wall, or floor/ceiling assembly that has a fire resistance rating of not less than one hour, provided the integrity of the repair booth can be maintained.

18.3.1.7.3 Paragraph 18.3.1.7 shall not prohibit locating a repair booth closer than 915 mm (3 ft) to an exterior wall or a roof assembly, provided the wall or roof is constructed of noncombustible material and provided the repair booth can be maintained.

18.3.2 Defueling Equipment. The discharge or defueling of hydrogen from fuel supply containers shall be required for fuel storage system modification or repair, or where welding or open flame activities occur within 455 mm (18 in.) of the vehicle fuel supply container. Defueling shall be in accordance with 18.3.2.1 through 18.3.2.10.

18.3.2.1 Applicability. The requirements in 18.3.2 shall apply to the defueling equipment in the repair garage and are not requirements for the vehicle.

18.3.2.2 Defueling Equipment Required at Vehicle Maintenance and Repair Facilities.

18.3.2.2.1 Major repair garages shall have equipment to defuel vehicle fuel supply containers.

18.3.2.2.2 Equipment used for defueling shall be listed, approved, or provided by the vehicle manufacturer.

18.3.2.3 Construction Documents.

18.3.2.3.1 Construction documents shall be provided illustrating the defueling system to be utilized.

18.3.2.3.2 Plan details shall be of sufficient detail and clarity to allow for evaluation of the piping and control systems to be utilized and include the method of support for cylinders, containers, or tanks to be used as part of a closed transfer system, the method of grounding and bonding, and other requirements specified herein.

18.3.2.4 Documented Procedure. A documented procedure that explains the logic sequence for defueling or discharging operations shall be maintained on-site and shall be provided to the authority having jurisdiction (AHJ) upon request.

18.3.2.5 Isolated Use. The defueling shall not be connected to another venting system used for any other purpose.

18.3.2.6* Specific Equipment Required. The defueling equipment that connects the vehicle fuel supply containers to the defueling system shall be specifically designed for the vehicle it is connecting to.

18.3.2.7 Grounding and Bonding.

18.3.2.7.1 Cylinders, containers, or tanks and piping systems used for defueling shall be bonded and grounded in accordance with NFPA 77 to avoid potential ignition sources due to static discharge.

18.3.2.7.2 The defueling system shall be bonded with the vehicle storage system prior to the commencement of discharge or defueling operations. Operator instructions to facilitate proper use shall be provided.

18.3.2.8 Methods of Discharge. The discharge of hydrogen from fuel storage tanks shall be accomplished through a closed transfer system in accordance with 18.3.2.9 or an approved method of atmospheric venting in accordance with 18.3.2.10.

N **18.3.2.8.1*** Outdoor defueling of hydrogen from a hydrogen motor vehicle shall be approved and meet the requirements in Section 6.17 and 18.3.2.10.

18.3.2.9 Closed Transfer System.

18.3.2.9.1 A documented procedure that explains the logic sequence for discharging the storage tank shall be provided to the fire code official for review and approval.

18.3.2.9.2 The procedure shall include what actions the operator is required to take in the event of a low-pressure or high-pressure hydrogen release during discharging activity.

18.3.2.9.3 Schematic design documents shall be provided illustrating the arrangement of piping, regulators, and equipment settings.

18.3.2.9.4 The construction documents shall illustrate the piping and regulator arrangement and shall be shown in spatial relation to the location of the compressor, storage vessels, and emergency shutdown devices.

18.3.2.9.5 Stability of Cylinders, Containers, and Tanks.

18.3.2.9.5.1 A method of rigidly supporting cylinders, containers, or tanks used during the closed transfer system discharge or defueling of hydrogen shall be provided.

18.3.2.9.5.2 The method shall provide not less than two points of support and shall be designed to resist lateral movement of the receiving cylinder, container, or tank.

18.3.2.9.5.3 The system shall be designed to resist movement of the receiver based on the highest gas release velocity through valve orifices at the receiver's rated service pressure and volume.

18.3.2.9.5.4* Supporting structures or appurtenances used to support receivers shall be constructed of noncombustible materials in accordance with the adopted building code.

18.3.2.10 Atmospheric Venting of Hydrogen from Fuel Storage Containers. Where atmospheric venting is used for the discharge of hydrogen from fuel storage tanks, such venting shall be in accordance with Section 6.17 and 7.1.16.

18.3.3 Hydrogen Detection System. Major repair garages shall be provided with an approved hydrogen detection system such that gas can be detected where vehicle hydrogen fuel storage systems are serviced or indoor defueling occurs. The detection system shall meet the requirements of Section 6.13.

18.3.3.1 System Design. The hydrogen detection system shall be designed to activate the actions in 18.3.3.3 when the level of hydrogen exceeds 25 percent of the lower flammable limit (LFL).

18.3.3.2 Location. The hydrogen detection system shall provide coverage of the motor vehicle service area. The hydrogen detection system shall have sensors in the following locations:

(1) At inlets to exhaust systems
(2) At high points in service bays
(3) At the inlets to mechanical ventilation systems

18.3.3.3 Operation. Activation of the hydrogen detection system shall result in all of the following:

(1) Initiation of distinct audible and visual alarm signals in the repair garage
(2) Deactivation of all heating systems located in the repair garage
(3)* Activation of the mechanical ventilation system, where the system is interlocked with gas detection

18.3.3.3.1 Remote sources of heating, such as forced hot air, hot water, or steam where the furnace, boiler, heat pump, and so on is located in a separate area that does not draw air from the repair area shall not be required to be deactivated when a hydrogen detection system is activated.

18.3.3.3.2 Classified heaters that are listed and labeled for Class I, Division 1, Group B (Class I, Zone 0 or 1, Group IIC) shall not be required to be deactivated when a hydrogen detection system is activated.

18.3.3.3.3 Failure of the hydrogen detection system shall result in the deactivation of the heating system and activation of the mechanical ventilation system and, where the ventilation system is interlocked with gas detection, shall cause a trouble signal to sound in an approved location.

18.3.3.3.4 Where connected to the building fire alarm system, circuits of the hydrogen detection system required by 18.3.3 shall be monitored for integrity in accordance with *NFPA 72*.

18.3.4 Heating, Ventilating, and Air Conditioning.

18.3.4.1 Forced air heating, air-conditioning, and ventilating systems serving a garage shall not be interconnected with any such systems serving other occupancies in the building. Such systems shall be installed in accordance with NFPA 90A.

18.3.4.2 Return air openings in areas of motor vehicle repair room, motor vehicle repair booth, or motor vehicle repair space used for the repair or servicing of hydrogen vehicles shall be more than 455 mm (18 in.) below the ceiling level measured to the bottom of the openings.

18.3.4.3 Combined ventilation and heating systems shall only recirculate air from areas that are more than 455 mm (18 in.) below the ceiling level.

18.3.4.4 Heat-Producing Appliances.

18.3.4.4.1* Heat-producing appliances shall be in accordance with the requirements of NFPA 30A and this chapter.

18.3.4.4.2 Where major repairs are conducted on hydrogen vehicles, open-flame heaters or the exposed surfaces of heating equipment shall be less than 400°C within 455 mm (18 in.) of the ceiling or in areas subject to ignitable concentrations of gas.

18.3.4.4.3 Electrical heat-producing appliances shall meet the requirements of Section 6.8.

18.3.5 Mechanical Exhaust Ventilation System. Each motor vehicle repair room, motor vehicle repair booth, or motor vehicle repair space for hydrogen vehicles shall be provided with an approved hydrogen mechanical exhaust ventilation system.

18.3.5.1 Where approved by the AHJ, natural ventilation shall be allowed in lieu of a mechanical exhaust ventilation system.

18.3.5.2 The mechanical exhaust ventilation system shall be in accordance with Section 6.18.

18.3.5.3 A local visual and audible alarm shall activate and repair activities shall cease upon the loss of continuous ventilation.

18.3.6 Electrical Installations.

18.3.6.1 General Requirements.

18.3.6.1.1 Electrical wiring and electrical utilization equipment shall be of a type specified by, and shall be installed in accordance with, NFPA 30A, *NFPA 70*, and Section 6.8.

18.3.6.1.2 For repair rooms, booths, or spaces where hydrogen vehicles are repaired, the area within 455 mm (18 in.) of the ceiling shall be designated a Class I, Division 2, Group B (Class I, Zone 2, Group IIC) hazardous (i.e., classified) location.

18.3.6.1.2.1 The requirement in 18.3.6.1.2 shall not apply where the continuous mechanical ventilation system meets the requirements in 18.3.5.

18.3.6.1.2.2 Areas adjacent to classified locations where flammable vapors are not likely to be released, such as stock rooms, switchboard rooms, and other similar locations, where mechanically and continuously ventilated at a rate of four or more air changes per hour or designed with positive air pressure, or where effectively cut off by walls or partitions shall be designated unclassified.

18.3.7 Storage and Handling of Flammable and Combustible Liquids, Liquefied Petroleum Gases, and Other Flammable Gases.

18.3.7.1 Except as otherwise provided by this code, the storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30A.

18.3.7.2 Except as otherwise provided by this code, the storage and handling of hydrogen shall be in accordance with Chapters 6 and 7.

18.3.8 Welding and Open-Flame Operations. Welding and open-flame operations shall meet the requirements of NFPA 30A.

18.3.9 Spray Painting and Undercoating. Spray painting and undercoating spray operations shall be in accordance with the requirements of NFPA 30A.

18.3.10 Drying Apparatus. Drying and baking apparatus shall be in accordance with the requirements of NFPA 30A.

18.3.11 Parts Cleaning. Parts cleaning shall be in accordance with the requirements of NFPA 30A.

18.3.12 Chassis Cleaning. Chassis cleaning shall be in accordance with the requirements of NFPA 30A.

18.3.13 Housekeeping. Housekeeping shall be in accordance with the requirements of NFPA 30A.

N **18.3.14 Portable Fire Extinguishers.** Repair garages for gaseous-hydrogen-fueled vehicles shall be provided with portable fire extinguishers in accordance with NFPA 30A.

18.4 Light-Duty Hydrogen Motor Vehicle Repair Garages. (Reserved)

N **18.5 Heavy-Duty Hydrogen Motor Vehicle Repair Garages.**

N **18.5.1 Ventilation.** The mechanical exhaust ventilation system shall be in accordance with Section 18.3 and 18.5.1.1.

N **18.5.1.1 Ventilation Rate.** Mechanical exhaust or fixed natural ventilation shall be provided at a rate based on analysis of IEC 60079-10 -1, *Explosives Atmospheres- Part 10-1: Classification of Areas- Explosive Gas Atmospheres,* using the quantity of hydrogen stored in the heavy-duty vehicles.

N **18.5.1.1.1** The ventilation rate of 18.5.1.1 shall meet the minimum requirements of 18.3.5.

18.6 Hydrogen-Powered Industrial Truck Repair Garages.

18.6.1 Minor Repair Garages for Hydrogen-Powered Industrial Trucks (HPIT).

18.6.1.1 Minor repair garages for HPIT shall comply with Chapter 8 of NFPA 505.

18.6.1.2* All automatic fuel valves in the HPIT to be serviced shall be closed before service is initiated and measures shall be taken to ensure that they remain closed during servicing.

18.6.1.3* Replacing cell stacks in FCPSs shall be allowed in minor repair garages for HPIT.

18.6.2 Major Repair Garages for HPIT.

18.6.2.1 Major Repair Garages for HPIT Only.

18.6.2.1.1 Major repair garages that service only HPIT shall comply with 18.6.2.1 through 18.6.2.4.

18.6.2.1.2 Major repair garages for HPITs shall also comply with Section 18.3.

18.6.2.2 Repair of the Hydrogen Fuel System. Repairs of the hydrogen fuel system, including piping and components up to the fuel cell stack or internal combustion engine, shall comply with 18.6.2.2.1 through 18.6.2.2.2.

18.6.2.2.1* All automatic fuel valves in the HPIT to be serviced shall be closed before service is initiated and measures shall be taken to ensure that they remain closed during servicing.

18.6.2.2.2 All manual fuel valves in the HPIT to be serviced shall be closed before service is initiated.

18.6.2.3* Servicing the Hydrogen Fuel Storage Containers. All hydrogen fuel storage containers (e.g., tanks, vessels, cylinders, and so on) in the HPIT to be serviced shall be defueled before service is initiated.

18.6.2.4 Major Repair Garages for HPIT and Powered Industrial Trucks Using Other Fuels. Major repair garages that service both HPIT and powered industrial trucks using other fuels shall comply with the requirements of Section 18.6 and with NFPA 30A.

N Chapter 19 Hydrogen-Powered Industrial Trucks (HPITs)

N **19.1 Scope.** This chapter shall apply to the design, construction, and use of hydrogen-powered industrial trucks (HPITs).

N **19.2 General.**

N **19.2.1 Trucks.** HPITs shall comply with NFPA 505.

N **19.2.2* Fuel Cell Power Systems (FCPSs).** Fuel cell power systems for HPITs shall be listed to UL 2267, *Fuel Cell Power Systems for Installation in Industrial Electric Trucks,* or approved.

N **19.3 Indoor Use.**

N **19.3.1** Indoor occupancy for HPIT usage shall including parking.

N **19.3.2** Hydrogen in the fuel supply container of an HPIT, in use or parked, shall not be considered part of the MAQ per 1.3.3.

N **19.4 Fueling.** HPITs shall be fueled in accordance with 10.5.3.2, and either 10.5.3.3 or 10.5.3.4.

N **19.5 Maintenance, Service, and Repairs.** Maintenance, service, and repairs of HPITS shall be performed in facilities that comply with Section 18.5.

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.1.3 Although the requirements established in NFPA 2 focus on gaseous and liquefied hydrogen, the provisions can be applied to deuterium, hydrogen's stable isotope. Hydrogen's unstable isotopes or other forms might have other controls that might be applicable. For example, the isotope tritium is radioactive, and while the flammable character of the material might have similarities, the radioactive nature of the material requires the application of other controls. NFPA 801 provides requirements for fire protection in facilities using radioactive materials. The material is used in extremely small quantities as an energy source in some exit signs. When used in other commercial applications, this material might be subject to other controls imposed by the Department of Defense or the Nuclear Regulatory Commission.

A.1.7.1 Use of NFPA documents for regulatory purposes should be accomplished through adoption by reference. The phrase "adoption by reference" means the citing of title, edition, and publishing information only. Any deletions, additions, and changes desired by the adopting authority should be noted separately in the adopting instrument.

Δ **A.2.3.7** 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.

Δ **A.3.3.7.6 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.

Δ **A.3.3.23.1 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.3.3.33 Chemical. For fire hazard ratings of many chemicals, see the NFPA's *Fire Protection Guide to Hazardous Materials*, which contains NFPA 49 and NFPA 325.

A.3.3.38 Class C Furnace. This type of furnace uses any type of heating system and includes a special atmosphere supply system(s). Also included in the Class C classification are integral quench furnaces and molten salt bath furnaces. [**86,** 2023]

N **A.3.3.39 Closed Piping System.** The assembly of a closed piping system can be made up of piping, tubing, valves, regulators, and so on. A closed piping system is designed to only transfer gas within the boundary of its piping network. A closed piping system is located downstream of a source valve containing piping components and extends to a storage tank where the total volume of the system is less than the volume considered as bulk hydrogen.

Δ **A.3.3.51.2 Explosion Control.** NFPA 68 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 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 adopted 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 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.

Δ **A.3.3.60 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.3.3.61 Defueling. Defueling of the vehicle storage system can be used for some vehicle maintenance procedures. Defueling systems can also be used at fueling stations to allow for the safe discharge of hydrogen from vehicle fuel tank test systems during dispenser calibration, certification, and periodic validation procedures. The dispensers at a fueling station are typically commissioned, validated, certified, and periodically tested by conducting test fills of H2 vehicle storage tanks. After a test fill, the test tank system can be vented safely using a vent system installed at the fueling station.

A.3.3.64 Distributed Integrated Controls (DIC). The DIC is made up of a collection of modules, each with its own function, interconnected to process data for a specific operation or function. Also referred to as distributed control system (DCS). [**853,** 2020]

A.3.3.74.1 Fire Risk Evaluation. The evaluation results in a list of required fire protection elements to be provided based on acceptable means for separation or control of common or special hazards (e.g., temperature and pressure), the control or elimination of ignition sources, the detection and suppression of fires, and the safeguarding of life. [**853,** 2020]

Δ **A.3.3.79 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, including rooms, such as control areas, with dedicated hazardous vapor/gas exhaust systems, in and of themselves, are not exhausted enclosures.

A.3.3.83.2.4 Motor Fuel Dispensing Facility Located Inside a Building. The motor fuel dispensing facility can be either enclosed or partially enclosed by the building walls, floors, ceilings, or partitions or can be open to the outside. The motor fuel dispensing area is that area required for dispensing of fuels to motor vehicles. Dispensing of fuel at manufacturing, assembly, and testing operations is not included within this definition. [**30A,** 2021]

N **A.3.3.83.3 Home Fueling Appliance (HFA).** The definition of home location is based on NFPA *101* and includes land and detached structures within the boundary of the home property limits assessed by the municipality, town, city or state. Home locations include, but are not limited to, one- and two-family dwelling units as defined by Chapter 24 of NFPA *101*.

A.3.3.84 Fail-Safe. Periodic testing of fail-safe systems should be conducted to ensure that the system performs as intended.

A.3.3.103.1 Nonstandard Automotive Fueling Protocol. Examples of published standards include those published by SAE or ANSI.

A.3.3.104 Full Trycock. The full trycock valve provides a physical indication of the filling status of a liquid tank, and it is typically used as a redundant means to that of other liquid level indicators. A full trycock line is used to connect the inner vessel vapor space near the top of a cryogenic fluid tank with an internal dip tube located at a point equivalent to the net liquid capacity of the tank. The vapor space in the inner vessel above the full trycock level is considered the tank ullage. The tank is determined to be full when liquid is emitted from the full trycock valve when the valve is opened.

Δ **A.3.3.106.1 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.3.3.106.3 Flammable Gas. The definition of flammable gas is applicable to all flammable cryogens, as the vapors released when the cryogen vaporizes are ignitable when mixed in the proper proportions with air.

Δ **A.3.3.106.6 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. Radon is inert under the definition provided, but because it is radioactive, it is not considered inert for the purposes of NFPA 55.

Δ **A.3.3.106.8 Other Gas.** A gas classified as an "other gas" might be a nonflammable gas or an inert gas.

Δ **A.3.3.106.12 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.3.3.116 Handling. Within the definition, the term *handling* is intended to address containers being transported from one location to another. The term *transportation* is not used because problems related to off-site transportation or modes of transportation regulated by the Department of Transportation (DOT) are not intermingled with the code, which can create confusion. Unloading of bulk cargo from a vehicle into stationary storage vessels is regulated by the DOT. The unloading of bulk GH_2 or LH_2 from independent transport vehicles into a storage system involves a transient function. Transport vehicles are regulated as a portion of the bulk system when they are connected and in the unloading process. Requirements for unloading have been organized under the requirements for "handling" to avoid confusing the unloading function with "use." It is not the intent to view materials transported by a pipeline or piping system as a "handling function," as such uses are other than transient in nature.

Δ **A.3.3.117 Hazard Rating.** The criteria for hazard rating are as defined in NFPA 704.

A.3.3.120.1 Canopy Hood. This is not a chemical fume hood and generally is not effective for exhausting toxic or flammable materials. [**45,** 2019]

A.3.3.120.2 Chemical Fume Hood. For further information on descriptions of types of chemical fume hoods and exhaust ventilation devices, see ANSI/AIHA Z9.5, *Laboratory Ventilation.* The following are types of chemical fume hoods:

(1) *Conventional hood.* A square-post hood without an airfoil directional vane across the bottom of the hood face, and in most cases without provision for a bypass. As the sash is lowered in hoods without an air bypass, the face velocity increases rapidly. The square-post design and absence of a deflector vane have been known to create turbulence at the hood face. The turbulence at the hood face can bring fumes from the hood interior out to the hood face, where they are easily drawn out into the room by the air turbulence caused by a person working at the hood, persons passing the hood, or minor room cross drafts. If hoods are not equipped with a bypass, face velocities could become objectionably high as the sash is closed, and with the sash completely closed, airflow can be insufficient to carry vapors away.
(2) *Bypass air hood.* A hood having a bypass protected by a grille that serves to maintain a relatively constant volume of airflow regardless of sash position. Current design recommends a streamlined entry profile with a deflector vane across the bottom of the hood to direct the airflow across the work surface.
(3) *Auxiliary air hood.* A bypass air hood with the addition of an auxiliary air bonnet to provide a direct source of makeup air in addition to the makeup air from the laboratory work area.
(4) Special purpose hoods are as follows:
    (a) *Radioisotope hoods.* Designed primarily for use with radiochemicals
    (b) *Perchloric acid hoods.* Designed primarily for use with perchloric acid
    (c) *Walk-in hoods.* Designed primarily for extra headroom to accommodate tall equipment

[**45,** 2019]

A.3.3.122 Hydrogen Equipment Enclosure (HEE). Hydrogen equipment enclosures can include repurposed shipping or ISO containers as defined in 3.3.8 of NFPA 307 as follows:

> A reusable, intermodal boxlike structure of rigid construction fitted with devices to permit lifting and handling particularly transfer from one mode of transportation to another mode of transportation. [**307,** 2021]

Hydrogen equipment located in enclosures larger than the largest standard intermodal container — presently 56 ft × 8 ft × 9.5 ft) (17 m × 2.4 m × 2.9 m) — typically are subject to the requirements for indoor installations.

Hydrogen equipment enclosures include those used for equipment that process or store hydrogen. Enclosures can be for weather protection, aesthetic treatment, security, or to prevent external damage. The enclosure can be designed to contain and control potential hydrogen leaks from hydrogen storage, compressors, and other hydrogen-fuel-processing equipment, and exterior walls can include a fire rating. Enclosures can be enterable but are not intended to be occupied. Hydrogen equipment in enclosures in laboratories are covered by Section 6.20.

Δ **A.3.3.128 Indoor Installation.** An indoor installation can be a separate building, room, or area within a building.

Δ **A.3.3.134 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.

A.3.3.139 Laboratory Work Area. This work area can be enclosed. [**45,** 2019]

A.3.3.142 LH_2. Hydrogen in a liquid state is a flammable cryogenic fluid, regardless of the pressure.

A.3.3.144.1 Ceiling Limit. The ceiling limits utilized are to be those published in 29 CFR 1910.1000. [**5000,** 2021]

Δ **A.3.3.144.2.1 Permissible Exposure Limit (PEL).** The maximum permitted time-weighted average exposures to be utilized are those published in 29 CFR 1910.1000.

Δ **A.3.3.144.2.2 Short-Term Exposure Limit (STEL).** STEL limits are published in 29 CFR 1910.1000.

A.3.3.147.1 Combustible Liquid. Combustible liquids are classified in accordance with the following:

(1) Class II Liquid — Any liquid that has a flash point at or above 100°F (37.8°C) and below 140°F (60°C)
(2) Class III Liquid — Any liquid that has a flash point at or above 140°F (60°C)
    (a) Class IIIA Liquid — Any liquid that has a flash point at or above 140°F (60°C), but below 200°F (93°C)
    (b) Class IIIB Liquid — Any liquid that has a flash point at or above 200°F (93°C)

Δ **A.3.3.147.2 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 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.3.3.149.1 Hazardous Material. Hazardous wastes might or might not be classified as hazardous materials. Management and disposal of hazardous waste is regulated by the Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA). The EPA requires wastes identified as hazardous to be handled, stored, treated, and disposed of according to the stipulations of the RCRA hazardous waste program in 40 CFR 260 to 265 and 40 CFR 266 to 299.

Not all of the hazardous materials categories are placed into the high hazard category, and some of these materials have been recognized as being of low or ordinary hazards, depending on their nature in a fire. Inert compressed gases and inert cryogenic fluids, Class IIIB combustible liquids, Class 1 unstable (reactive) materials, Class 1 water-reactive materials, Class 1 oxidizing solids and liquids, and Class IV and Class V organic peroxides are high hazard materials, which, in some cases, do not have an established maximum allowable quantity per control area (MAQ) and, therefore, are not required to comply with the requirements for hazardous occupancies within the context of the adopted building codes.

A.3.3.152 Maximum Operating Pressure. The maximum operating pressure should not exceed the allowable working pressure, and it is usually kept at a suitable level below the setting of pressure-limiting/relieving devices to prevent their frequent functioning.

A.3.3.160 Mobile [Fueling]. The mobile fueling vehicle or trailer can also contain a compressor for pressurizing the gas to be dispensed and a dispenser, which is the interface between the supply vehicle and the vehicle to be fueled.

A.3.3.166.2 Light-Duty Hydrogen Motor Vehicle. These vehicles typically include passenger cars and light trucks, minivans, passenger vans, pickup trucks, and sport-utility vehicles.

N **A.3.3.166.3 Heavy-Duty Hydrogen Motor Vehicle.** Heavy-duty hydrogen motor vehicles typically include buses and trucks.

A.3.3.169 Non-Bulk Hydrogen Compressed Gas. Non-bulk GH_2 includes individual cylinders, containers, or tanks of compressed hydrogen gas typically found in storage with the valves shut and protective caps in place. A non-bulk GH_2 system can include interconnected cylinders, containers, or tanks that have been manifolded or connected for use providing the aggregate volume of individual systems does not exceed 5000 scf (141.6 Nm^3).

A.3.3.186 Parking Structure. A parking structure is permitted to be enclosed or open, use ramps, and use mechanical control push-button-type elevators to transfer vehicles from one floor to another, or mechanical or stacked systems. Motor vehicles are permitted to be parked by the driver or an attendant where a mechanical or stacker parking system is used. Motor fuel is permitted to be dispensed, and motor vehicles are permitted to be serviced in a parking structure in accordance with NFPA 30A. [**88A,** 2023]

Δ **A.3.3.197.1 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).

A.3.3.197.4 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.3.3.198 Pressure Class. The most common pressure classes are H70, H35, and H25.

Δ **A.3.3.203.1 Cathodic Protection.** This protection renders a metallic container or piping system or component negatively charged with respect to its surrounding environment.

Δ **A.3.3.204 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 and *NFPA 5000* 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.3.3.205 Purge (Special Atmosphere Applications). The term *high oxygen-bearing atmosphere* is a relative term. In the case of furnaces the concern is that the oxygen is reduced to a point where a flammable mixture can be formed. A concentration less than from 1 percent to 3 percent oxygen might be acceptable. In other cases, any oxygen might be detrimental. Therefore the term *high* is subjective, depending on the use. See Annex C of NFPA 69 for additional information on limiting oxygen concentration.

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A.3.3.214.2 Minor Repair Garage (Hydrogen Vehicle). Work on the components of a hydrogen fuel cell vehicle that are similar or identical to conventional liquid-fueled vehicles (i.e., gasoline or diesel fuel) such as wheels, tires, brakes, shock absorbers, and so forth, does not present any unique fire hazard; therefore, no additional fire safety requirements beyond those in place for conventional liquid-fueled vehicles are warranted.

A.3.3.216 Safety Data Sheet (SDS). SDSs in the United States are prepared in accordance with the Occupational Safety and Health Administration (OSHA) hazard communication standard (29 CFR 1910.1200, "Hazard Communication"). Chemicals transported internationally might include additional requirements. *(See Annex B of NFPA 400 for additional information regarding SDSs.)* [**400,** 2022]

A.3.3.217 Safety Device. Safety devices are redundant controls, supplementing controls utilized in the normal operation of a furnace system. Safety devices act automatically, either alone or in conjunction with operating controls, when conditions stray outside of design operating ranges and endanger equipment or personnel. [**86,** 2023]

A.3.3.221 Self-Service Motor Fuel Dispensing Facility. Self-service motor fuel dispensing facilities can also include, where provided, facilities for the sale of other retail products.

A.3.3.227 Special Atmosphere. A special atmosphere in a furnace can be inert, nonflammable, flammable, or indeterminate. Atmospheres containing hydrogen are typically not considered to be inert.

If a surge tank blending scheme is used, a separate pipeline can be required to supply inert gas directly to the furnace.

Δ **A.3.3.237.2 Bulk Hydrogen Compressed Gas System.** The bulk system terminates at the source valve, which is commonly referred to as 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.3.3.237.2(a) through Figure A.3.3.237.2(f).

Δ **A.3.3.237.3 Bulk Liquefied Hydrogen LH_2 System.** The bulk system terminates at the source valve, which is commonly referred to as 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. For systems that are composed of combined gaseous and liquefied hydrogen storage systems and have separate source valves for both systems, the system can be viewed as having two source valves for determining minimum separation distances for bulk storage systems in accordance with 7.3.2.3.1 and 8.3.2.3.1.6. Identifying two source valves means that each portion of the system is subject to its respective minimum separation distances in accordance with 7.3.2.3.1 or 8.3.2.3.1.6.

Δ **A.3.3.237.4 Bulk Oxygen System.** The bulk oxygen system terminates at the point where oxygen at service pressure first enters the supply line. 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.3.3.237.7 Engineered and Field-Constructed Fuel Cell Power System. The power system is engineered and designed for the assembly of various components from various sources and is installed on site. *(See Figure B.1 of NFPA 853 for a schematic of a typical fuel cell power system.)* [**853,** 2020]

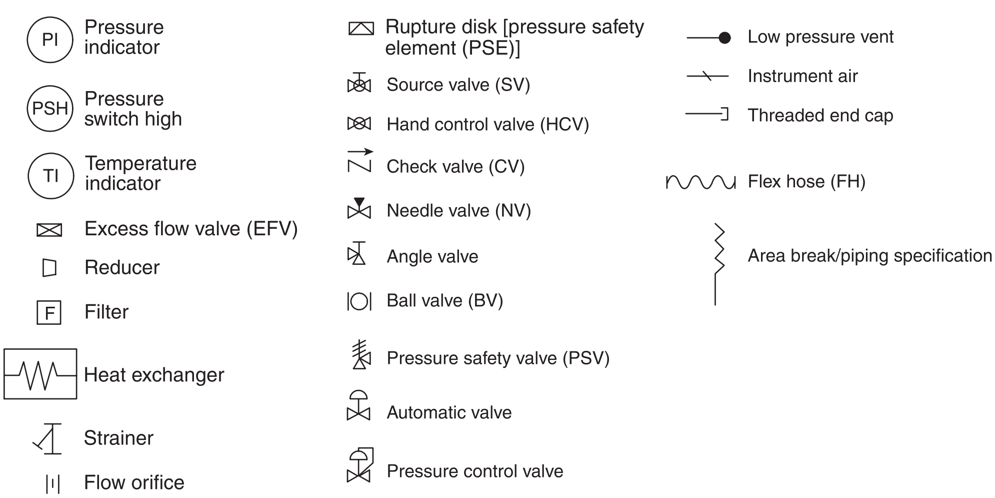
A.3.3.237.11 Gaseous Hydrogen (GH_2) System. The gaseous hydrogen system terminates at the point where hydrogen at service pressure first enters the distribution piping.

A.3.3.237.16 Liquefied Hydrogen (LH_2) System. The system originates at the storage container fill connection and terminates at the point where hydrogen at service pressure first enters the supply line.

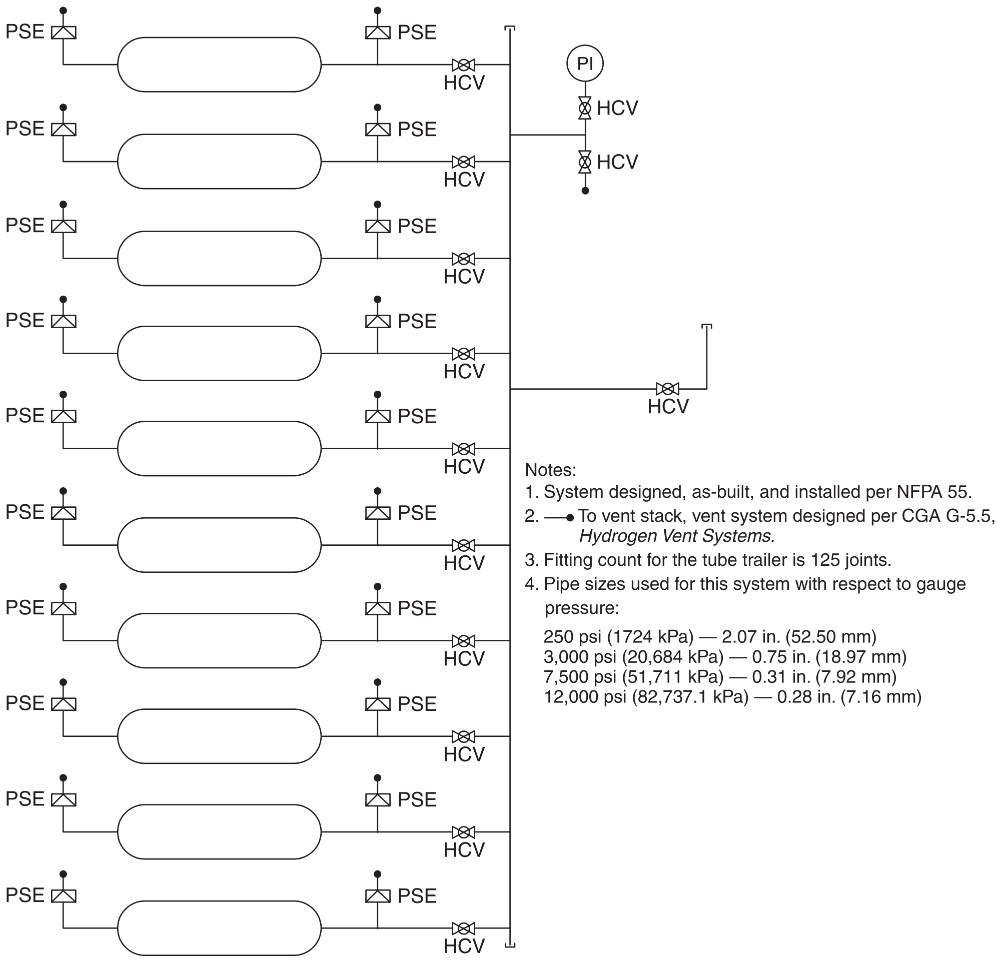
Δ **A.3.3.237.19 Non-Bulk Flammable Gas System.** Non-bulk systems can have more than 5000 scf (141.6 Nm^3) as long as the volume of any individual container or connected system is less than 5000 scf (141.6 Nm^3). Table 7.2.2.3.2 shows exposure distances for non-bulk flammable gases with a total storage of up to 200,000 scf (5664 Nm^3).

Δ **A.3.3.237.20 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.3.3.237.21 Pre-Engineered and Matched Modular Components Fuel Cell Power System. The modules are matched to be installed in the field. [**853,** 2020]



Δ **FIGURE A.3.3.237.2(a) Symbol Legend for Figure A.3.3.237.2(b) through Figure A.3.3.237.2(f).**



Δ **FIGURE A.3.3.237.2(b) Typical Tube Trailer.**

Δ **A.3.3.238.3 Stationary Tank.** A stationary tank does not include a cylinder having less than 1000 lb (453.5 kg) water capacity.

A.3.3.240 Thermal Spraying. Thermal spray can consist of any of the following operations:

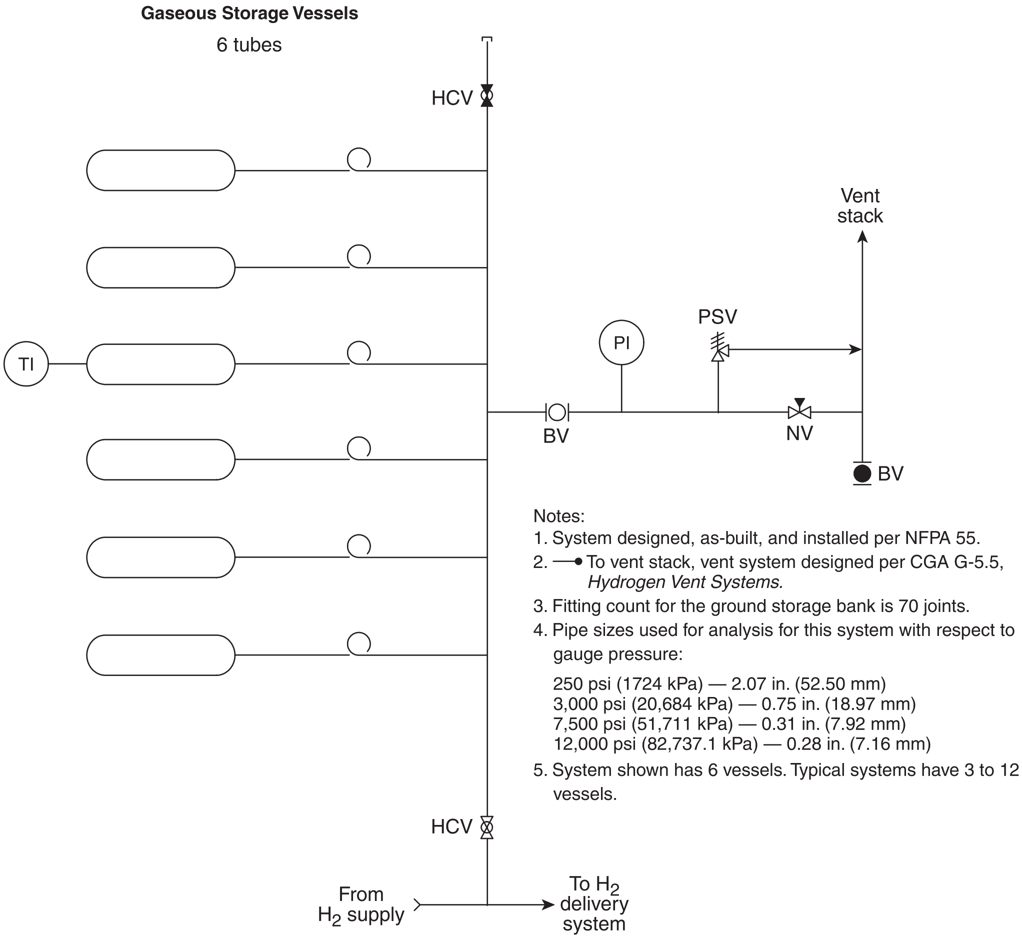
(1) *Plasma Thermal Spray.* Process gases and feedstock are electrically heated by passing through an electric arc to produce a plasma plume.
(2) *Combustion Spray.* A fuel gas is combusted with an oxidizer to produce a combustion flame with the feedstock entrained within the flame.
(3) *High-Velocity Oxy-Fuel (HVOF)* A fuel gas is combusted with an oxidizer at high pressures and flows to produce a high-velocity combustion flame, with the feedstock entrained within the flame.

Δ **A.3.3.244 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.3.3.245.1 Laboratory Unit. A laboratory unit can include offices, lavatories, and other incidental contiguous rooms maintained for or used by laboratory personnel, and corridors within the unit. It can contain one or more separate laboratory work areas. It can be an entire building. A laboratory unit is classified as A, B, C, or D in accordance with Section 4.2 of NFPA 45. [**45,** 2019]

Δ **A.3.3.245.2 Mobile Supply Unit.** Examples include ISO modules, tube trailers, and cylinder packs.

A.3.3.250 Vacuum Jacket. Construction of this type is normally used for tanks that contain cryogenic fluids. The outer vessel is called a jacket, as it is formed around the inner vessel. The inner vessel is used to contain the substance under pressure, and the annular space between the inner and outer vessel is used as a form of insulation to reduce the transfer of ambient heat to the inner vessel. The space between the inner vessel and outer vessel is maintained gastight to avoid condensation as well as heat transfer. Any residual atmosphere that might be retained in the annular space between the vessels is evacuated by the use of vacuum pumps before the vessel is placed in service. The annular space might also contain insulating material that serves to increase the insulating properties of the construction.



Δ **FIGURE A.3.3.237.2(c) Typical Bulk Compressed Gaseous Storage System.**

A.3.3.252.2.1 Safety Shutoff Valve. The valve can be opened either manually or automatically, but only after the solenoid coil or other holding mechanism is energized. [**86,** 2023]

Δ **A.3.3.252.3 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.3.3.253 Vaporizer. The outside source of heat can include, but is not limited to, ambient air, steam, thermal fluids (such as water or oil), or other sources that are capable of adding heat to the system.

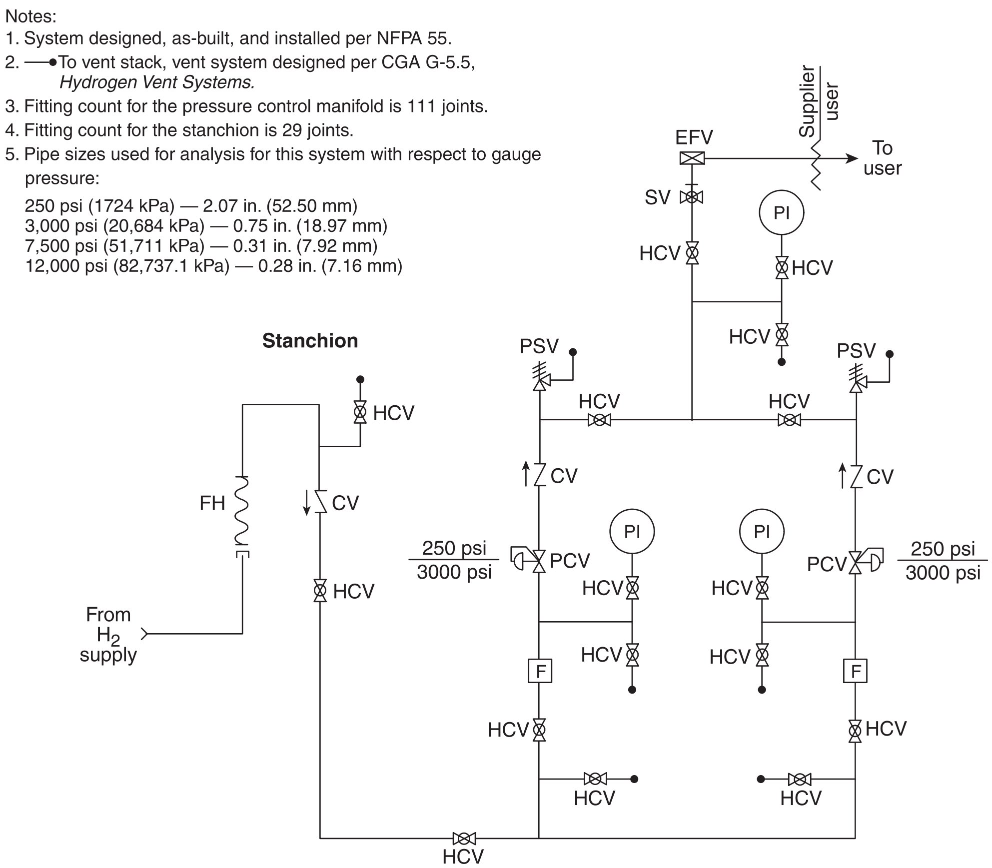
N **A.3.3.255 Vent System.** Vent systems are used for normal discharge, abnormal discharge, or emergency discharge as required.

A.3.4.7 Exposure Fire. An exposure fire usually refers to a fire that starts outside a building, such as a wildlands fire or vehicle fire, and that, consequently, exposes the building to a fire. [***101,*** 2021]

A.3.4.8 Fire Model. Due to the complex nature of the principles involved, models are often packaged as computer software. Any relevant input data, assumptions, and limitations needed to properly implement the model will be attached to the fire models. [***101,*** 2021]

A.3.4.9 Fire Scenario. A fire scenario defines the conditions under which a proposed design is expected to meet the fire safety goals. Factors typically include fuel characteristics, ignition sources, ventilation, building characteristics, and occupant locations and characteristics. The term *fire scenario* includes more than the characteristics of the fire itself but excludes design specifications and any characteristics that do not vary from one fire to another; the latter are called assumptions. The term *fire scenario* is used here to mean only those specifications required to calculate the fire's development and effects, but, in other contexts, the term might be used to mean both the initial specifications and the subsequent development and effects (i.e., a complete description of fire from conditions prior to ignition to conditions following extinguishment). [***101,*** 2021]

A.3.4.14 Performance Criteria. Performance criteria are stated in engineering terms. Engineering terms include temperatures, radiant heat flux, and levels of exposure to fire products. Performance criteria provide threshold values used to evaluate a proposed design. [***101,*** 2021]



Δ FIGURE A.3.3.237.2(d) Typical Tube Trailer Discharge Stanchion and Pressure Control Manifold.

A.3.4.15 Proposed Design. The design team might develop a number of trial designs that will be evaluated to determine whether they meet the performance criteria. One of the trial designs will be selected from those that meet the performance criteria for submission to the authority having jurisdiction as the proposed design. [***101*****,** 2021]

The proposed design is not necessarily limited to fire protection systems and building features. It also includes any component of the proposed design that is installed, established, or maintained for the purpose of life safety, without which the proposed design could fail to achieve specified performance criteria. Therefore, the proposed design often includes emergency procedures and organizational structures that are needed to meet the performance criteria specified for the proposed design. [***101*****,** 2021]

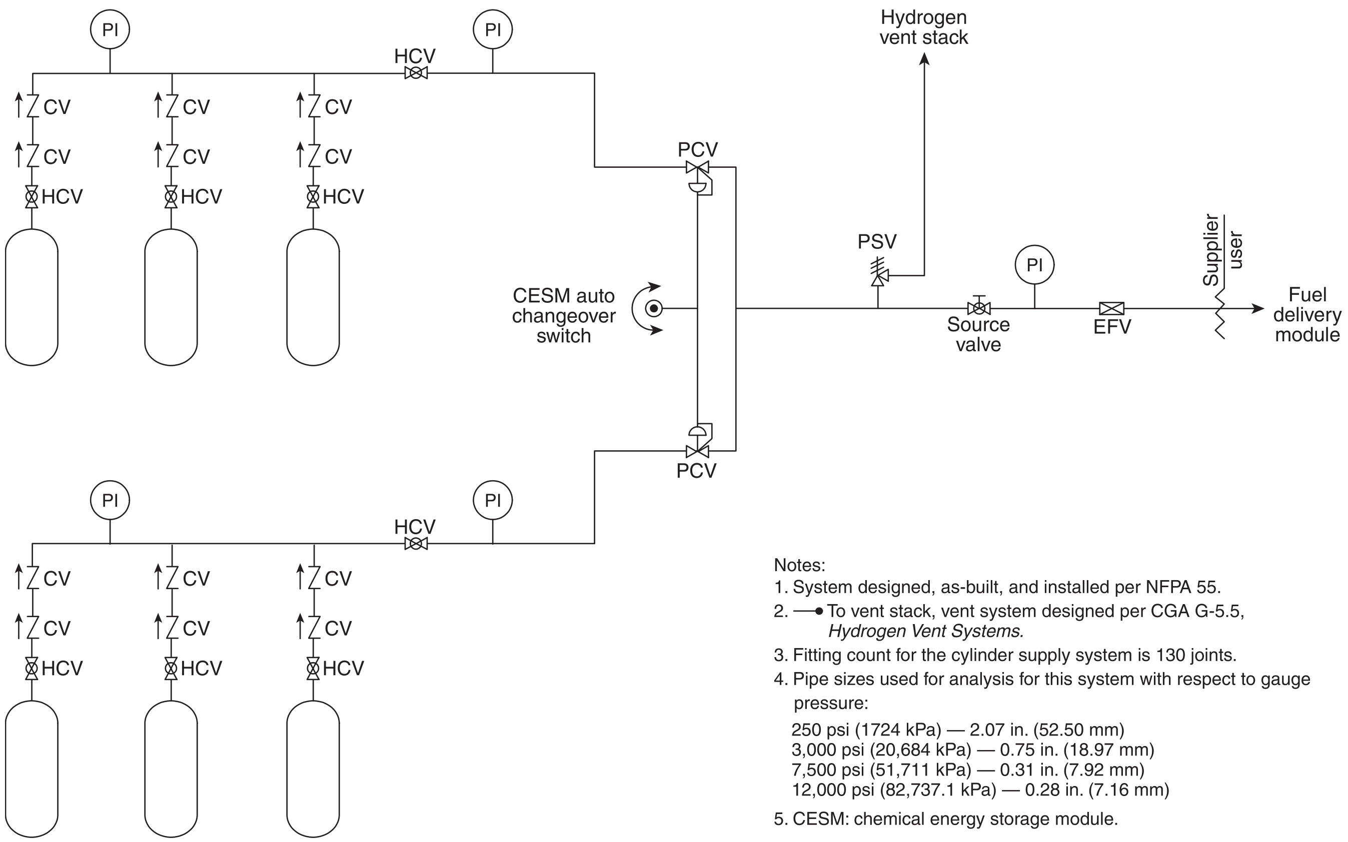
A.3.4.20.1 Design Specification. Design specifications include both hardware and human factors, such as the conditions produced by maintenance and training. For purposes of performance-based design, the design specifications of interest are those that affect the ability of the building to meet the stated goals and objectives. [**5000,** 2021]

A.4.1.2 Zoning codes in some jurisdictions will determine whether a proposed use is permitted. In some jurisdictions, the installation of bulk hydrogen systems might not be permitted in densely populated areas or in other than industrial zones. Local zoning regulations will dictate requirements, and users are responsible for determining the limitations of zoning regulations on a case-by-case basis.

A.4.1.3 Permits for construction of facilities, whether indoors or outdoors, will vary based on jurisdictional requirements. Not all jurisdictions require permits. Some jurisdictions might require permits for hydrogen, others might require permits for the operation of certain equipment. The local fire prevention code or adopted building code might require permits, depending on the operation or the facility to be constructed. Users are responsible for determining whether permits are required and for meeting the requirements on a case-by-case basis.

A.4.2 The overall goals of this code are presented in 4.2.1. These overall goals are treated in greater depth in 4.2.3 through 4.2.5. In each of these subsections, an overall goal for the subsection is defined, specific goals relating to the overall goal are presented next, and the objectives that relate to the specific goal follow. This format is intended to enhance the usability of the code.

A.4.2.1 These highest level goals are intentionally general in nature. Each includes a broad spectrum of topics as shown in 4.2.3. The property protection goal is not just a goal unto itself, as it is also achieved in part as a result of designing to achieve the other stated goals. A reasonable level of safety is further defined by subsequent language in the Code. The facility/property owner or an insurance representative might also have other goals, which might necessitate more stringent objectives as well as more demanding criteria. [**1:**A.4.1.1]



Δ FIGURE A.3.3.237.2(e) Typical Chemical Energy Storage Module (CESM).

A.4.2.2 The objectives apply regardless of which option a user of the Code selects for a design — the performance-based option or the prescriptive-based option. The objectives are stated in more specific terms than the goals and tend to be more quantitative. The goals and objectives, taken together, form the broad, general targets at which a performance-based design can take aim. Specific criteria for design follow in Chapter 5. [**1:**A.4.1.2]

A.4.2.3 The concept of providing for safety applies not only to safety during a fire, explosion, or hazardous materials incident, but also during the normal use of a building or facility. A reasonable level of safety should be provided for occupants in and individuals near the facility or building in question. The resultant design in addition to providing for occupant's safety also promotes the public welfare. Public welfare is also provided as a result of the mission continuity provisions of this Code. [**1:**A.4.1.3]

A.4.2.3.1.1 The phrase *reasonably safe* from fire is defined by subsequent language in this Code, primarily in the objectives. [**1:**A.4.1.3.1.1]

A.4.2.3.1.2.2 In many cases, the provisions of the Code to provide safety for occupants satisfies this goal for protection of emergency responders. [**1:**A.4.1.3.1.2.2]

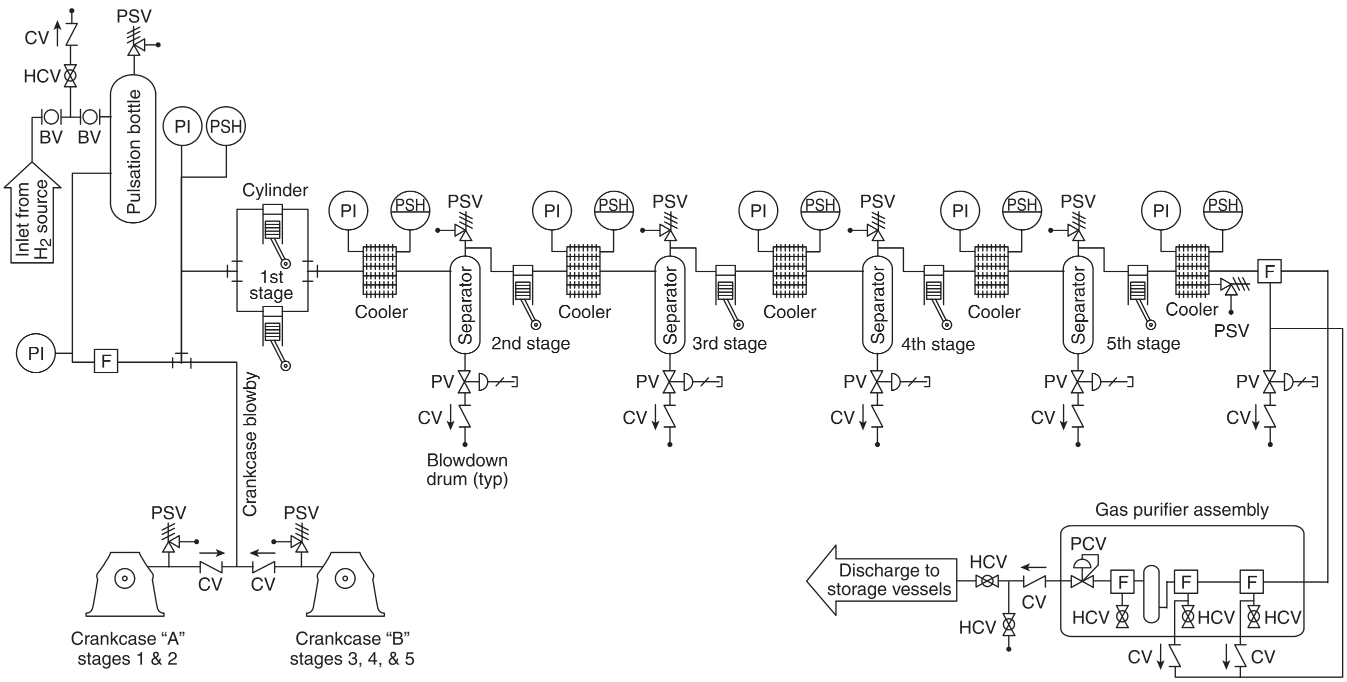
A.4.2.3.1.2.5 This provision addresses the fire safety objectives of operations addressed elsewhere in the Code, such as hot work, tar kettle operation, and so forth, that are not directly related to building construction and use. [**1:**A.4.1.3.1.2.5]

A.4.2.3.2.1 The phrase *reasonably safe during normal use* is defined by subsequent language in this Code, primarily in the objectives. Certain requirements, such as heights of guards and stair dimensions, are provided to ensure that the occupants are safe during nonemergency use of the buildings. Failure to address these features could result in falls or other injuries to occupants in their normal day-to-day activities in the building. [**1:**A.4.1.3.2.1]

A.4.2.3.3 The focus of NFPA 2 is on hydrogen. However, this should not detract from the overall safety goal of reducing the hazards from exposure to or mishap with other hazardous materials. For example, hydrogen can be generated from natural gas or ammonia. One cannot disregard the hazards of these materials and focus solely on the hazards of hydrogen. It is not intended that NFPA 2 be used as the sole means to regulate the broad category of hazardous materials. For additional information on hazardous materials refer to the adopted fire prevention code or other referenced codes and standards. See Section 2.2 and Annex O for additional information.

A.4.2.3.3.2.2 For item 3, the phrase *external force* refers to the application of factors such as heat, water, shock, or other phenomenon onto hazardous materials that are sensitive to such factors and could react vigorously to produce unsafe conditions. [**1:**A.4.1.3.3.2.2]

A.4.2.4.2.1 Ignition occurs when combustible materials come into contact with a source of heat of sufficient temperature and power for a requisite time in an atmosphere where oxygen is



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)

Δ FIGURE A.3.3.237.2(f) Typical Compressor Module.

present. Combustible material does not necessarily ignite immediately upon contact with a source of heat. [**1:**A.4.1.4.2.1]

A.4.2.4.2.2 Examples of specific conditions to avoid include, but are not limited to, flashover, fire spread beyond the item or room of fire origin, overheating of equipment, and overpressure of exterior walls. [**1:**A.4.1.4.2.2]

A.4.2.5.1 This goal is applicable to certain buildings and facilities that have been deemed to be necessary to the continued welfare of a community. Depending on the nature of the critical mission provided by the building, various stakeholders, including community leaders, AHJs, and owners will identify the mission critical buildings. Mission critical areas should be identified and appropriately protected. The objectives for property protection and mission continuity are sometimes difficult to differentiate. Achieving the objectives for property protection could, to a certain extent, accomplish the objectives for mission continuity. [**1:**A.4.1.5.1]

A.4.2.5.2 Examples of buildings and facilities that provide a public welfare role for a community could include hospitals, police and fire stations, evacuation centers, schools, water and sewerage facilities, and electrical generating plants. Also included are buildings and facilities with significant impact on the economic viability of the community. This objective is intended to ensure that such buildings and facilities are capable of providing essential services following a disaster since the community's well-being depends on such service being available. [**1:**A.4.1.5.2]

A.4.3.1 Additional assumptions that need to be identified for a performance-based design are addressed in Chapter 5. [**1:**A.4.2.1]

A.4.3.2 It is not assumed that a design scenario will be considered that simulates the hazards produced when unauthorized releases of hazardous materials occur simultaneously at different locations within a facility, unless it is reasonable to expect that a single incident, such as a fork lift accident or pipe failure, could be expected to create such a condition. However, when hazardous materials are in close proximity to one another, such as on a shelf or in adjacent storage cabinets, it could be reasonable to apply a design scenario where multiple releases of the hazardous materials occur simultaneously from these close proximity areas. In this case, it is not unreasonable to expect the shelf to collapse or a forklift to damage adjacent hazardous materials containers. [**1:**A.4.2.2]

A.4.3.3 It is not assumed that a design scenario will be considered that simulates the hazards produced when a fire, explosion, or external force that creates a dangerous condition occurs at the same time that hazardous materials have been subject to an unauthorized release. This does not preclude considering a scenario where a fire or explosion occurs and impinges on hazardous materials that are in their normal storage, use, or handling conditions. [**1:**A.4.2.3]

The phrase *external force that creates a dangerous condition* refers to the application of factors such as heat, water, shock, or other phenomenon onto hazardous materials that are sensitive to such factors and could react vigorously to produce unsafe conditions. [**1:**A.4.2.3]

Δ **A.4.8** 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.4.9.2 See Section C.2 of NFPA 400 for a model hazardous materials inventory statement (HMIS).

A.4.10.1 GH_2 and LH_2 releases do not currently require the issuance of environmental permits. The release of GH_2 and LH_2 creates potential safety concerns that are addressed by this code but are not likely to negatively impact the environment.

A.4.10.3 The discharges recorded as unauthorized are those that are prohibited by 4.10.1 or that are catastrophic or that occur beyond the design of the system. This is not intended to include releases that are part of the design of the system, such as normal venting and operations.

A.4.11 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.4.11.4 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 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:**A.6.1.4.4]

A.4.11.4.1 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.4.11.4.2 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.4.11.4.3 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.4.13.1.1 An example of a nationally recognized standard for signage is the ANSI Z535 series for safety signs, colors, and symbols. This series includes ANSI Z535.1, *Safety Colors*; ANSI Z535.2, *Environmental Facility and Safety Signs*; ANSI Z535.3, *Criteria for Safety Symbols*; ANSI Z535.4, *Product Safety Signs and Labels*; ANSI Z535.5, *Safety Tags and Barricade Tapes (for Temporary Hazards)*; and ANSI Z535.6, *Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials*.

A.4.13.2.1(4) Such locations could include vaults and other systems located underground.

A.4.14.1.1(1) The term *tank* is used in a generic way. All pressure vessels should be included in this requirement.

Δ **A.4.15** The term *materials* used throughout this section applies to building construction materials and not to hazardous materials, compressed gases, or cryogenic fluids.

Δ **A.4.15.1** The provisions of 4.15.1 do not require inherently noncombustible materials to be tested in order to be classified as noncombustible materials. [**5000:**A.7.1.4.1]

Δ **A.4.15.1(1)** Examples of such materials include steel, concrete, masonry, and glass. [**5000:**A.7.1.4.1.1(1)]

Δ **A.4.15.2** 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 and NFPA 220). [**5000:**A.7.1.4.2]

Δ **A.5.1** The performance option of this *Code* establishes acceptable levels of risk for facilities (i.e., buildings and other structures and the operations therewith associated) as addressed in Section 1.3. (Note that "facility" and "building" can be used interchangeably with facility being the more general term.) While the performance option of this *Code* does contain goals, objectives, and performance criteria necessary to provide for an acceptable level of risk, it does not describe how to meet these goals, objectives, and performance criteria. Design and engineering are needed to meet the provisions of Chapter 5. For fire protection designs, the *SFPE Engineering Guide to Performance-Based Fire Protection* provides a framework for these assessments. [**1:**A.5.1]

Pre-construction design requirements address those issues, which have to be considered before the certificate of occupancy is issued for a facility. [**1:**A.5.1]

A.5.1.3 Qualifications should include experience, education, and credentials that demonstrate knowledgeable and responsible use of applicable models and methods. [**1:**A.5.1.3]

Δ **A.5.1.4** The *SFPE Engineering Guide to Performance-Based Fire Protection* outlines a process for using a performance-based approach in the design and assessment of building fire safety design and identifies parameters that should be considered in the analysis of a performance-based design. As can be seen this process requires the involvement of all stakeholders who have a share or interest in the successful completion of the project. The steps that are recommended by the *SFPE Engineering Guide to Performance-Based Fire Protection* for this process are shown in Figure A.5.1.4. [**1:**A.5.1.4]

The guide specifically addresses building fire safety performance-based design. It might not be directly applicable to performance-based designs involving other systems and operations covered within this *Code*, such as hot work operations or hazardous materials storage. However, the various steps for defining, developing, evaluating, and documenting the performance-based design should still provide a useful framework for the overall design process. [**1:**A.5.1.4]

The steps in the performance-based design process are as follows:

(1) *Step 1: Defining Project Scope.* The first step in a performance-based design is to define the scope of the

project. Defining the scope consists of identifying and documenting the following:

(a) Constraints on the design and project schedule
(b) The stakeholders associated with project
(c) The proposed building construction and features desired by the owner or tenant
(d) Occupant and building characteristics
(e) The intended use and occupancy of the building
(f) Applicable codes and regulations

An understanding of these items is needed to ensure that a performance-based design meets the stakeholders' needs.

(2) *Step 2: Identifying Goals.* Once the scope of the project is defined, the next step in the performance-based design process is to identify and document the fire safety goals of various stakeholders. Fire safety goals could include levels of protection for people and property, or they could provide for continuity of operations, historical preservation, and environmental protection. Goals could be unique for different projects, based on the stakeholders needs and desires. The stakeholders should discuss which goals are the most important for the project. In order to avoid problems later in the design process, all stakeholders should be aware of and agree to the goals prior to proceeding with the performance-based design process (*see Step 7*).

(3) *Step 3: Defining Stakeholder and Design Objectives.* The third step in the design process is to develop objectives. The objectives are essentially the design goals that are further refined into tangible values that can be quantified in engineering terms. Objectives could include mitigating the consequences of a fire expressed in terms of dollar values, loss of life, or other impact on property operations, or maximum allowable conditions, such as extent of fire spread, temperature, spread of combustion products, and so forth.

(4) *Step 4: Developing Performance Criteria.* The fourth step in the design process is the development of performance criteria to be met by the design. These criteria are a further refinement of the design objectives and are numerical values to which the expected performance of the trial designs can be compared. Performance criteria could include threshold values for temperatures of materials, gas temperatures, carboxyhemoglobin (COHb) levels, smoke obscuration, and thermal exposure levels.

(5) *Step 5: Developing Design Scenarios.* Once the performance criteria have been established, the engineer will develop and analyze design alternatives to meet performance criteria. The first part of this process is the identification of possible scenarios and design scenarios. Fire scenarios are descriptions of possible fire events, and consist of fire characteristics, building characteristics (including facility operations), and occupant characteristics. The fire scenarios identified will subsequently be filtered (i.e., combined or eliminated) into a subset of design fire scenarios against which trial designs will be evaluated. Hazardous materials scenarios can be treated similarly.

(6) *Step 6: Developing Trial Design(s).* Once the project scope, performance criteria, and design scenarios are established, the engineer develops preliminary designs, referred to as trial designs, intended to meet the project requirements. The trial design(s) include proposed fire protection systems, construction features, and operation that are provided in order for a design to meet the performance criteria when evaluated using the design fire scenarios. The evaluation method should also be determined at this point. The evaluation methods used should be appropriate for the situation and agreeable to the stakeholders.

(7) *Step 7: Developing a Fire Protection Engineering Design Brief.* At this point in the process a fire protection engineering design brief should be prepared and provided to all stakeholders for their review and concurrence. This brief should document the project scope, goals, objectives, trial designs, performance criteria, design fire scenarios, and analysis methods. Documenting and agreeing upon these factors at this point in the design process will help avoid possible misunderstandings later.

(8) *Step 8: Evaluating Trial Designs.* Each trial design is then evaluated using each design scenario. The evaluation results will indicate whether the trial design will meet the performance criteria. Only trial design(s) that meet the performance criteria can be considered as final design proposals. Yet, the performance criteria can be revised with the stakeholders' approval. The criteria cannot be arbitrarily changed to ensure that a trial design meets a criterion, but can be changed based on additional analysis and the consideration of additional data.

(9) *Step 9: Modifying Designs or Objectives.* If none of the trial designs evaluated comply with the previously agreed upon performance criteria, it could be necessary to either develop and evaluate new trial designs, or revisit the objectives and performance criteria previously agreed upon by the stakeholders to determine if stakeholder objectives and performance criteria should be modified.

(10) *Step 10: Selecting the Final Design.* Once an acceptable trial design is identified using the evaluation, it can be considered for the final project design. If multiple trial designs are evaluated, further analysis will be needed to select a final design. The selection of an acceptable trial design for the final design could be based on a variety of factors, such as financial considerations, timeliness of installation, system and material availability, ease of installation, maintenance and use, and other factors.

(11) *Step 11: Preparing Performance-Based Design Report.* Once the final design is identified, design documents need to be prepared. Proper documentation will ensure that all stakeholders understand what is necessary for the design implementation, maintenance, and continuity of the fire protection design. The documentation should include the fire protection engineering design brief, a performance design report, detailed specifications and drawings, and a facility operations and maintenance manual.

(12) *Step 12: Preparing Specifications, Drawings, and Operations and Maintenance Manual.* The specifications and drawings portion of the performance-based design report convey to building and system designers and installing contractors how to implement the performance design. Specifications and drawings could include required sprinkler densities, hydraulic characteristics and spacing requirements, the fire detection and alarm system components and programming, special construction requirements including means of egress and location of fire-resistive walls, compartmentation, and the coordination of interactive systems. The detailed specifications are the implementation document of the performance-

based design report. The detailed drawings will graphically represent the results of the performance design. The Operations and Maintenance (O&M) Manual clearly states the requirement of the facility operator to ensure that the components of the performance design are in place and operating properly. The O&M Manual describes the commissioning requirements and the interaction of the different systems' interfaces. All subsystems are identified, and inspection and testing regimes and schedules are created.

[**1:**A.5.1.4]

The O&M Manual also gives instruction to the facility operator on restrictions placed on facility operations. These limitations are based on the engineering assumptions made during the design and analysis. These limiting factors could include critical fire load, sprinkler design requirements, building use and occupancy, and reliability and maintenance of systems. The O&M Manual can be used to communicate to tenants and occupants these limits and their responsibilities as a tenant. It could also be used as a guide for renovations and changes. It also can be used to document agreements between stakeholders. [**1:**A.5.1.4]

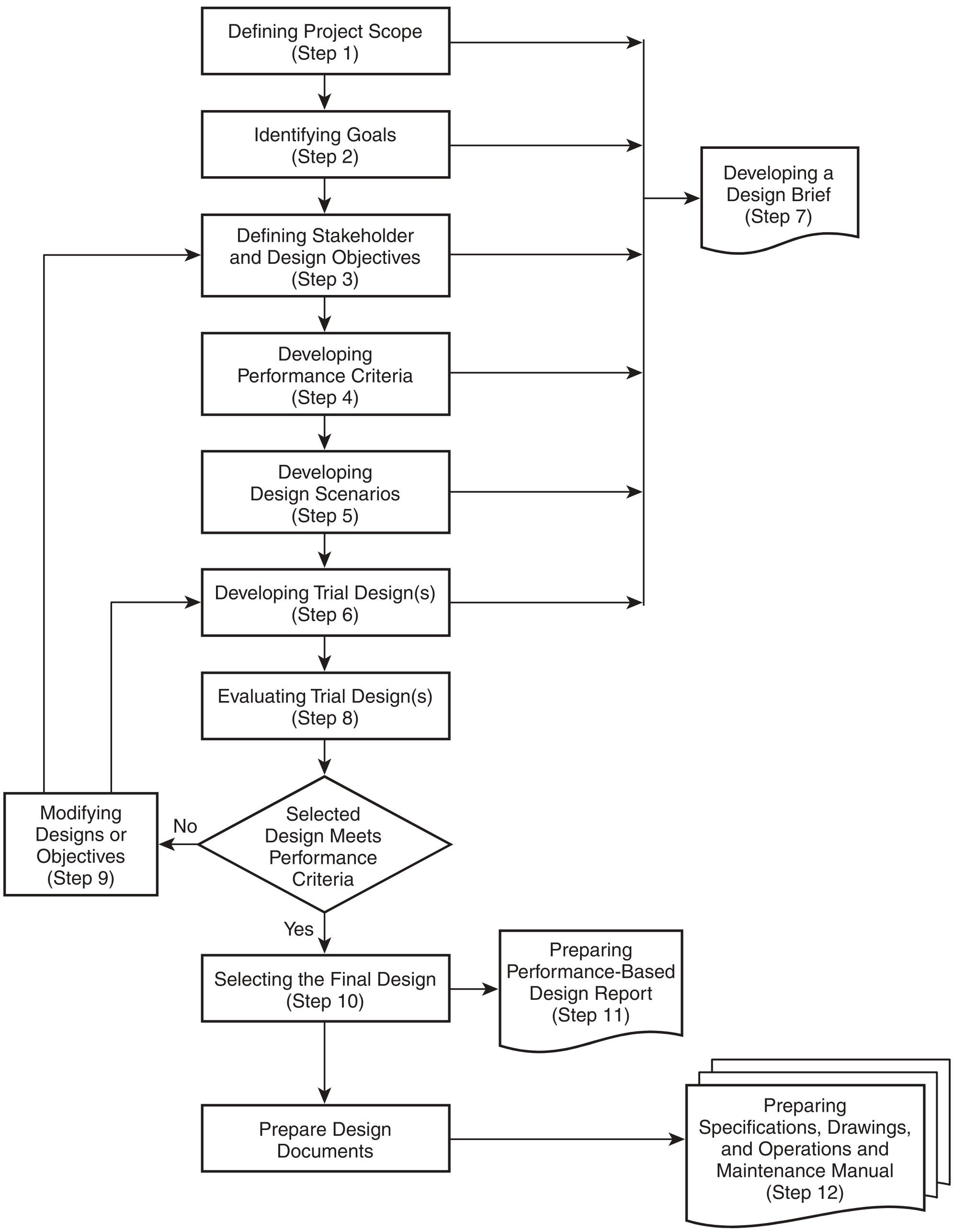


FIGURE A.5.1.4 Steps in the Performance-Based Analysis and the Conceptual Design Procedure for Fire Protection Design. [1:Figure A.5.1.4]

A.5.1.5 A third-party reviewer is a person or group of persons chosen by the AHJ to review proposed performance-based designs. Qualifications of the third-party reviewer should include experience, education, and credentials that demonstrate knowledgeable and responsible use of applicable models and methods. The *SFPE Guide for Peer Review in the Fire Protection Design Process* provides a method for the initiation, scope, conduct, and report of a peer review for a fire protection engineering design. [**1:**A.5.1.5]

A.5.1.8 See Step 12 of A.5.1.4 for a description of these documents. [**1:**A.5.1.8]

Δ **A.5.1.9** Information that could be needed by the fire service arriving at the scene of a fire in a performance-based designed facility includes, but is not limited to, the following:

(1) Safe shutdown procedures of equipment and processes
(2) Facility personnel responsible for assisting the fire service
(3) Operating procedures required to maintain the effectiveness of the performance-based designed fire protection system: when it is and is not appropriate to alter, shut down, or turn off a design feature; assumptions that have to be maintained if a fire occurs; suggested fire-fighting tactics that relate to the specific nature of the performance-based design

[**1:**A.5.1.9]

The design specifications and O&M Manual documentation described in 5.1.8 should provide a guide for the facility owner and tenants to follow in order to maintain the required level of safety anticipated by the original design. It should also provide a guide for the AHJ to use in conducting ongoing inspections of the facility. [**1:**A.5.1.9]

Δ **A.5.1.10** Continued compliance with the goals and objectives of the *Code* involves many factors. The building construction, including openings, interior finish, and fire- and smoke-resistive construction, and the building and fire protection systems need to retain at least the same level of performance as is provided for by the original design parameters. The use and occupancy should not change to the degree that assumptions made about the occupant characteristics, combustibility of furnishings, and existence of trained personnel are no longer valid. In addition, actions provided by other personnel, such as emergency responders, should not be diminished below the documented assumed levels. Also, actions needed to maintain reliability of systems at the anticipated level need to meet the initial design criteria. [**1:**A.5.1.10]

Subsection 5.1.10 deals with issues that arise after the facility has been constructed and a certificate of occupancy has been issued. Therefore, any changes to the facility, or the operations conducted therein, up to and including the demolition of the facility, that affect the assumptions of the original design are considered as part of the management of change. [**1:**A.5.1.10]

The following is a process for evaluating performance-based facilities:

(1) Review of original design analysis and documentation as follows:
    (a) Assumptions
    (b) Input parameter values
    (c) Predictions and/or results of other calculations
(2) Review of design analysis and documentation for any subsequent renovations, additions, modifications, and so forth, as in Step 1 of A.5.1.4
(3) Review of the facility's operations and maintenance manual, including any and all revisions to it
(4) On-site inspection, involving the following:
    (a) Consideration of "prescriptive" issues (e.g., blocked egress paths, poor maintenance of systems)
    (b) Comparison of assumptions to specific, pertinent on-site conditions
    (c) Comparison of input parameter values to pertinent on-site conditions
    (d) Review of maintenance and testing documentation to ensure adherence to the schedules detailed in the facility's O&M Manual
(5) Reconciliation of discrepancies as follows:
    (a) Develop a list of discrepancies
    (b) Consultation with the facility owner and/or their representative
    (c) Preparation of a schedule that reconciles the discrepancies

[**1:**A.5.1.10]

A.5.1.11 Private fire inspection services can be used to meet this provision provided that they are qualified to assess the impact of changes on the performance-based design and assumptions. [**1:**A.5.1.11]

A.5.2.2 The performance criteria in 5.2.2 define an acceptable level of performance that should be agreed upon by the stakeholders, including the owner and the AHJ. The acceptable level of performance can vary widely between different facilities based on a number of factors, including the existence of potential ignition sources, potential fuel loads present, reactivity and quantity of hazardous materials present, the nature of the operations conducted at the facility, and the characteristics and number of personnel likely to be present at the facility. [**1:**A.5.2.2]

A.5.2.2.1 Many of the performance criteria related to safety from fire can also be found in the annex of NFPA *101*. [**1:**A.5.2.2.1]

Δ **A.5.2.2.2** It is anticipated that the design provides protection for occupants who are not intimate with the initial unintentional detonation or deflagration of explosive materials, and individuals immediately adjacent to the property. It is recognized that employees should be trained and knowledgeable in the hazards of the materials present in the workplace. It is recognized that some of these individuals could experience psychological and physical injuries, such as hearing problems, on either a short- or long-term basis. However, the intent is that they do not experience thermal burns or loss of life or limb as a direct result of the explosion. [**1:**A.5.2.2.2]

It is not the intent of the *Code* to provide protection against explosions caused by acts of terrorism. This would involve the introduction of an unknown quantity of explosives in an unknown location within or adjacent to a building. Where protection is needed against such acts of terrorism, the appropriate military and law enforcement agencies should be consulted. [**1:**A.5.2.2.2]

Δ **A.5.2.2.3** Given the nature and variety of hazardous materials, more than one performance criterion for a specific facility could need to be developed. Criteria have to be developed for each hazardous material and possibly for different personnel; for example, higher levels of exposure can be tolerated by personnel that are in some way protected than those personnel having no protection. Development of performance criteria for hazardous materials should be developed by the facility owner and the facility's safety personnel in conjunction with the AHJ and the emergency response personnel expected to respond to an incident. [**1:**A.5.2.2.3]

It is anticipated that the design provides protection for occupants inside or immediately adjacent to the facility who are not intimate with the initial unauthorized release of hazardous materials, or the initial unintentional reaction of hazardous materials. However, it is assumed that these individuals depart from the area of the incident in a time frame reasonable for their circumstances, based on their observation of the event, or some other form of notification. [**1:**A.5.2.2.3]

It is also anticipated that employees and emergency response personnel are trained and aware of the hazardous materials present in the facility, and the potential consequences of their involvement in the incident, and take appropriate measures to ensure their own safety during search and rescue operations. [**1:**A.5.2.2.3]

It is not the intent of the *Code* to provide protection against acts of terrorism involving the introduction of hazardous materials into a facility. This involves the introduction of an unknown quantity of materials in an unknown location within or adjacent to a building. Where protection is needed against such acts of terrorism, the appropriate military and law enforcement agencies should be consulted. [**1:**A.5.2.2.3]

A.5.2.2.4 Each facility designed using a performance-based approach most likely has different levels of acceptable and unacceptable property damage. This reflects the unique aspects of the performance-based designed facility and the reasons for pursuing a performance-based design. Therefore, the definition of an acceptable and an unacceptable level of property damage results from discussions between the facility's owner, manager and engineer, the designer, (possibly) the insurance underwriter and field engineer, and the AHJ. There could be cases where a property damage criterion is not needed. [**1:**A.5.2.2.4]

Note that the structural integrity performance criteria for property damage most likely differs from the structural integrity performance criteria for life safety. This reflects the difference in the associated objectives: a life safety criterion probably is more restrictive than one for property damage. [**1:**A.5.2.2.4]

A.5.2.2.5 Each facility designed using a performance-based approach most likely has a different level of acceptable and unacceptable interruption of the facility's mission. This reflects the unique aspects of the performance-based designed facility and the reasons for pursuing a performance-based design. Therefore, the definition of an acceptable and an unacceptable interruption of the facility's mission results from discussions between the facility's owner, manager and engineer, the designer, (possibly) the insurance underwriter and field engineer, and the AHJ. There could be cases where a mission continuity criterion is not needed. [**1:**A.5.2.2.5]

N **A.5.2.2.8** Performance-based design of structural fire resistance requires three major steps:

(1) Determination of the thermal exposure to a structure resulting from a fire
(2) Determination of the temperature history within the structure, or portion thereof
(3) Determination of the structural response

[**1:**A.5.2.2.8]

SFPE Standard S.01, *Calculating Fire Exposures to Structures*, provides methodologies to predict thermal boundary conditions for fully developed fires to a structure (Step 1). SFPE Standard S.02, *Calculation Methods to Predict the Thermal Performance of Structural and Fire Resistive Assemblies*, provides methodologies to predict the thermal response of structures (Step 2). Appendix E, *Performance-Based Design Procedures for Fire Effects on Structures*, of ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, provides methodologies to predict the structural response (Step 3). [**1:**A.5.2.2.8]

A.5.4 Many events can occur during the life of a facility; some have a higher probability of occurrence than others. Some events, though not typical, could have a devastating effect on the facility. A reasonable design should be able to achieve the goals, objectives, and performance criteria of this *Code* for any typical or common design scenario and for some of the nontypical, potentially devastating scenarios, up to some level commensurate with society's expectations as reflected in this *Code*. [**1:**A.5.4]

The challenge in selecting design scenarios is finding a manageable number that are sufficiently diverse and representative so that, if the design is reasonably safe for those scenarios, it should then be reasonably safe for all scenarios, except for those specifically excluded as being unrealistically severe or sufficiently infrequent to be fair tests of the design. [**1:**A.5.4]

Δ **A.5.4.1.2** The *SFPE Engineering Guide to Performance-Based Fire Protection* identifies methods for evaluating fire scenarios. [**1:**A.5.4.1.2]

A.5.4.1.3 It is desirable to consider a wide variety of different design scenarios to evaluate the complete capabilities of the building or structure. Design scenarios should not be limited to a single or a couple of worst-case events. [**1:**A.5.4.1.3]

Δ **A.5.4.2** Building construction including requirements for life safety affecting the egress system should be in accordance with the adopted building code. In the absence of requirements established by the adopted building code, considerations regarding design scenarios affecting matters of construction and/or egress related to fire can include the following:

Fire Design Scenario 1. Fire Design Scenario 1 involves an occupancy-specific design scenario representative of a typical fire for the occupancy.

This design scenario should explicitly account for the following:

(1) Occupant activities
(2) Number and location of occupants
(3) Room size
(4) Furnishings and contents
(5) Fuel properties and ignition sources
(6) Ventilation conditions

The first item ignited and its location should be explicitly defined.

An example of such a scenario for a health care occupancy involves a patient room with two occupied beds with a fire initially involving one bed and the room door open. This is a cursory example in that much of the explicitly required information indicated in A.5.4.2 can be determined from the information provided in the example. Note that it is usually necessary to consider more than one scenario to capture the features and conditions typical of an occupancy.

Fire Design Scenario 2. Fire Design Scenario 2 involves an ultrafast-developing fire in the primary means of egress with interior doors open at the start of the fire. This design scenario should address the concern regarding a reduction in the number of available means of egress.

Examples of such scenarios are a fire involving ignition of gasoline as an accelerant in a means of egress, clothing racks in corridors, renovation materials, or other fuel configurations that can cause an ultrafast fire. The means of egress chosen is the doorway with the largest egress capacity among doorways normally used in the ordinary operation of the building. The baseline occupant characteristics for the property are assumed. At ignition, doors are assumed to be open throughout the building.

Fire Design Scenario 3. Fire Design Scenario 3 involves a fire that starts in a normally unoccupied room that can potentially endanger a large number of occupants in a large room or other area. This design scenario should address the concern regarding a fire starting in a normally unoccupied room and migrating into the space that can, potentially, hold the greatest number of occupants in the building.

An example of such a scenario is a fire in a storage room adjacent to the largest occupiable room in the building. The contents of the room of fire origin are specified to provide the largest fuel load and the most rapid growth in fire severity consistent with the normal use of the room. The adjacent occupiable room is assumed to be filled to capacity with occupants. Occupants are assumed to be somewhat impaired in whatever form is most consistent with the intended use of the building. At ignition, doors from both rooms are assumed to be open. Depending on the design, doorways connect the two rooms or they connect via a common hallway or corridor.

For purposes of this scenario, an occupiable room is a room that could contain people (i.e., a location within a building where people are typically found).

Fire Design Scenario 4. Fire Design Scenario 4 involves a fire that originates in a concealed wall or ceiling space adjacent to a large occupied room. This design scenario should address the concern regarding a fire originating in a concealed space that does not have either a detection system or suppression system and then spreading into the room within the building that can, potentially, hold the greatest number of occupants.

An example of such a scenario is a fire originating in a concealed wall or ceiling space adjacent to a large, occupied function room. Ignition involves concealed combustibles, including wire or cable insulation and thermal or acoustical insulation. The adjacent function room is assumed to be occupied to capacity. The baseline occupant characteristics for the property are assumed. At ignition, doors are assumed to be open throughout the building.

Fire Design Scenario 5. Fire Design Scenario 5 involves a slow-developing fire, shielded from fire protection systems, in close proximity to a high occupancy area. This design scenario should address the concern regarding a relatively small ignition source causing a significant fire.

An example of such a scenario is a cigarette fire in a trash can. The trash can is close enough to room contents to ignite more substantial fuel sources but is not close enough to any occupant to create an intimate-with-ignition situation. If the intended use of the property involves the potential for some occupants to be incapable of movement at any time, then the room of origin is chosen as the type of room likely to have such occupants, filled to capacity with occupants in that condition. If the intended use of the property does not involve the potential for some occupants to be incapable of movement, then the room of origin is chosen to be an assembly or function area characteristic of the use of the property, and the trash can is placed so that it is shielded by furniture from suppression systems. At ignition, doors are assumed to be open throughout the building.

Fire Design Scenario 6. Fire Design Scenario 6 involves the most severe fire resulting from the largest possible fuel load characteristic of the normal operation of the building. This design scenario should address the concern regarding a rapidly developing fire with occupants present.

An example of such a scenario is a fire originating in the largest fuel load of combustibles possible in normal operation in a function or assembly room or in a process/manufacturing area, characteristic of the normal operation of the property. The configuration, type, and geometry of the combustibles are chosen so as to produce the most rapid and severe fire growth or smoke generation consistent with the normal operation of the property. The baseline occupant characteristics for the property are assumed. At ignition, doors are assumed to be closed throughout the building.

This scenario includes everything from a big couch fire in a small dwelling to a rack storage fire in combustible liquids stock in a big box retail store.

Fire Design Scenario 7. Fire Design Scenario 7 involves an outside exposure fire. This design scenario should address the concern regarding a fire starting at a location remote from the area of concern and either spreading into the area, blocking escape from the area, or developing untenable conditions within the area.

An example of such a scenario is an exposure fire. The initiating fire is the closest and most severe fire possible consistent with the placement and type of adjacent properties and the placement of plants and combustible adornments on the property. The baseline occupant characteristics of the property are assumed.

This category includes wildland/urban interface fires and exterior wood shingle problems, where applicable.

Fire Design Scenario 8. Fire Design Scenario 8 involves a fire originating in ordinary combustibles in a room or area with each passive or active fire protection system or feature independently rendered ineffective. This set of design scenarios should address concerns regarding each fire protection system or fire protection feature, considered individually, being unreliable or becoming unavailable. This scenario should not be required to be applied to fire protection systems or features for which both the level of reliability and the design performance in the absence of the system are acceptable to the AHJ.

This scenario addresses a set of conditions with a typical fire originating in the building with any one passive or active fire protection system or feature being ineffective. Examples include unprotected openings between floors or between fire walls or fire barrier walls, rated fire doors that fail to close automatically or are blocked open, sprinkler system water supply that is shut off, fire alarm system that's nonoperative, smoke management system that is not operational, or automatic smoke dampers that are blocked open. This scenario should represent a reasonable challenge to the other building features provided by the design and presumed to be available.

The exemption from Fire Design Scenario 8 is applied to each active or passive fire protection system individually and requires two different types of information to be developed by analysis and approved by the AHJ. System reliability is to be analyzed and accepted. Design performance in the absence of the system is also to be analyzed and accepted, but acceptable performance does not require fully meeting the stated goals and objectives. It might not be possible to meet fully the goals and objectives if a key system is unavailable, and yet no system is totally reliable. The AHJ determines which level of performance, possibly short of the stated goals and objectives, is acceptable, given the very low probability (that is, the system's unreliability probability) that the system will not be available.

A.5.4.4 Design hazardous materials scenarios should explicitly account for the following:

(1) Occupant activities, training, and knowledge
(2) Number and location of occupants
(3) Discharge location and surroundings
(4) Hazardous materials' properties
(5) Ventilation, inerting, and dilution systems and conditions
(6) Normal and emergency operating procedures
(7) Safe shutdown and other hazard mitigating systems and procedures
(8) Weather conditions affecting the hazard
(9) Potential exposure to off-site personnel

[**1:**A.5.4.4]

Design hazardous materials scenarios should be evaluated as many times as necessary by varying the factors previously indicated. Design hazardous materials scenarios could need to be established for each different type of hazardous material stored or used at the facility. [**1:**A.5.4.4]

A.5.4.4.4.2 This provision should be applied to each protection system individually and requires two different types of information to be developed by analysis and approved by the AHJ. System reliability is to be analyzed and accepted. Design performance in the absence of the system is also to be analyzed and accepted, but acceptable performance does not require fully meeting the stated goals and objectives. It might not be possible to meet fully the goals and objectives if a key system is unavailable, and yet no system is totally reliable. The AHJ determines which level of performance, possibly short of stated goals and objectives, is acceptable, given the very low probability (that is, the systems' unreliability probability) that the system will be unavailable. [**1:**A.5.4.4.4.2]

A.5.4.5.1 An example of such a scenario would involve a fire or earthquake effectively blocking the principal entrance/exit but not immediately endangering the occupants. The full occupant load of the assembly space has to exit using secondary means. [**1:**A.5.4.5.1]

A.5.6 The assessment of precision required in 5.7.2 requires a sensitivity and uncertainty analysis, which can be translated into safety factors. [**1:**A.5.6]

Sensitivity Analysis. The first run a model user makes should be labeled as the base case, using the nominal values of the various input parameters. However, the model user should not rely on a single run as the basis for any performance-based fire safety system design. Ideally, each variable or parameter that the model user made to develop the nominal input data should have multiple runs associated with it, as should combinations of key variables and parameters. Thus, a sensitivity analysis should be conducted that provides the model user with data that indicates how the effects of a real fire could vary and how the response of the proposed fire safety design could also vary. [**1:**A.5.6]

The interpretation of a model's predictions can be a difficult exercise if the model user does not have knowledge of fire dynamics or human behavior. [**1:**A.5.6]

Reasonableness Check. The model user should first try to determine whether the predictions actually make sense, that is, they don't upset intuition or preconceived expectations. Most likely, if the results don't pass this test, an input error has been committed. [**1:**A.5.6]

Sometimes the predictions appear to be reasonable but are, in fact, incorrect. For example, a model can predict higher temperatures farther from the fire than close to it. The values themselves could be reasonable, for example, they are not hotter than the fire, but they don't "flow" down the energy as expected. [**1:**A.5.6]

A margin of safety can be developed using the results of the sensitivity analysis in conjunction with the performance criteria to provide the possible range of time during which a condition is estimated to occur. [**1:**A.5.6]

Safety factors and margin of safety are two concepts used to quantify the amount of uncertainty in engineering analyses. Safety factors are used to provide a margin of safety and represent, or address, the gap in knowledge between the theoretically perfect model, that is, reality and the engineering models that can only partially represent reality. [**1:**A.5.6]

Safety factors can be applied to either the predicted level of a physical condition or to the time at which the condition is predicted to occur. Thus, a physical or a temporal safety factor, or both, can be applied to any predicted condition. A predicted condition (that is, a parameter's value) and the time at which it occurs are best represented as distributions. Ideally, a computer fire model predicts the expected or nominal value of the distribution. Safety factors are intended to represent the spread of these distributions. [**1:**A.5.6]

Given the uncertainty associated with data acquisition and reduction, and the limitations of computer modeling, any condition predicted by a computer model can be thought of as an expected or nominal value within a broader range. For example, an upper layer temperature of 1110°F (600°C) is predicted at a given time. If the modeled scenario is then tested (that is, full-scale experiment based on the computer model's input data), the actual temperature at that given time could be 1185°F or 1085°F (640°C or 585°C). Therefore, the temperature should be reported as 1110°F + 75°F, –25°F (600°C + 40°C, –15°C) or as a range of 1085°F to 1184°F (585°C to 640°C). [**1:**A.5.6]

Ideally, predictions are reported as a nominal value, a percentage, or an absolute value. As an example, an upper layer temperature prediction could be reported as 1112°F (600°C), 86°F (30°C) or 1112°F (600°C), 5 percent. In this case, the physical safety factor is 0.05 (that is, the amount by which the nominal value should be degraded and enhanced). Given the state-of-the-art of computer fire modeling, this is a very low safety factor. Physical safety factors tend to be on the order of tens of percent. A safety factor of 50 percent is not unheard of. [**1:**A.5.6]

Part of the problem in establishing safety factors is that it is difficult to state the percentage or range that is appropriate. These values can be obtained when the computer model predictions are compared to test data. However, using computer fire models in a design mode does not facilitate this since (1) the room being analyzed has not been built yet and (2) test scenarios do not necessarily depict the intended design. [**1:**A.5.6]

A sensitivity analysis should be performed based on the assumptions that affect the condition of interest. A base case that uses all nominal values for input parameters should be developed. The input parameters should be varied over reasonable ranges, and the variation in predicted output should be noted. This output variation can then become the basis for physical safety factors. [**1:**A.5.6]

The temporal safety factor addresses the issue of when a condition is predicted and is a function of the rate at which processes are expected to occur. If a condition is predicted to occur 2 minutes after the start of the fire, then this can be used as a nominal value. A process similar to that described for physical safety factors can also be employed to develop temporal safety factors. In this case, however, the rates (for example, of heat release and toxic product generation) will be varied instead of absolute values (for example, material properties). [**1:**A.5.6]

The margin of safety can be thought of as a reflection of societal values and can be imposed by the AHJ for that purpose. Since the time for which a condition is predicted is most likely the focus of the AHJ (for example, the model predicts occupants have 5 minutes to safely evacuate), the margin of safety is characterized by temporal aspects and tacitly applied to the physical margin of safety. [**1:**A.5.6]

Escaping the harmful effects of fire (or mitigating them) is, effectively, a race against time. When assessing fire safety system designs based on computer model predictions, the choice of an acceptable time is important. When an AHJ is faced with the predicted time of untenability, a decision needs to be made regarding whether sufficient time is available to ensure the safety of facility occupants. The AHJ is assessing the margin of safety. Is there sufficient time to get everyone out safely? If the AHJ feels that the predicted egress time is too close to the time of untenability, then the AHJ can impose an additional time that the designer has to incorporate into the system design. In other words, the AHJ can impose a greater margin of safety than that originally proposed by the designer. [**1:**A.5.6]

The *SFPE Handbook of Fire Protection Engineering* has a discussion on the use of safety factors and the evaluation of uncertainty in a performance-based design. [**1:**A.5.6]

Δ **A.5.7.1** The *SFPE Engineering Guide to Performance-Based Fire Protection* describes the documentation that should be provided for a performance-based design. [**1:**A.5.7.1]

Proper documentation of a performance design is critical to the design acceptance and construction. Proper documentation also ensures that all parties involved understand what is necessary for the design implementation, maintenance, and continuity of the fire protection design. If attention to details is maintained in the documentation, then there should be little dispute during approval, construction, start-up, and use. [**1:**A.5.7.1]

Poor documentation could result in rejection of an otherwise good design, poor implementation of the design, inadequate system maintenance and reliability, and an incomplete record for future changes or for testing the design forensically. [**1:**A.5.7.1]

A.5.7.2 The sources, methodologies, and data used in performance-based designs should be based on technical references that are widely accepted and used by the appropriate professions and professional groups. This acceptance is often based on documents that are developed, reviewed, and validated under one of the following processes:

(1) Standards developed under an open consensus process conducted by recognized professional societies, codes or standards organizations, or governmental bodies
(2) Technical references that are subject to a peer review process and published in widely recognized peer-reviewed journals, conference reports, or other publications
(3) Resource publications such as the *SFPE Handbook of Fire Protection Engineering*, which are widely recognized technical sources of information

[**1:**A.5.7.2]

The following factors are helpful in determining the acceptability of the individual method or source:

(1) Extent of general acceptance in the relevant professional community. Indications of this acceptance include peer-reviewed publication, widespread citation in the technical literature, and adoption by or within a consensus document.
(2) Extent of documentation of the method, including the analytical method itself, assumptions, scope, limitations, data sources, and data reduction methods.
(3) Extent of validation and analysis of uncertainties. This includes comparison of the overall method with experimental data to estimate error rates as well as analysis of the uncertainties of input data, uncertainties and limitations in the analytical method, and uncertainties in the associated performance criteria.
(4) Extent to which the method is based on sound scientific principles.
(5) Extent to which the proposed application is within the stated scope and limitations of the supporting information, including the range of applicability for which there is documented validation. Factors such as spatial dimensions, occupant characteristics, and ambient conditions can limit valid applications.

[**1:**A.5.7.2]

In many cases, a method is built from and includes numerous component analyses. These component analyses should be evaluated using the same factors that are applied to the overall method as outlined in items (1) through (5). [**1:**A.5.7.2]

A method to address a specific fire safety issue, within documented limitations or validation regimes, might not exist. In such a case, sources and calculation methods can be used outside of their limitations, provided that the design team recognizes the limitations and addresses the resulting implications. [**1:**A.5.7.2]

The technical references and methodologies to be used in a performance-based design should be closely evaluated by the design team and the AHJ, and possibly by a third-party reviewer. The strength of the technical justification should be judged using criteria in items (1) through (5). This justification can be strengthened by the presence of data obtained from fire testing. [**1:**A.5.7.2]

A.5.7.11 Documentation for modeling should conform to ASTM E1472*, Standard Guide for Documenting Computer Software for Fire Models*, and the *SFPE Guide for Substantiating a Fire Model for a Given Application*. [**1:**A.5.7.11]

A.6.4.1.5.1 Occupancies, including industrial and storage occupancies, are defined by the building code adopted by the jurisdiction. *Occupancy* is a term used to define the activity or purpose of a building or space within a building where activity occurs. In general, occupancies are separated into various categories depending on the use. Some of the categories, depending on the adopted building code, can include, but are not limited to, the following: assembly, business, educational, factory (or industrial), hazardous, institutional, mercantile, residential, storage, and so on.

Construction features as well as engineering controls are influenced by the occupancy. The greater the hazard, the more restrictive the controls to be applied within the context of construction features and engineering controls integral to the use of the building. Limitations are placed on building heights, areas, construction types, and construction features, including building or area exits and the egress system in general, depending on the risk based on a predefined set of conditions imposed by the occupancy category. Industrial occupancies are typically involved with manufacturing of a product and involve factories and workshops used to manufacture or process a wide array of materials. A storage occupancy is one in which manufactured goods are stored. Activity in these areas is limited to the storage of goods or materials. The quantity of hazardous materials in occupancies other than those classified as hazardous is limited. When the need for quantity of various hazardous materials, including hydrogen, increases, the occupancy of the area can revert to that of a "hazardous occupancy," or the excess quantities might have to be isolated from the factory floor by either placing them into a room that is isolated by fire-resistive construction, or by transferring the materials outside of the building or to a separate building where they can be piped to a point of use.

N **A.6.5** Some hydrogen systems include pressures above the limits of ASME B31.12, *Hydrogen Piping and Pipelines*. In such cases, another section of ASME B31, such as ASME B31.3, *Process Piping*, might be more appropriate.

Some hydrogen generators (e.g., reformers or gasifiers) can produce a gas mixture that is less than 95 percent hydrogen or above the temperature limits of ASME B31.12, *Hydrogen Piping and Pipelines*. In such cases, another section of ASME B31 might be more appropriate.

Δ **A.6.5.1** Any reference to listed or approved equipment in the noted sections of the IFGC is within the context of ASME B31.12, *Hydrogen Piping and Pipelines,* and describes a material or component that conforms to the specifications integral to ASME B31.12.

Δ **A.6.5.3.1.3** 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.

Δ **A.6.8** Electrical and electronic equipment and wiring for use in hazardous locations as defined in Article 500 of *NFPA 70* 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.

Δ **A.6.9** 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 can 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 Annex K contains additional nonmandatory guidance relative to prevention and mitigation of hydrogen explosions.

Δ **A.6.10.3** 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.

A.6.13 See Annex L for guidance on hydrogen gas detectors.

A.6.13.2.1.1 Many manufacturers recommend at least quarterly testing or calibration, but more frequent testing during the initial operating period. The installation of the detector in extreme or harsh environments can also warrant more frequent testing.

A.6.14 *NFPA 70* and NFPA 497 should be used for guidance in determining the appropriateness of various lighting fixtures.

Δ **A.6.17** The termination point for piped vent systems serving cylinders, containers, tanks, and gas systems used for the purpose of operational or emergency venting should 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.

N **A.6.17.2** The discharge from the vent creates a hazardous (classified) area that extends from the vent termination (outlet). IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres* provides a method for determining the extent of hazardous (classified) areas.

N **A.6.17.4** Analysis can be used to justify smaller horizontal separation distances provided that the hydrogen concentration at the exposure is 25 percent or less of the LFL when factors such as wind and gas temperature are taken into account.

Δ **A.6.18** The ventilation systems should be designed to ensure that fire hazards and risks are minimized. Designers should consider the use of the *Industrial Ventilation:A Manual of Recommended Practice for Design,* in the design of local exhaust systems.

A.6.18.2.1.4.3 When LH_2 systems are employed, the density of the liquid when released should be considered. For a transient time period, the vapors might be heavier than air.

A.6.18.2.1.7 See 501.3 of the ICC *International Mechanical Code* for additional guidance on exhaust outlets including ventilation discharge.

N **A.6.18.2.1.8.1** This section addresses systems that use ventilation to dilute potential releases of hydrogen. While this technique has some similarities to the purge and pressurization protection technique for equipment in hazardous (classified) areas addressed by NFPA 496, it is not the same and the two should not be confused.

N **A.6.18.2.1.8.3** The components of the ventilation system, detection system, and the circuit or system that accomplishes 6.18.2.1.8.2 should also be listed or approved. Standards applicable to the control components include UL 508, *Standard for Industrial Control Equipment*, UL 60947-1, *Standard for Low-Voltage Switchgear and Controlgear — Part 1: General Rules*, and UL 60730-1, *Automatic Electrical Controls — Part 1: General Requirements*.

The circuits or systems that accomplish 6.18.2.1.8.2 should be as follows:

(1) Compliant with the requirements of Chapter 9 of NFPA 79, which includes applicable sections on emergency stop and safety-related functions
(2) Compliant with at least SIL 2 per IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Parts 1 to 7*, or a similar safety standard
(3) Listed or approved to UL 1998, *Standard for Software in Programmable Components*, if the system relies on software or programming

Δ **A.6.21** Figure A.6.21 shows three possible locations of the source valve.

N **A.6.21.3** There are several guidelines and standards describing best practices in the design and implementation of improved human-machine interface (HMI) in process and pipeline controls. These include publications by the Abnormal Situation Management Consortium, the ISO, and the American Petroleum Institute. The advantages of a graphical controls interface for these controls is described in AIChE article, “Safe Operations Using Advanced Operator Graphics,” by David A. Lee.

Δ **A.6.22.1.1(3)** 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. The requirement is to not introduce new containments during the repair (e.g., cutting oils, grinding debris, contaminated hardware, etc.). Conversely, when a piping system is extended, or when the system needs to be rendered safe for maintenance purposes, purging the system out of service before disassembly likely will be required as will internal cleaning if new piping or materials of construction are introduced.

Δ **A.6.22.1.1(4)** Cleaning and purging of hydrogen systems can be conducted as individual functions, that is, just cleaning, just purging, or in combination as required to satisfy the requirements of the procedures.

Δ **A.6.22.1.3** It is not intended that a new written procedure be required each time the activity occurs within a facility.

Guidance on considerations for the written procedure is outlined in Section 4.3 of NFPA 56.

Δ **A.6.22.1.3.1** The review of the written procedures should not be performed solely by the same person(s) 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.

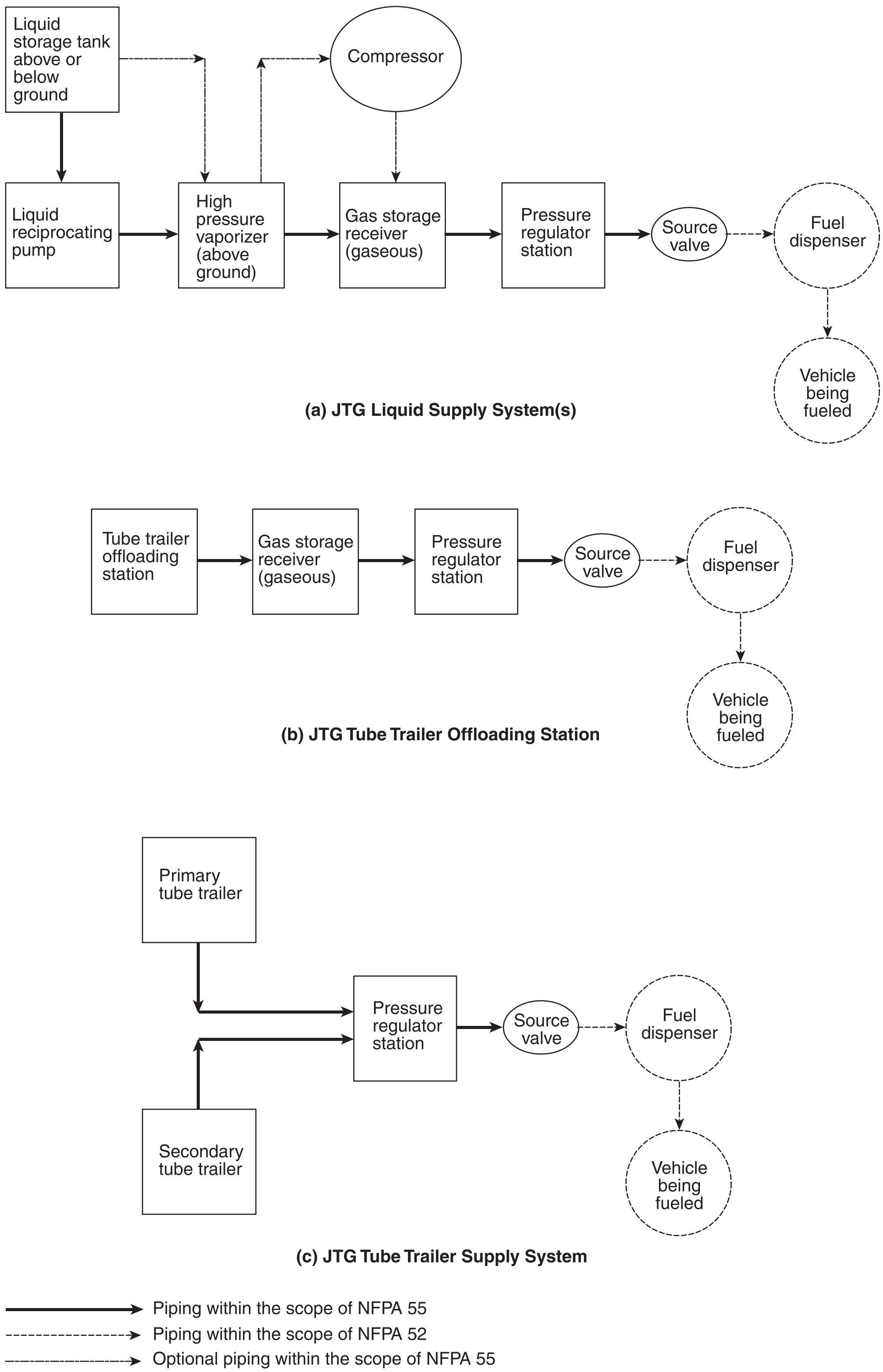
A.6.22.1.4.2 *Replacement-in-kind* refers to a situation in which a piece of equipment is replaced with equipment of the same design and service. [**56:**A.4.6.2]

Δ **A.6.22.1.5.2** The notification is given to warn personnel that such procedures are about to occur so 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 be an audible and/or visible alarm or 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 frequently are 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 located primarily in the occupied work area.

N **A.6.22.1.6** Annex N provides guidelines and practices for repairing leaks in hydrogen systems.

Δ **A.7.1.2** The GH_2 system equipment referenced is intended to include fuel cell power system 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.



Δ **FIGURE A.6.21 Three Examples of Source Valve Locations.**

Δ **A.7.1.4** 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.7.1.4.1.4 The original equipment manufacturer (OEM), for the purpose of this paragraph, should be considered to include a duly authorized and trained representative of the OEM.

Δ **A.7.1.7.2** 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.

A.7.1.8.1 Storage tubes, including ground-mounted tubes and mobile equipment, are typically not provided with caps or collars. The condition is normally encountered for bulk systems where the containers used are not conventionally provided with caps or collars as the valves are connected to piping systems or manifolds for the purpose of distributing the gas. The term *similar devices* should not be limited to devices that attach to the container. The intent is to include protection for valves on cylinders, containers, and tanks that are not otherwise equipped against physical damage by barriers, security fencing, spatial arrangement, or other means.

Δ **A.7.1.9.1.1** 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.

Δ **A.7.1.9.1.8.1** 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.

A.7.1.13.1 Compressed gas systems in hydrogen service are subject to leakage; however, leakage has not been defined in quantitative terms. Leak rates for outboard leakage sufficient to support stable flames have been the source of recent study, "Limits for hydrogen leaks that can support stable flames," by Butler et al.[1] The mass flow rate of hydrogen at its quenching limit has been reported to be 3.9 μg/s (0.05 scc/s). Butler, et al., report that the minimum flow rate necessary for sustaining a hydrogen flame on a leaky 6.3 mm tube compression fitting is 28 μg/s (0.3 scc/s). Leaks below a level sufficient to sustain a hydrogen flame for systems in the open will diffuse into the atmosphere without consequence. In unventilated spaces, bubble leaks as low as 0.1 scc/s (8.6 L/day) can warrant repair depending on the natural or mechanical ventilation available to the space in which the containers are found.

Δ **A.7.1.13.3** The gas supplier should be consulted for advice under these circumstances.

N **A.7.1.21.1.1(3)** The flight train [balloon and lofted instrument(s)] ascends until the balloon expands and bursts at a high altitude between 80 ft to 100,000 ft (24,000 m to 30,480 m). The hydrogen is released harmlessly there, and the instrument(s) falls back to earth with its descent rate typically slowed by either a small parachute or the lightweight and aerodynamically inefficient shape of the instrument package or both. No hydrogen is present when the instrument(s) lands.

N **A.7.1.21.1.2** Because hydrogen is a flammable gas and a balloon is a weak, non-robust container, an analysis to certify a balloon inflation facility should evaluate the following factors:

(1) Inflation area design
(2) Electrical classification of the inflation area
(3) Exhaust ventilation requirements
(4) Overinflation
(5) Underinflation
(6) Hydrogen flow rate
(7) Interlocks and an automatic safety system to interrupt hydrogen flow
(8) Hydrogen generation system(s)
(9) Hydrogen storage system(s)
(10) Hydrogen distribution system(s)
(11) Fire exposure to the inflation area or building

N **A.7.1.22(2)** Examples of national aviation authorities include the Federal Aviation Administration (FAA), Transport Canada, or European Union Aviation Safety Agency (EASA).

N **A.7.1.22(3)** Dissipation of any static potential can be mitigated by bonding and grounding in accordance with Article 250 of *NFPA 70*.

N **A.7.1.22(4)** Dissipation of any static potential can be mitigated by bonding and grounding in accordance with Article 250 of *NFPA 70*.

N **A.7.1.22(6)(a)** Examples of appropriate signage could include "FLAMMABLE GAS PRESENT – KEEP BACK" or "FLAMMABLE GAS – DANGER" or "DANGER – AUTHORIZED PERSONNEL ONLY."

N **A.7.1.22(7)** Examples of immobile GH_2 sources include cylinder banks or pallets not containing wheels. Examples of mobile GH_2 sources include tube trailers. Mobile GH_2 sources can be rendered immobile using chocks, chains, or other suitable means.

N **A.7.1.22(9)(a)** Examples of national aviation authorities include the Federal Aviation Administration (FAA), Transport Canada, or European Union Aviation Safety Agency (EASA).

A.7.1.23.6 Compliance with 7.1.23.6 is not required for enclosures where operation or maintenance-related work is performed from the exterior of the enclosure.

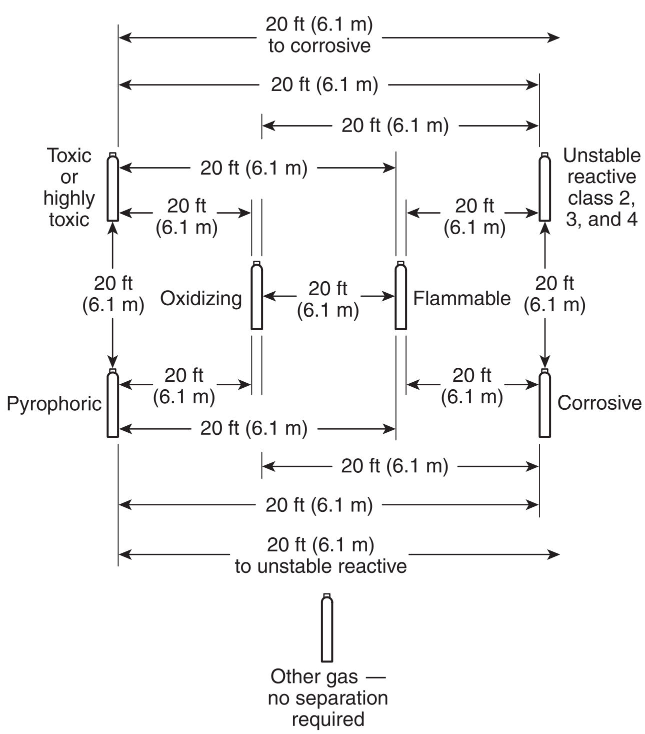
A.7.1.23.9.2 Consideration should be given to locating automatic emergency shutoff valves prior to where the pipe enters the HEE or compartment, or on each GH_2 storage tank directly after, or connected to, the primary tank manual shutoff valve.

N **A.7.1.23.12.2** An area classification analysis can be performed to determine the extent of the hazardous (classified) area, using IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*, or a similar standard. General purpose electrical equipment can be located within 15 ft (4.6 m) of the ventilation opening or exhaust discharge if it is outside of the hazardous area. An AHJ can require the applicant to provide evidence of an area classification analysis.

A.7.1.23.16.1.2 The intent of the two-hour rating for the wall is to ensure that the wall be of substantial construction and built per the building code. It is not based on a requirement that a two-hour fire is an expected scenario for the HEE. It also it not intended to make an HEE into a "building" and therefore subject to all requirements of the building code.

Δ **A.7.1.24.1.1** 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.

Δ **A.7.2.1.1** Figure A.7.2.1.1 is a schematic showing the separation distances required by 7.2.1.1.



Δ **FIGURE A.7.2.1.1 Separation of Gas Cylinders by Hazard.**

N **A.7.2.2.3.2** Table 7.2.2.3.2 applies when multiple containers are stored in the same area with each containing less than a bulk quantity of gas. Where cylinders or cylinder packs are not in use and located in a storage area, their valves are closed and are not manifolded to create a single bulk system. When non-bulk systems are in use they should be limited to no more than 5000 scf (142 Nm^3). Bulk systems should align with Section 7.3.

Δ **A.7.2.2.3.2.3(A)** 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 protective structure. The protective structure serves to protect those portions of the system that are the most vulnerable along with the necessary controls used to operate the system.

Δ **A.7.3.2.1.2** 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.

Δ **A.7.3.2.2.2.3** For guidance in these construction techniques, see NFPA 68.

A.7.3.2.2.3.5 Alternatively, Article 505 details requirements for this equipment and wiring in hazardous locations and uses a zone classification method rather than the division method of Article 500. Class 1, Division 2 locations are equivalent to the Class 1, Zone 2 locations of Article 505.

N **A.7.3.2.3.1.1** Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), and Table 7.3.2.3.1.2(B)(c) define minimum distances between exposures and components of a bulk hydrogen compressed gas system. The exposure distances are a function of exposure type (Groups 1, 2, and 3), system design pressure, and maximum internal diameter. A bulk hydrogen compressed gas system may have portions of the system that operate within differing pressure ranges. For example, components that operate within a system between 15 psig (103 kPa) and 250 psig (1724 kPa) with a largest pipe size less than or equal to 2.09 in (53 mm) have a minimum Group 1 exposure distance of 16 ft (4.9 m). Components that operate within a different portion of the system between 250 psig (1724 KPa) and 3000 psig (20684 kPa) with the largest pipe size less than or equal to 0.75 in (19 mm) have a minimum Group 1 exposure of 20 ft (6 m). It is not necessary to apply the 20 feet minimum Group 1 exposure distances to the components that form a portion of the system that operate between 15 (103 kPa) and 250 psig (1724 kPa).

Δ **A.7.3.2.3.1.2** Conversions for distance between inch-pound and SI units of measure cannot be consistently performed using typical mathematical conversion factors. The majority of separation distances shown in the SI table have been determined by the application of a risk-informed approach substantiated by statistical evaluation and modeling based on validated models for both ignited and unignited release of hydrogen gas. Where distance has been determined to allow for access or for correlation with the electrical code, the distances were not established through the use of models. Tabular distances in the inch-pound table have been determined by first converting SI units into inch-pound units and then rounding the distance to the nearest 5 ft for ease of application by code enforcers and users. A similar rounding technique has not been applied in the tabular distances shown in the SI table.

The exposures integral to Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), and Table 7.3.2.3.1.2(B)(c) have been arranged into groups based on similar risks. The estimated leak area was changed from 3 percent to 1 percent of the pipe diameter to evaluate separation distances. 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 was 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 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.

A 50 percent safety factor was added to all resulting separation distance values.

Table 7.3.2.3.1.2(B)(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 can 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 7.3.2.3.1.2(B)(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.

CGA PS-48, *Clarification of Existing Hydrogen Setback Distances and Development of New Hydrogen Setback Distances in NFPA 55*, provides guidance and clarification on types of exposures as well as applications of the separation distances.

Δ **A.7.3.2.3.1.2(B)(4)** 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.3.3.237.2(a) through Figure A.3.3.237.2(f) for additional information in this regard.

The use of Table 7.3.2.3.1.2(B)(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.

Δ **A.7.3.2.3.1.2(B)(5)** The methodology used to determine the distances listed in Table 7.3.2.3.1.2(B)(b) and Table 7.3.2.3.1.2(B)(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.

Δ **A.7.3.2.3.1.4** 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 7.3.2.3.1.2(B)(a) and Table 7.3.2.3.1.2(B)(b). The lot lines described under item (a) of Group 1 Exposures in Table 7.3.2.3.1.2(B)(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.

Δ **A.7.3.2.3.1.4(A)** 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 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 is 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.

N **A.7.3.2.3.1.4(A)(6)** See Figure A.8.3.2.3.1.5(D)(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 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), and Table 7.3.2.3.1.2(B)(c).

Δ **A.7.3.2.3.1.4(B)** 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.*

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]

N **A.7.3.2.3.1.7.1** Other than at vent outlets, where a fire barrier is used to separate an exposure, the electrical area classification can terminate on the opposite side of the fire barrier.

Δ **A.7.3.2.4.1.1** 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*.

Δ **A.7.3.2.4.3** Straight threads alone are not considered to be a seal.

Δ **A.7.3.2.4.5.6** 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.

Δ **A.7.3.2.4.8** 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.

Δ **A.8.1.2** 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.8.1.3.1.5.2 Cold gas can expand to overpressurize a pipe in much the same way as liquid. Cold gas should be considered by designers for portions of the piping system operating at temperatures less than ambient.

Δ **A.8.1.4.5.1** 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.

Δ **A.8.1.6.1.1.2** An example of this identification is 360 degree wraparound tape.

Δ **A.8.1.7.2.1** The basis of this requirement is to prevent unauthorized personnel or those unfamiliar with gas storage systems from tampering with the equipment. Where LH_2 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.

Δ **A.8.2.2.3.8** 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.

Δ **A.8.2.2.3.9.4(B)** 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*, 1997) show that the use of dikes around liquid hydrogen storage facilities serves to prolong ground-level flammable cloud travel and that the dispersion mechanism is enhanced by vaporization-induced turbulence. The travel of spilled or leaked 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.8.3.1.2.1.1 Refer to Figure A.8.3.1.2.1.1 for application of the 18 in. (46 cm) dimension to typical tank supports.

Δ **A.8.3.1.2.3** 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.

Δ **A.8.3.1.2.3.2** Piping and tubing used for liquid hydrogen and cold gas hydrogen (such as venting from a liquid hydrogen tank or a liquid hydrogen line) typically operates at temperatures below −20°F (−29°C).

Δ **A.8.3.1.2.3.8** 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.

Δ **A.8.3.1.2.5.1** 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.

Δ **A.8.3.1.2.5.2** 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

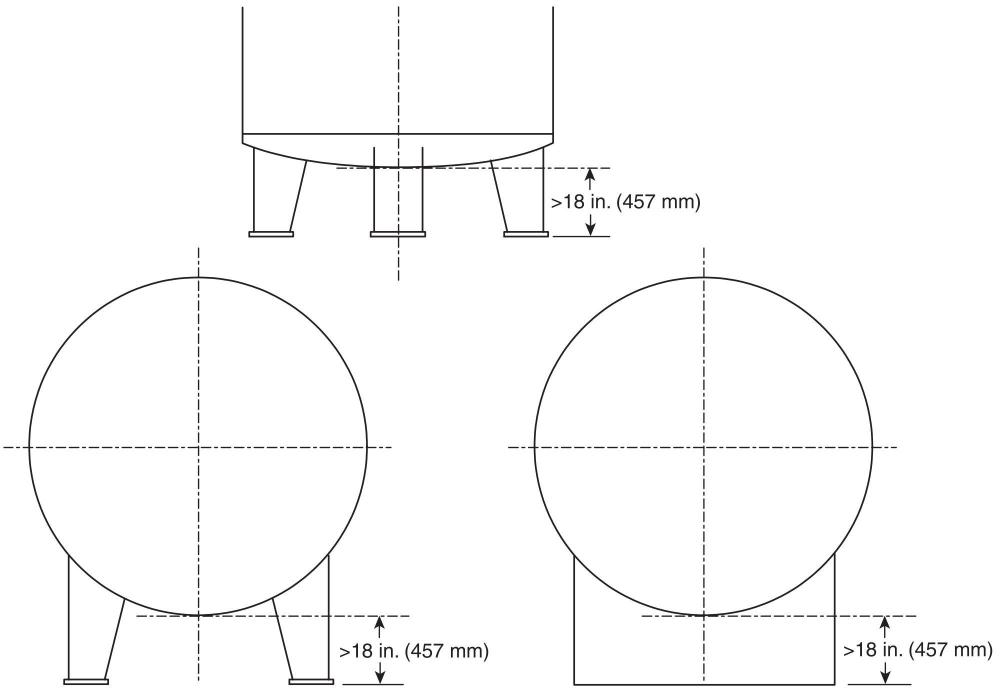


FIGURE A.8.3.1.2.1.1 Dimensions for Typical Tank Supports.

been designed to accommodate liquid can result in a loss of hydrogen and the generation of hazardous conditions.

Δ **A.8.3.1.2.8.5** Liquid hydrogen supply systems typically store the liquid, a cryogenic fluid, in storage tanks with maximum allowable working pressures (MAWP) that range from 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 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*.

Δ **A.8.3.2.1.2** 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.

Δ **A.8.3.2.1.5.4(C)** Vaporizers or heat exchangers used to vaporize LH_2 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.

Δ **A.8.3.2.2.2.3** 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.

Δ **A.8.3.2.3.1.3** 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.

Δ **A.8.3.2.3.1.5(C)** CGA P-41, *Locating Bulk Storage Systems in Courts*, provides guidance to determine the suitability of a court or enclosed court.

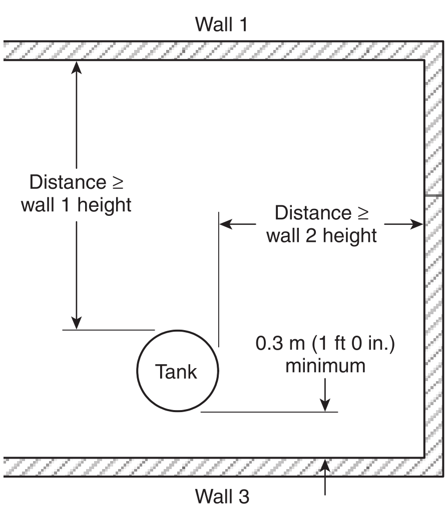
Δ **A.8.3.2.3.1.5(D)** The placement of stationary containers is limited with respect to exposure hazards. Table 8.3.2.3.1.6(A) establishes the minimum separation distance between a building and any stationary tank at 1 ft (0.3 m). Additional limitations are placed on wall openings, air intakes, and 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.

Δ **A.8.3.2.3.1.5(D)(1)** The separation distances shown in Figure A.8.3.2.3.1.5(D)(1) are required to provide for ventilation in the space in order to avoid creating a confined space. Chapter 8 of NFPA 55, 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.8.3.2.3.1.5(D)(1) could be an exterior building wall, and the gas could be hydrogen. Refer to Table 8.3.2.3.1.6(a) for specific details regarding building walls, wall openings, air intakes, and similar conditions.

Δ **A.8.3.2.3.1.5(E)(1)** The basis of this requirement is to prevent unauthorized personnel or those unfamiliar with gas storage systems from tampering with the equipment. Where the LH_2 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.



Δ **FIGURE A.8.3.2.3.1.5(D)(1) Bulk Cryogenic System Located in a Courtyard.**

Δ **A.8.3.2.3.1.6** Table 8.3.2.3.1.6(a) has been split into two tables, with one representing distances to exposure in inch-pound units of measure and the other representing distance to exposure in SI units of measure. At the present time, mathematical rounding of distances in a manner similar to that used in the formulation of Table 8.3.2.3.1.6(b) and Table 7.3.2.3.1.2(B)(a) has not been applied, and the use of conventional conversion factors between the tables remains relevant with Table 8.3.2.3.1.6(a) accordingly.

The Occupational Safety and Health Administration (OSHA) established requirements for hydrogen systems in 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 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 8.3.2.3.1.6(a). 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 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. 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.

• *N* **A.8.3.2.3.1.6(B)(3)** The maximum operating pressure (MOP) is the setpoint of the tank pressure control system and is lower than the tank maximum allowable working pressure (MAWP). A permanently installed automatic tank vent system can be used to control the pressure at or below the MOP. The pressure control system is provided with a means to ensure its function and should be periodically inspected to assure its integrity. This system can employ mechanical regulators, electrical control systems that open a control valve to relieve tank pressure, or other similar means that accomplish the same purpose. It is not

TABLE H-4 - MINIMUM DISTANCE (FEET) FROM LIQUEFIED HYDROGEN SYSTEMS TO EXPOSURE (1)(2)

Type of Exposure	Liquefied hydrogen storage (capacity in gallons)		
	39.63 (150 liters) to 3,500	3,501 to 15,000	15,001 to 30,000
1. Fire-resistive building and fire walls(3)	5	5	5
2. Noncombustible building(3)	25	50	75
3. Other buildings(3)	50	75	100
4. Wall openings, air-compressor intakes, inlets for air-conditioning or ventilating equipment	75	75	75
5. Flammable liquids (above ground and vent or fill openings if below ground) (see 513 and 514)	50	75	100
6. Between stationary liquefied hydrogen containers	5	5	5
7. Flammable gas storage	50	75	100
8. Liquid oxygen storage and other oxidizers (see 513 and 514)	100	100	100
9. Combustible solids	50	75	100
10. Open flames, smoking and welding	50	50	50
11. Concentrations of people	75	75	75

Footnote(1) The distance in Nos. 2, 3, 5, 7, 9, and 12 in Table H-4 may be reduced where protective structures, such as firewalls equal to height of top of the container, to safeguard the liquefied hydrogen storage system, are located between the liquefied hydrogen storage installation and the exposure.

Footnote(2) Where protective structures are provided, ventilation and confinement of product should be considered. The 5-foot distance in Nos. 1 and 6 facilitates maintenance and enhances ventilation.

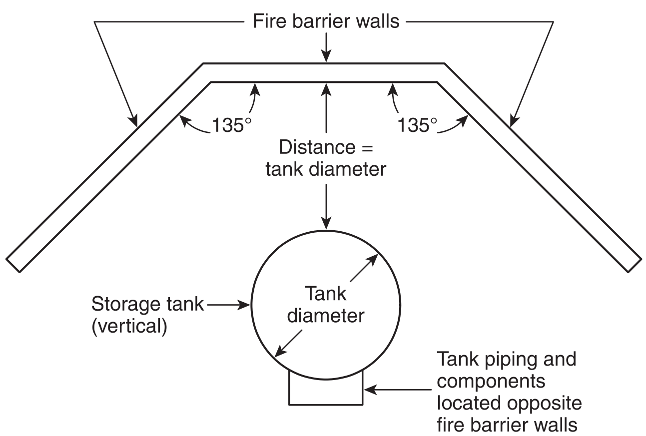
Footnote(3) Refer to Standard Types of Building Construction, NFPA No. 220-1969 for definitions of various types of construction.

FIGURE A.8.3.2.3.1.6 OSHA Table H-4.

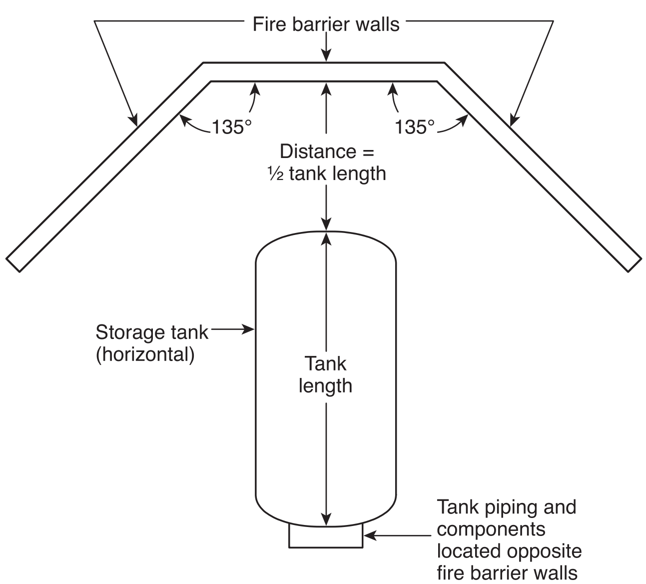
recommended to lower the primary tank safety relief devices below the MAWP since that would increase the probability of a premature release.

N **A.8.3.2.3.1.6(C)(1)(b)(vi)** See Figure A.8.3.2.3.1.5(D)(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 distance to walls constructed as fire barrier walls for exposure protection is not less than that required by Table 8.3.2.2.1.4.

N **A.8.3.2.3.1.6(C)(1)(b)(vii)** Figure A.8.3.2.3.1.6(C)(1)(b)(vii)(a) and Figure A.8.3.2.3.1.6(C)(1)(b)(vii)(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.



N **FIGURE A.8.3.2.3.1.6(C)(1)(b)(vii)(a) Schematic of Three-Sided Fire Barrier Wall Enclosure for a Vertical Hydrogen Storage System.**



N **FIGURE A.8.3.2.3.1.6(C)(1)(b)(vii)(b) Schematic of Three-Sided Fire Barrier Wall Enclosure for a Horizontal Hydrogen Storage System.**

N **A.8.3.2.3.1.6(C)(2)** To determine the acceptability of technologies, processes, products, facilities, materials, and uses attending the design, operation, or use of such systems, the AHJ can 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 can require design submittals to be prepared by, and bear the stamp of, a registered design professional or professional engineer.

N **A.8.3.2.3.1.6(C)(2)(b)** An ESS can enhance safety and reduce risk for a given installation by reducing the quantity and duration of released hydrogen. The ESS for a public fueling station should include features to automatically shut isolation valves to supplement requirements as specified in 8.3.1.2.4.2. The ESS should include the following attributes:

(1) Cryogenic rated valves that upon activation, will shut off the supply of hydrogen when fire or hydrogen leakage is detected to prevent an uncontrolled flow of hydrogen from the bulk liquid storage system.
(2) ESS automatic shutoff valves should not be installed on piping for pressure relief circuits serving the bulk liquid source so that actuation of relief devices is not impeded.
(3) In addition to use lines, ESS automatic shutoff valves should be installed on liquid lines greater than ½ in. and vapor lines of 2 in. Failure of these lines or components within the system could result in a large release of hydrogen. Liquid hydrogen circuits of ½ in. and smaller and vapor circuits of 2 in. and smaller are generally not required.
(4) The ESS should include manual operation of the ESS locally on the equipment and at a remote location that is easily accessible, visible, and not less than 15 ft from the system.
(5) The ESS valves should be located as close as possible to the bulk source.
(6) Automated controls for ESS valves should be independent of other control systems for increased reliability. Automatic ESS activation is designed to operate without human intervention. Manual ESS activation capability is a separate feature included in the system.
(7) Local audible and visual alarms upon ESS activation should be considered to alert nearby personnel of an issue with the hydrogen system.
(8) ESS shutoff devices should be protected from fire exposure that can prevent normal operation. Components in the shutdown system should be fail-safe. A device rendered inoperable should initiate a signal and shutdown. Maintenance warnings from a device should signal a supervisory alarm. The common practice is to use an air-to-open/fail-closed valve with the bottom of the valve oriented towards the bulk system. The actuator is configured such that, if exposed to a fire, the spring that holds the valve closed is effectively retained. An example of an ineffective actuator is an aluminum-bodied actuator that can weaken in a fire, allowing the spring to be ejected, and in turn, allowing the valve to open.
(9) A report indicating the ESS components and design should be included in the hazardous materials management plan.
(10) A preventative maintenance program that includes a periodic visual inspection of the ESS sensors and actua-

tion devices and an annual activation test. If the system fails inspection, the system should be shut down until repaired.

Δ **A.8.3.2.3.1.7(D)(1)** 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.8.3.2.3.1.7(J)(1) Users should notify suppliers where a tank is to be left in place but not refilled for an extended period of time. The supplier can inert the tank or otherwise prepare the tank for ultimate removal.

A.8.3.4.5.10 Liquid tanks, when buried underground, should meet the following provisions:

(1) Liquid hydrogen tanks and associated piping are installed with considerations for physical damage prevention, corrosion protection, and proper layout of piping runs.
(2) Manually operated valves, controls, PRDs, and instrumentation are located above ground, outdoors, and accessible to authorized personnel. Manually operated valves, controls, and instrumentation for filling and routine operations should be readily available to mobile supply equipment at ground level.
(3) Remotely operated emergency shutoff valves can be located below grade to allow for product isolation. These valves should be in a corrosion-resistant area that is accessible from ground level and does not create a confined space.

N **A.10.1.1.5** This chapter only applies to facilities and equipment that dispense to the fuel supply container of a hydrogen motor vehicle. Examples include fueling stations that dispense to light-duty vehicles, buses, material-handling vehicles, trucks, and trains.

A.10.2.1 Additional information on NFPA 2 code compliance for hydrogen fueling stations, including permitting checklists for hydrogen fueling stations, can be found on H2Tools.org at https://h2tools.org/.

A.10.2.1.1 Several standards have been published and are in use for product certification, listing, or labeling of fueling facility equipment. For example, light-duty vehicle fueling, a specific-use case of material covered by dispensing to the public, applicants might propose a system that uses CSA HGV 4.9, *Hydrogen Fueling Stations*. Also, for powered industrial trucks (e.g., forklifts), a specific-use case of material covered by dispensing to nonpublic users, applicants might propose a system that uses CSA HPIT 2, *Dispensing systems and components for fueling hydrogen powered industrial trucks*. Additional information regarding certification and approval for hydrogen systems is available through the H2 Tools website at https://www.h2tools.org.

A.10.2.1.2 A hazard(s) analysis can be performed by a number of methods where the end result can be achieved through the use of more than one method. Several of the more common methods employed by those involved in systems safety today include, but are not limited to, hazard and operability studies (HAZOPs), failure modes effects and criticality analysis (FMECA), preliminary hazards analysis (PHA), fault tree analysis (FTA), and event tree analysis. Standard designs that have been analyzed by recognized methodology need not be studied each and every time such an installation occurs. Rather, site-specific elements that are unique to the installation should be reviewed in concert with the analysis performed on the standard system to ensure that the standard design has not been altered in a way that would negatively affect the hazard analysis.

The reviews conducted frequently involve a series of meetings between members of a multidisciplinary team that methodically "brainstorms" the system design, following a structure provided by study format and the team leader's experience. Members of the team can include engineers as well as other personnel skilled in the application of a systems safety approach.

A.10.2.2 Dispensers can be listed and certified to meet the requirements of ANSI/CSA HGV 4.1. It is acknowledged that with a developing technology not all components included in 10.3.1.2 have standards to which they can be listed. The purpose of the language "listed or approved" is to require listing documentation for those items for which listing standards exist, and for an appropriate amount of documentation proving suitability and safety of the intended use be provided to the AHJ to allow for the "approval" of components that do not have listings.

The following are examples of standards that can be used for listing or certification:

(1) Valves can be listed and certified to meet the requirements of ANSI/CSA HGV 4.6 or ANSI/CSA HGV 4.7.
(2) Hoses can be listed and certified to meet the requirements of ANSI/CSA HGV 4.2.
(3) Hydrogen dispensers can be listed and certified to meet the requirements of ANSI/CSA HGV 4.1.
(4) Breakaway devices can be listed and certified to meet the requirements of ANSI/CSA HGV 4.4.
(5) Compressors can be listed and certified to meet the requirements of ANSI/CSA HGV 4.8.
(6) Fittings can be listed and certified to meet the requirements of ANSI/CSA HGV 4.10.

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A.10.3.2.4 The full flow capacity of the dispenser is intended to represent the maximum flow rate of gas possible. This determination could be made by identifying the smallest flow restriction in the dispenser, then assuring the flow capacity of the relief device exceeds that value.

A.10.3.5.2 The following are examples of materials and components that should not be used for gaseous GH_2 service:

(1) Grey, ductile, or cast iron
(2) Certain stainless steels
(3) Nickel and its alloys such as Inconel and Monel
(4) Nickel steels such as 2.25, 3.5, and 9 percent Ni

A.10.3.5.3.2 A joint containing thread compound that leaks during leak testing can be seal welded provided all compound is removed from exposed threads.

N **A.10.3.10.2** Special test equipment used for station testing is not considered an adapter.

N **A.10.3.10.5** The intent of this requirement is to prevent the unauthorized dispensing into containers that are not rated for the operating pressure of the dispenser. Since a lower rated pressure class vehicle cannot fuel from an H70 nozzle, a station supplier might choose to install a lower pressure rating class nozzle on a dispenser, either temporarily or permanently, that otherwise is capable of flowing H70 pressure hydrogen. For example, an H35 nozzle could be installed on an H70-supplied dispenser hose to allow it to fill H35 fuel supply containers. This would defeat the safety feature of having mechanically incompatible hardware for lower-pressure-rated vehicles and result in a hazardous overpressure of both the nozzle and lower-pressure-rated vehicles. Overpressurization could cause serious equipment damage and cause injury or fatality to the user or public. See A.10.5.1.

A.10.3.11.1 See API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*.

A.10.4.3.6 Mechanical joints can be disassembled and include flanged, threaded, or equivalent joints, including crimped connections. Welded joints do not need to be in an accessible location.

A.10.4.4 Vent locations should be designed such that if the safety valve is relieving at capacity and ignited, radiated heat felt by an individual who can be present at grade will not exceed 500 Btu/hr/ft^2 (5.68 MJ/hr/m^2). This does not apply to locations where access is restricted to personnel with appropriate protection.

A.10.4.5.1 Either the media used for leak testing should be compatible with all equipment according to the manufacturer's instructions or the equipment should be isolated during the test. It is not necessary to pressure test equipment that has already been pressure tested before installation. If a pressure test is required on a system or portion of a system that includes previously tested equipment, either the testing media should be compatible with the previously tested equipment according to the manufacturer's instructions or the equipment should be isolated during the test.

A.10.4.5.5 The removal of all oxygen implies the total absence of oxygen. Such removal is not feasible as oxygen is a contaminant even in the commercial hydrogen used as a fuel. Good practice standards advise users to assume that every system contains air before testing any system with hydrogen. The limiting oxygen concentration for oxygen in air (i.e., nitrogen as diluents of air) is 3.0 percent or the percentage of oxygen below which flammable mixtures with hydrogen does not exist. An oxygen concentration of not more than 1 percent reduces the oxygen concentration to an acceptable level, assuming that the system previously contained atmospheric air.

A.10.4.7 The purpose of the extinguisher is not to extinguish a hydrogen fire but other fires in the area, or to keep a hydrogen fire from spreading. Hydrogen fires should be extinguished by shutting off the source of the gas, or in the case of a vehicle fire, letting the supply of hydrogen deplete.

A.10.4.8.4.2 A video display is an acceptable means of providing the operating instruction provided the display is visible from each point of transfer.

N **A.10.5.1** There are currently no specific fueling nozzles for dispensers that can fuel vehicles, such as hydrogen-powered industrial trucks or medium- and heavy-duty hydrogen motor vehicles. With no specific nozzles there is no mechanical method to prevent light duty hydrogen motor vehicles from connecting to dispensers that might have a significantly higher flow rate, which can cause damage to the fuel supply containers. To protect light-duty hydrogen motor vehicles, if a public dispenser offers fueling protocols for both light- and non-light-duty hydrogen motor vehicles, the standard protocol should be the light-duty one. Accessing the non-light-duty protocol should require separate steps as discussed in 10.5.1.3.

A.10.5.1.1.1 In addition to the initial integrity check at the beginning of the fueling event, additional integrity checks have been effective at finding leaks that develop during the fueling process. The 2011 edition of NFPA 2 required this integrity check at 3000 psi (20 MPa) increments. Specifying the pressures at which these tests occur will result in greater standardization and consistency of the fueling process. The leak tests should occur within 5 percent of the specified pressure values. For example, the 85 percent fill-point check can occur between 80 percent and 90 percent of the service pressure.

A.10.5.1.4 SAE J2601, *Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*, is strongly recommended as the standard automotive fueling protocol for dispensers. This standard has been developed by the automotive and hydrogen industry, to ensure that the fueling protocol will not overheat, overpressurize, or overfill the vehicle fuel supply container. SAE J2601 provides methods of fueling fuel supply containers from 50 to 250 L at service pressures of 35 or 70 MPa. SAE J2601 assumes that the fuel systems and fuel supply containers meet the requirements in SAE J2578, *Recommended Practice for General Fuel Cell Vehicle Safety*, and SAE J2579, *Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles*. Vehicles not designed to these standards should not use public dispensers without appropriate review or safeguards.

A default protocol is the protocol used to fuel a hydrogen vehicle without any action by the user or operator of the dispenser.

A.10.5.1.4.1 CSA/ANSI HGV 4.3, *Test Methods for Hydrogen Fueling Parameter Evaluation*, is a standard test method to validate that a dispenser properly applies the fueling protocols in SAE J2601, *Fueling ProtocolF[s for Light Duty Gaseous Hydrogen Surface Vehicles*, and communication protocols in SAE J2799, *Hydrogen Surface Vehicle to Station Communications Hardware and Software*, and has the proper fault controls in place. Care should be taken that the fueling protocol is validated with the appropriate version of ANSI/CSA HGV 4.3.

A.10.5.1.4.2 Dispensers that use nonstandard automotive fueling protocols should not be used to fuel vehicles not designed and tested to the protocol. Doing so could cause damage to the vehicle due to overheating, overpressurization, or overfilling the fuel supply container.

A.10.5.1.4.2.1 The intent of this requirement is to prevent unauthorized fueling of light-duty vehicles using fueling protocols that can damage the fuel supply container. Not all users have the proper training to select the correct protocol. Therefore, a dispenser that can fuel a hydrogen vehicle using a nonstandard automotive fueling protocol, must have a robust method of selecting the correct protocol. User-activated methods of selecting a nonstandard protocol, such as PIN codes and access cards are discouraged, because they can be copied or traded. Keys or access cards are acceptable means to select a nonstandard protocol, but should only be used by nonpublic users and when defined procedures exist to limit their use to the proper vehicles. Hardware solutions that do not require user or operator action, such as unique nozzles/receptacles, or unique communication systems, are preferred methods of preventing the use of a nonstandard protocol.

A.10.5.1.4.2.2 Attendants should be trained to understand when nonstandard fueling protocols are appropriate and compatible with the vehicle. Dispensers that use an attendant to authorize a nonstandard automotive fueling protocol should be equipped with a means to limit authorization of the nonstandard protocol to the trained attendant only.

A.10.5.1.4.4 The limit of 0.1323 lb (60 g) per second was not intended to include short, transient excursions that occur prior to the start of filling due to opening and closing of valves.

N **A.10.5.1.5.1.1** There are currently no standard fueling protocols with high flow rates for medium- and heavy-duty hydrogen motor vehicles. It is recommended that a third party approve the protocol based upon the existing requirements for light-duty hydrogen motor vehicle fueling protocols.

A.10.5.1.6.1 The SAE J2799, *Hydrogen, Surface Vehicle to Station Communications Hardware and Software*, communication protocol is recommended for light-duty hydrogen motor vehicle dispensers. This standard has been developed by the automotive and hydrogen industry to ensure that proper information is passed from the vehicle to ensure that the fueling protocol will not overheat, overpressurize, or overfill the vehicle tank.

It is recommended that the communication system and protocol should be listed, approved, or tested to ANSI/CSA HGV 4.3, *Test Methods for Hydrogen Fueling Parameter Evaluation*.

A.10.5.1.7.2 The intent of this requirement is to prevent the unauthorized dispensing into containers that are not rated for the operating pressure of the dispenser. Two means of protection are necessary because overpressurization could severely damage the container or cause injury or fatality to the user or public. An example of this undesired scenario is an H70 dispenser filling hydrogen into an H35 fuel supply container. This requirement is intended to prevent accidental or inadvertent dispensing by users who use components not rated for the appropriate service pressure. It will help deter, but not necessarily fully prevent, vandalism, users who purposely attempt to defeat the means of protection, and vehicles where the incorrect receptacles have been installed.

Other means of protection can include having the dispenser limit the final pressure of the fueling when communication is not operational, or having a trained attendant on-site to prevent unauthorized dispensing into containers that are either rated to a lower pressure than the dispenser rating or containers that are not compatible with the fueling protocol, or other approved means.

A.10.5.1.8.2 Hydrogen containers/cylinders designed for hazardous material transport are constructed to different standards and usually have different pressure and temperature ratings than hydrogen fuel supply containers. For example, 49 CFR 178.71(L) requires composite pressure vessels (e.g., gas cylinders or fuel supply containers) that are used for the transportation of pressurized gases to meet the requirements of ISO 11119-3, *Gas Cylinders - Refillable Composite Gas Cylinders And Tubes - Design, Construction And Testing*. This ISO specification requires design testing of the pressure receptacles between 60°C and 70°C (140°F and 158°F). However, based on hydrogen fuel supply container standards and testing, hydrogen stations are designed to dispense hydrogen at container temperatures up to 85°C (185°F). Overheating can damage and affect the strength and integrity of fuel supply containers rated to 49 CFR 178.71(L) if fueling operations are allowed. Additionally, industrial hydrogen containers often do not have the same pressure rating [e.g., 2400 psig, 3600 psig, 5000 psig, 6400 psig, and 7500 psig (16,547 kPa, 24,821 kPa, 34,474 kPa, 44,126 kPa, and 51,711 kPa)] as standard hydrogen fueling pressures [e.g., H35 at 5078 psig (35,012 kPa) and H70 at 10,156 psig (70,023 kPa)]. Filling algorithms and standard fueling hardware could overfill/overpressure typical industrial containers.

N **A.10.5.2.2.1.2** Equipment located above grade is considered an aboveground installation.

Δ **A.10.5.2.2.1.3** Motor vehicles can acquire an electrostatic charge while traveling. The resistance offered by the tires through an uncoated concrete surface is low enough that this charge dissipates to ground very quickly (i.e., seconds or less). However, under dry conditions, an asphalt surface can offer sufficient resistance that the charge will not dissipate in a timely manner. A small number of incidents have occurred in Europe where a nonabsorbent polymer having unusually high resistance was used at service stations to prevent soil contamination from gasoline spills. Therefore, paved surfaces that result in a resistance greater than 1 megohm should not be used. Transfer surface materials meeting the criteria specified will provide for the dissipation of static charge built up on the vehicle before the driver opens the door to initiate refueling. The 1 megohm criterion is cited from the API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*. Measurement of the resistivity of the vehicle fueling pad can be conducted using BS EN 1081, *Resilient, laminate and modular multilayer floor coverings — Determination of electrical resistance*.

N **A.10.5.3.2.2** Section 3.2.3 of SAE J2601-3, *Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks*, defines slow fueling as a rate less than 1.5 g/s (1 Nm^3/min). Section 10.1 of CSA HPIT 2 describes a reduced flow rate for "Design by rule for HPIT dispensers" of less than 10 g/s.

The "Design by rule for HPIT dispensers" option of CSA HPIT 2 also facilitates the use on non-communication filling; see item (g) in Annex B of HPIT 2. Similarly, Section 8 of SAE J2601-3 includes communications fills as options for HPIT dispensers.

N **A.10.5.3.2.3** Section 3.2.1 of SAE J2601-3, *Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks*, defines fast fueling as a rate that exceeds 1.5 g/s (1 Nm^3/min) and notes that it is typically rates of 6 to 10 g/s. Sections 1.1(b) and 10.1 of CSA HPIT 2 imply a fast-fill rate for HPITs as greater than or equal to (≥) 10 g/s and less than or equal to 33 g/s, i.e., 10 g/s ≤ fueling rate ≤ 33 g/s.

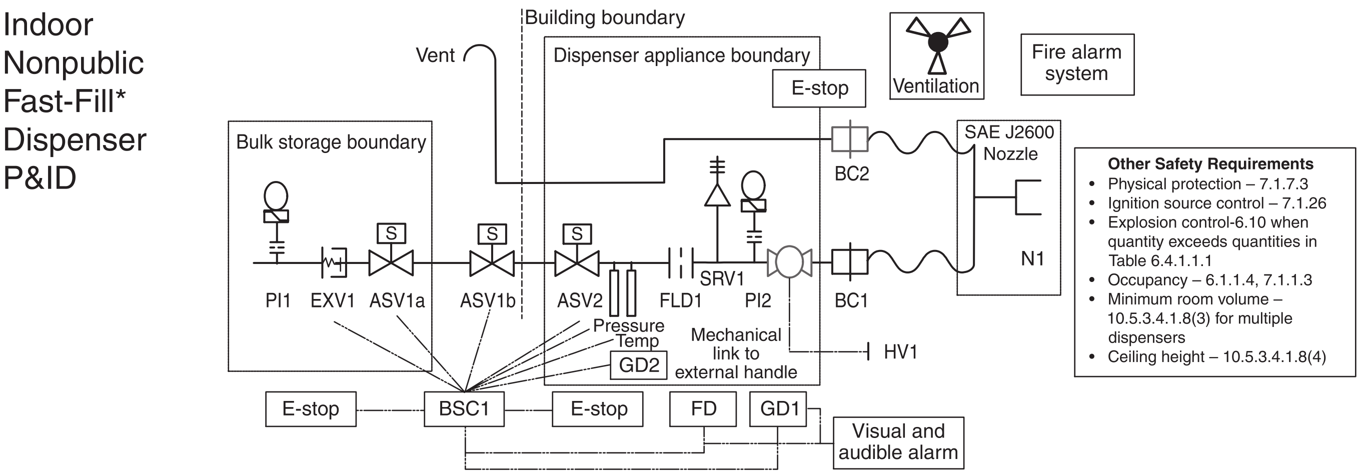
A.10.5.3.4 A generic dispenser piping and instrumentation diagram with NFPA 2 references is provided to help the user to apply the requirements. See Figure A.10.5.3.4.

N **A.10.5.3.4.3** See A.10.5.3.2.3.

Note: 10.5.3.4.1.8(5) limits indoor nonpublic fast-fueling rates to 2.2 lb/min (1 kg/min.) or 16.7 g/s unless the room is ventilated per Section 6.18.

N **A.10.5.3.4.3.7(6)** The lower flammable limit (LFL) of hydrogen in air is 4 percent according to NFPA 497. Therefore, 25 percent of the LFL corresponds to 1 percent hydrogen concentration in air.

A.10.6.3.1 The ASME *Boiler and Pressure Vessel Code* is applicable for new design and construction. Other organizations, such as the NBBI, handle repair and inspection of relief valves. The AHJ should refer to the applicable regulations.



P&ID Tag	Description	Code/Standard Reference	P&ID Tag	Description	Code/Standard Reference
ASV1a	Auto shutoff (solenoid) valve (Source Valve)	6.21 – Source Valve 7.1.24 – Accessible manual or automatic emergency shutoff valve (HGV 4.4/HGV 4.6 Component Standards)	PI1/PI2	Dispense delivery pressure indicator (6 in. circular mechanical gauge; 0-10000 psig)	10.3.3.2 – indication of storage, dispenser discharge pressure 10.3.3.3 – protect personnel under overpressure conditions NOTE – a third pressure gauge at compressor discharge is also required (10.3.3.2)
ASV1b	Auto shutoff (solenoid) valve (building isolation)	7.1.24.2...at the point where the system piping enters the building 10.3.13.4 – building isolation valve required	SRV1	Safety (Overpressure) relief valve (6000 psig)	10.3.2.2 – overpressure device shall be installed; 10.3.2.3 – setting shall not exceed 138 percent of service pressure 10.6.3.2 – inspected every 5 years
ASV2	Auto shutoff (solenoid) valve	7.1.24.2...at the point of use 10.5.3.4.3.7(2) – Automatic shutoff valve	N1	Nozzle	10.3.8 – transfer system capable of depressurization to facilitate disconnection 10.3.10.1 – SAE J2600 or ISO 17268 required
EXV1	Excess Flow Device	7.1.24.1 Excess flow control – leak detection and emergency shutoff or excess flow control 10.3.13.3 – excess flow valve requirements	Vent	Vent Pipe and Vent Pipe Termination	6.17 – CGA G-5.5, 7.1.16.2
FD1	Flame detector	10.3.12 – gas, flame detected at the fueling area 10.5.3.4.3.5 – Fire detection system tied to local visual and audible alarm	Ventilation	Required ventilation for indoor fueling	10.5.3.4.1.7 – in accordance with 6.18
GD1, GD2	Gas detector	10.3.12 – gas, flame detected at the fueling area 10.5.3.4.3.7(6) – GD2 added, inside of the dispenser housing (a Class 1 Div 1 area) with similar requirements to 10.3.12 and with additional requirements: activation shuts down dispenser, visual/audible alarm and functions during maintenance	Estop x 3	Manual Emergency Stops	10.3.13.5 – local and remote located manual shutdown 10.5.3.4.3.6 – Emergency shutdown device similar to 10.3.13.5 with more specified location requirements 10.5.3.4.3.6(2) – 3rd manual shutdown device on the dispenser 10.2.2 – listed or approved
BC1	Breakaway coupling (dispensing hose)	10.3.6.6 – breakaway coupling required	H1	Flexible dispensing/vent hose	10.3.6 – Hose connections (note – no reference to HGV 4.4.) 10.6.2.1 – Hose assemblies 10.5.3.4.1.8(7) – limited to 25 ft; Protected from abrasion or driven over by vehicle
FLD1	Flow limiting device	10.5.3.4.1.8(5) – max fueling rate 2.2 lb/min (1 kg/min)	BC2	Breakaway coupling (vent hose)	Not required
Fire Alarm	Fire Alarm System	10.5.3.4.3.5 – dispensing area local fire alarm system, pull box between 20 and 100 ft of dispenser, at nearest exit from area, pull boxes shutdown dispenser	HV1	Hand Valve – “quarter turn” manual shut off	10.5.3.4.3.7(3) – not required when ASV2 is located immediately upstream and a control arm or ESD closes the valve
BSC1	Building Safety Circuit (Logic Controller)	10.5.1.1.1 – controller performs 5 sec pressure test prior to fueling A.10.5.1.1.1 – repeat integrity check at 3000 psi 10.3.13.6 – control circuit requirement for manual reset after emergency stop activation 10.5.3.4.1.11 – manual restart after emergency activation 10.5.3.4.1.8(2)(a) automatic shutoff control when max fuel quantity per event or vehicle fueled to capacity 10.5.3.4.1.8(6) – references 10.5.1.1.1 and 10.5.1.1.2 10.5.3.4.3.7(8) – overpressure and over temperature sensing capabilities (assume that this could be communication with vehicle)			

Δ FIGURE A.10.5.3.4 Indoor Fueling P & ID.

A.10.6.4 As a precaution to keep pressure relief devices in reliable operating condition and to avoid damage, care should be taken in the handling or storage of GH_2 containers.

Care also should be exercised to avoid plugging by paint or other dirt accumulation in pressure relief device channels or other parts that could interfere with the functioning of the device.

N **A.10.7.3.3** Gas cabinets, as defined in 3.3.23.1, are intended for compressed gas cylinders only. cHFSs contain additional equipment, such as hydrogen compression, dispensing, and generation hardware, which require additional considerations when packaging into a single enclosure. This clause is not intended to apply to external storage systems used by cHFS with separate hydrogen vent systems and automatic isolation of gas upon activation of the ESS.

N **A.10.7.6.1** NFPA 497 can also be helpful in classifying a cHFS.

N **A.10.7.7.1** Offsets and separation distances for a cHFS with a hydrogen capacity equal to or less than MAQ are based on Section 7.1 and the applicable sections of Chapter 10 as detailed in Table A.10.7.7.1. Additional offsets for special cases, such as building openings, overhead utilities, and flammable gas metering as specified in Section 7.3 should be considered.

N **A.10.8.3.9** Gaseous hydrogen might be required to perform leak checks during initial connection of the refueling nozzle to the vehicle receptacle. To accomplish this, HFAs can require an onboard buffer of gaseous hydrogen either contained in the piping system, compressor or other equipment. Since this equipment is installed in residential locations, the onboard storage is limited to reduce hazards based on maximum allowable quantity and requirements specified in CSA NGV 5.1, *Residential Fueling Appliances*. Additional assessments should be performed to determine the permissible buffer volume for the structure volume where the HFA is installed.

N **A.10.10.1** The requirements in Section 10.10 apply only to dispensing of gaseous hydrogen and do not provide guidance on mobile fueling vehicles or trailers that dispense gaseous hydrogen from liquid hydrogen storage.

N **Table A.10.7.7.1 Recommended Considerations for Separation Distances**

System Component	Exposure	Separation Distance	Basis
cHFS	Outdoor installed systems—intakes of ventilation, air conditioning equipment, air compressors or intakes form HVAC systems	20 ft (6.1 m)	7.2.2.3.2.4
	Indoor installed systems—intakes of ventilation, air conditioning equipment, air compressors or intakes form HVAC systems	50 ft (15.2 m)	7.2.2.2.2.1
	Nearest important building or line of adjoining property that can be built upon or from any source of ignition	10 ft (3 m)	10.5.2.2.1.4
	Building openings or operable openings in buildings and structures	25 ft (7.6 m)	7.3.2.3.1.1
	Encroachment by overhead utilities (horizontal distance from the vertical plane below the nearest overhead electrical wire of building service)	15 ft (4.6 m)	7.3.2.3.1.1
	Flammable gas metering and regulating stations such as natural gas or propane	15 ft (4.6 m)	7.3.2.3.1.1
	Property lines or property that can be built upon	10 ft (3 m)	7.2.2.3.2
	Distance to public streets, public alleys, or public ways	10 ft (3 m)	10.5.2.2.1.4
	Buried utilities	3 ft (0.9 m)	7.3.2.4.5.6
	Combustible vegetation	10 ft (3 m)	7.1.9.1.1
	Smoking or open flames	25 ft (7.6 m)	—
	Nearest rail or any railroad main track	10 ft (3 m)	10.5.2.2.1.4
Point of Transfer and Dispensing Equipment	Any important building other than buildings of Type I or Type II construction with exterior walls having a fire resistance rating of not less than 2 hours	10 ft (3 m)	10.5.2.2.1.4
	Buildings of Type I or II construction with exterior walls having a fire resistance rating of not less than 2 hours or walls constructed of concrete or masonry, or of other material having a fire resistance rating of not less than 2 hours	No Limit	—
	Storage containers	3 ft (0.9 m)	10.5.2.2.1.4

N **A.10.10.3** The safety and emergency response plan is intended to be completed, maintained, and updated by the mobile fueling operator to help ensure that fueling operations are conducted in a safe manner that is acceptable to the authority having jurisdiction. Such a plan might include some or all of the following elements:

(1) Written safety and emergency response plan that establishes policies and procedures for fire safety, spill prevention and control, personnel training, and compliance with other applicable requirements of this code.
(2) Where required by the authority having jurisdiction, a site plan for each location at which mobile fueling occurs. The site plan should be in sufficient detail to indicate all buildings, structures, lot lines, property lines, and appurtenances on site and their use or function; all uses adjacent to the lot lines of the site; fueling locations, the locations of all storm drain openings, and adjacent waterways or wetlands; information regarding slope, natural drainage, curbing, impounding, and how a spill will be retained upon the site property; and the scale of the site plan.
(3) If the authority having jurisdiction does not require site plans of approved fueling locations, the safety and emergency response plan should include guidelines for locations within the jurisdiction where mobile fueling can and cannot be provided, such as on residential streets, on school grounds, and so on.

[**30A:**A.14.2.3]

N **A.10.10.4.1** In addition to any other training, education, and certifications that might be required by federal regulations and HAZCOM, the operator should also be trained on the requirements of this code. [**30A:**A.14.2.4.1]

N **A.10.10.5.1** In addition to the requirements in 10.10.5, mobile fueling vehicles should comply with DOT requirements for vehicles used to transport hydrogen.

N **A.10.10.6.1** The source of lighting can originate from the mobile fueling vehicle or trailer.

N **A.10.10.6.2** External warning signals are allowable.

N **A.10.10.6.5** The hose and nozzle assembly can provide bonding.

N **A.10.10.6.7** The hydrogen motor vehicle is not considered an ignition source.

A.11.2.11.1 Although pressure gauges can be used to determine system pressure, pressure transducers are commonly used to monitor pressure and are typically designed to withstand and indicate 20 percent or greater than the maximum system pressure.

A.11.2.11.2 A pressure relief device must be installed on all sections of piping where liquid or cold gas can be trapped between valves.

A.11.3.1.3.3 The temperature of LH_2 is extremely cold. When liquid is transferred, portions of the system are cooled. After transfer occurs and the system warms, the liquid can change to a gaseous state. All portions of the system that are used to transport liquid can also contain cold gas. The trapping of cold gaseous hydrogen represents the same level of concern as that of the liquid when expansion occurs due to warming. Pressure relief devices are used as a means to prevent the rupture of the piping system due to expansion as warming of the system occurs.

A.11.3.1.5.4 The removal of all oxygen implies the total absence of oxygen. Such removal is not feasible as oxygen is a contaminant even in the commercial hydrogen used as a fuel. Good practice standards advise users to assume that every system contains air before testing any system with hydrogen. The limiting oxygen concentration for oxygen in air (nitrogen as diluents of air) is 3.0 percent or the percentage of oxygen below which flammable mixtures with hydrogen does not exist. An oxygen concentration of not more than 1 percent reduces the oxygen concentration to an acceptable level, assuming that the system previously contained atmospheric air.

A.11.3.3.4.6 Additional fire protection considerations can include fixed suppression systems, automatic fire detection, manual fire alarm stations, transmission of alarms to off-site locations, and limitation of the quantity of motor fuel delivered per transaction. [**30A:**A.9.5.6]

A.11.3.3.4.7 Refer to Articles 510 and 511 of NFPA 70 with respect to electrical wiring and equipment for other areas as lubritoriums, service rooms, repair rooms, offices, salesrooms, compressor rooms, and similar locations. [**70:**100] (*Motor Fuel Dispensing Facility,* Informational Note)]

Δ **A.12.2** Fuel cell technology is evolving. Early editions of the standard for testing fuel cell power systems, ANSI/CSA FC1, *Fuel cell technologies — Part 3-100: Stationary fuel cell power systems — Safety*, limited designs by output power, fuels, and construction techniques. ANSI/CSA FC 1 has matured so that its current edition has no limitation on output power, permits all credible fuels and fuel cell technologies, and allows designs to be packaged in a single enclosure or matched modules to be assembled on-site. Outside the scope of ANSI/CSA FC 1, there are one-of-a-kind designs that could possibly be constructed on-site. In the latter's case, engineered and field-constructed fuel cell power systems may be accepted at the site based on documentation. This documentation includes a fire risk evaluation that can be prepared by a registered engineer or by a third-party that is acceptable to the AHJ. See Section 4.4, Engineered and Field-Constructed Fuel Cell Power Systems, in NFPA 853. [**853:**A.4.1]

A.12.2.1 The equipment referenced is intended to include fuel cell power system 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.12.3.2.1 ANSI/CSA FC 3, *Portable Fuel Cell Power Systems,* applies to ac- and dc-type portable fuel cell power systems, with a rated output voltage not exceeding 600 volts, for commercial, industrial, and residential indoor and outdoor use in nonhazardous locations, in accordance with *NFPA 70*. ANSI/CSA FC 3 does not apply to portable fuel cell power systems that are permanently connected (i.e., stationary) to either fuel or electric supply, designed to export power to a grid, replacement fuel cell power units for appliances, or fuel cell systems for propulsion. Additional guidance pertaining to portable fuel cell power systems is provided by IEC 62282-5-100, *Portable Fuel Cell Power Systems, Safety*.

Δ **A.12.3.4** NFPA 855, the ICC *International Fire Code,* and the ICC *International Residential Code* all provide for the temporary use of the dwelling unit owner's or occupant's electric vehicles to power the home for no more than 30 days.

A.13.2.1 The equipment referenced is intended to include stationary applications and generation of hydrogen from portable or transportable hydrogen generation equipment. It does not include hydrogen production facilities intended to produce hydrogen used for distribution or repackaging operations operated by gas producers, distributors, and repackagers.

Where the listing of the hydrogen generator already addresses the requirements in specific sections of Chapter 6 and/or 7, the provisions of those specific sections do not need to be applied. Many of these sections typically are not relevant for small hydrogen generation equipment. For generators in unoccupiable enclosures, the enclosure is typically not considered to be a building.

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N **A.13.3.1** Listing standards for water electrolyzers are available. The 2019 edition of ISO 22734, *Hydrogen generators using water electrolysis process—Industrial, commercial, and residential applications,* combines and supersedes the 2008 edition of ISO 22734-1, *Hydrogen generators using water electrolysis process—Part 1: Industrial and commercial applications*, and the 2011 edition of ISO 22734-2, *Hydrogen generators using water electrolysis process—Industrial, commercial, and residential applications*. CSA Group is working with the Compressed Gas Association regarding the adoption of ISO 22734 with US deviations.

N **A.13.3.1.1** Small electrolyzers of less than 6.6 lbm/day (3 kg/day) hydrogen output have been specifically listed to UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements,* for laboratory and other uses.

A.13.3.3 Listing standards for residential-use electrolyzers, such as ISO 22734, *Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications,*allow manufacturers to list electrolyzers for residential applications, such as energy conversion and vehicle fueling. Limiting GH_2 content to 250 scf, GH_2 per 6.4.1.5.1.1 aligns with non-industrial use.

N **A.13.4.1** CSA Group is working with the Compressed Gas Association regarding the adoption of ISO 16110-1, *Hydrogen Generators Using Fuel Processing Technologies – Part 1: Safety,* with US deviation.

N **A.13.4.2** NFPA 853 specifically addresses installation of stationary fuel cell power systems that are listed or approved to CSA FC1, *Fuel cell technologies — Part 3-100: Stationary fuel cell power systems — Safety.* CSA FC 1 was originally written for fuel cells using reformers. Since FC 1 and NFPA 853 are written primarily for reformer-based fuel cells and reformer-based hydrogen generators are essentially a subset of these fuel cells (see Annex B of NFPA 853), most of NFPA 853 is also applicable to reformer-based hydrogen generators.

N **A.13.5.2.3** Protection can either be integral to the hydrogen generator gasifier (e.g., locked enclosures, guards, and so on), or the hydrogen generator gasifier can be installed in a controlled-access area.

A.13.5.3 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.13.5.3.1 This equipment consists of piping, valves, vessels, and instrumentation for monitoring of the process.

N **A.13.5.3.7** Strobes and rotating lights are examples of visual warning signals.

N **A.13.5.3.9.3** The manual shutoff valve can be a separate, independent valve from the isolation valve required by 13.5.3.9.4.2(1) or it can be the same valve with a manual operator handle attached.

N **A.13.5.3.9.4.2(1)** The emergency stop isolation valve can be a separate, independent valve from the manual shutoff valve required by 13.5.3.9.3 or it can be the same valve with a remote operator handle controlled by the emergency stop system.

A.13.5.3.10.2.1 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 permissible exposure level (PEL) information should be made for other toxic constituents.

A.13.5.3.10.3 Due to the high temperatures associated with the gasification process, ignition of leaks is very 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.13.5.3.10.5 The application of water deluge fire protection against the gasifier vessel and other very hot components must be done very 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 (i.e., 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 contains additional recommendations applicable to fire protection of gasifiers.

A.13.5.4.2 Pressure relief panels should be designed as outlined in NFPA 68.

A.14.1.1 Examples of the use of hydrogen used as a fuel involving flame, include, but would not be limited to, combustion of the gas in a torch used in welding or heating operations where the gas is used to provide a flame and accompanied by a reducing atmosphere. The melting of quartz or glass frequently involves the use of hydrogen combustion operations.

A.14.3.1.2 Thermal spraying is typically conducted with robotic equipment in isolated chambers or otherwise protected areas to isolate persons from hazards such as noise, intense ultraviolet light, process gases, and vapors. The equipment includes multiple flexible piping or hoses, which pass through the chamber walls to deliver the gas from a control source to the process device or gun. The flexible portions of the fuel delivery system represent potential leak sources.

NFPA 497 provides guidance on the classification of areas.

A.14.3.1.2.1 System preventive maintenance typically includes regular leak checks and the replacement of hoses in accordance with the manufacturer's recommendations. An increase in the frequency might be warranted based on maintenance experience.

A.14.3.1.2.2 NFPA 497 provides guidance on the classification of areas.

A.14.3.1.2.4 Features such as solid beams that form a tight fit with the roof deck should be avoided. The intakes for the ventilation system should be located at high points in the ceiling to prevent the trapping of hydrogen in the thermal spraying area.

A.14.3.1.2.6.1 The gas detection should be located in the spray area, at the gas controller, and at the gas supply when the source of supply is located indoors.

A.15.3.1.1.1 Special atmospheres can be produced by a number of technologies, including ammonia dissociation or endothermic or exothermic gas generation, or by blending nitrogen or another inert gas with a reactive gas or gases, such as hydrogen, methane, ammonia, carbon monoxide, water, or other reactive gases. Pure hydrogen can also be used as a special atmosphere.

NFPA 86 categorizes furnaces and ovens used for processing of materials into four classes, including Class A, B, C, and D. The terms *furnaces, ovens*, and *dryers* are used interchangeably and apply to heated enclosures used for the processing of materials. The term *furnace* as used in NFPA 2 is intended to apply to any of the aforementioned equipment individually or collectively. Refer to A.1.1 of NFPA 86 for a detailed description of the various classes of furnaces.

The hazards of Class A furnaces are associated with those generated by the materials being processed. Class A furnaces do not typically use a hydrogen atmosphere. Class B furnaces are those operating at approximately atmospheric pressure that do not contain a flammable atmosphere, nor are flammable volatiles produced or combustible materials heated. There might be blends containing low levels of hydrogen mixed with inert gases in a nonflammable range that can be encountered in use in a Class B furnace. For the purpose of this Chapter, Class B furnaces with atmospheres containing hydrogen in any quantity should be treated as a Class C furnace.

The hazards of Class C furnaces are associated with special atmospheres used in the furnace for the treatment of materials in process. The use of hydrogen is most commonly encountered in furnaces of this type.

Class C ovens and furnaces typically operate at elevated temperatures, often higher than 1400°F (760°C). There are two classes of hazards associated with Class C furnaces. The first is the hazard associated with the physical furnace and its heating system. The second is associated with the atmosphere within the furnace and the equipment to create and control this atmosphere. Furnaces and ovens can be hazardous in and of themselves even without their atmospheres.

In addition, hydrogen is used in Class D furnaces, which are furnaces that operate at pressures ranging from vacuum to several atmospheres.

A.15.3.1.1.2.1 The location of a furnace or oven must be selected carefully so as to not create additional hazards. Furnaces should be located so as to minimize exposure of people to possible injury from fire, explosion, asphyxiation, and hazardous materials and should not obstruct travel to exits.

The location of the furnaces relative to other equipment and to combustible materials is an important consideration. The design of the furnace and oven also requires careful attention. Refer to Chapter 5 of NFPA 86 for guidance on specific considerations relative to design features and location of a furnace within a building or structure.

N **A.15.3.1.1.2.2** Ladder-type schematic diagrams are recommended. [**86:**A.4.1.1.2]

Δ A.15.3.1.1.3.1 Atmospheric vents can serve the following two functions:

(1) Provide a reference to atmospheric pressure for the vented device. This is commonly seen where separating diaphragms inside the device are used to drive a switch or mechanism due to the difference in atmospheric pressure from the gas pressure inside the device. A key aspect of this operation is that discharge of gas is not normal if the device's seals and diaphragm are intact. This type of operation is essential to the reliable functioning of the device, since plugged or back-loaded vent lines can create unintended functional responses from the device.
(2) Provide a means to vent released gas from the device to a predetermined location that minimizes hazard to life and property. This can obviously occur upon failure of the membranes or seals inside the device. It also can occur with regular frequency as a result of internal relief valves. Regulators often have internal relief valves to prevent surges in pressure from overdriving the device and rupturing the membrane.

Sub-subparagraph 15.3.1.1.3.1 covers venting of flammable and oxidizing gases only. Gases that are asphyxiants, toxic, or corrosive are outside the scope of this code. In this regard, other standards should be consulted for appropriate venting. Flammable gases and oxidizers should be vented to an approved location to prevent fire or explosion hazards. Where gases are vented, the vent line design and installation should be in accordance with the following:

(1) The vent line should be sized to minimize the pressure drop associated with length, fitting, and elbows at the maximum vent flow rate. For example, do not use excessive fittings or long pipe runs, keep elbows to an absolute minimum, and never reduce the vent pipe size.
(2) If rigid pipe is used, do not apply a bending moment on the vent line. This can apply a large bending force (i.e., a severe stress) to the vent connection and damage the device.
(3) Apply proper hangers and supports so that the vent line connection is not loaded with the weight of the vent line.
(4) The vent line should not have any manual shutoff valves.

External points of discharge for the vent line should be in accordance with all of the following:

(1) Gas should not impinge on equipment, support, building, windows, or materials because the gas could ignite and create a fire hazard.
(2) Gas should not impinge on personnel at work (e.g., roofers or other maintenance professionals) in the area or in the vicinity of the exit of the vent line because the gas could ignite and create a fire hazard.
(3) Gas should not be vented in the vicinity of air intakes, compressor inlets, or other devices that utilize ambient air. See NFPA 54 for acceptable clearances.
(4) The vent outlet should not be subject to physical damage or foreign matter that could block the exit. To limit the consequences of rain or debris getting into the vent, always turn the outlet of the vent down toward the ground. If a vent line runs through a roof, verify that the vent line terminates above the point where water and snow accumulation does not cover or isolate the vent outlet.
(5) Bugs can be attracted to the smell of the natural/LP gas odorant and will nest in the vent line, which will further reduce stack effect or will completely seal the vent exit. Install a bug screen on the vent exit to deter insects from nesting in the line, and do not paint over the bug screen.

For points of discharge inside the building, the following additional guidance is offered:

(1) If the gas is flammable and lighter than air, the flammable gases should be vented to a location where the gas is diluted below its LFL before coming in contact with sources of ignition and the gas cannot reenter the work area without extreme dilution.
(2) If the gas is oxygen or air enriched with oxygen, the vent gas should be vented to a location where the gas will

blend with atmospheric air to a point between 19 percent and 23 percent oxygen before coming in contact with combustibles or personnel.

(3) See also Chapter 4 of NFPA 56, which provides information about the development and implementation of written procedures for the discharge of flammable gases.

[**86:**A.6.2.7]

A.15.3.1.1.4.1 The object of this requirement is to prevent infiltration of air that could be detrimental to the work being processed or could result in the creation of flammable gas–air mixtures within the furnace. The flow rates can be varied during the course of a heat treatment cycle. [**86:**A.13.5.7.1]

A.15.3.1.1.4.3 After closure of an outer vestibule door of a batch-type furnace or pusher furnace, a delay usually occurs before burn-off resumes at the vent opening. The duration of the delay depends on the special [hydrogen] atmosphere flow rate, its combustibles content, the vestibule volume, and other factors. [**86:**A.13.5.7.3]

A.15.3.1.1.5 Gas atmosphere mixing systems are used to create special processing atmospheres made up of two or more gases. The majority are built to create binary nitrogen–hydrogen blends, but they also are able to create mixtures of other gases. The blended gas of gas atmosphere mixing systems usually has a constant flammable or indeterminate composition and is supplied on a pressure or demand basis to the special processing atmosphere flow controls situated at one or more furnaces. [**86:**A.13.5.6]

Gas atmosphere mixing systems typically incorporate a surge tank mixing scheme that cycles between set pressure limits. This feature distinguishes them from the flow control systems covered in 15.3.1.1.4. [**86:**A.13.5.6]

A.15.3.1.1.5(1) Consideration should be given to the inclusion of filters or strainers to improve reliable functioning of pressure regulators, flowmeters, flow monitors, control valves, and other components. [**86:**A.13.5.6(1)]

A.15.3.1.1.5(3) ASME B31.3, *Process Piping*,is the traditional reference for the piping used in these systems. ASME B31.12, *Hydrogen piping and pipelines: ASME Code for Pressure Piping*, has been published as a hydrogen specific piping standard and might be more appropriate than ASME B31.3.

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N **A.15.3.1.1.6.2(B)** Visual indication permits detection of sensor failures, such as thermocouple short circuits, that will not result in the action required by 15.3.1.1.6.2(1). Operator or maintenance personnel can evaluate the 1400°F (760°C) bypass interlock by observing the temperature indication. It is also acceptable to bring the 1400°F (760°C) bypass interlock thermocouple output into a PLC or another instrument in parallel with the 1400°F (760°C) bypass interlock, providing the accuracy of the 1400°F (760°C) bypass interlock is not diminished. The PLC or other instrument can be used to monitor, trend, and alarm the 1400°F (760°C) bypass interlock thermocouple output by comparing its output with that of an independent temperature measurement, such as from the operating temperature controller. [**86:**A.8.16.3]

N **A.15.3.1.1.6.2(C)** Temperature-sensing components, such as thermocouple and extension wires, that are not rated for the environment are at greater risk of short circuits. [**86:**A.8.16.4]

N **A.15.3.1.1.6.2(E)** The sensing element should be positioned where the difference between the temperature control sensor and the excess temperature limit sensor is minimized. The temperature-sensing element of the excess temperature limit interlock should be located where it will sense the excess temperature condition that will cause the first damage to the furnace or work as temperatures within the furnace rise above the maximum operating set point most critical to safe operation. [**86:**A.8.15.8]

N **A.15.3.1.1.6.2(F)** The temperature-sensing element of the excess temperature limit interlock can be monitored by other instrumentation, provided that the accuracy of the excess temperature limit interlock temperature reading is not diminished. [**86:**A.8.15.9]

N **A.15.3.1.1.6.2(H)** An auxiliary contact in the excess temperature limit interlock device can be used as a 1400°F (760°C) bypass interlock providing the requirements of 15.3.1.1.6.2(A) are satisfied. [**86:**A.8.16.8]

A.15.3.1.1.6.6 ASME B31.3, *Process Piping*, is the traditional reference for the piping used in these systems. ASME B31.12, *Hydrogen piping and pipelines: ASME Code for Pressure Piping*, has been published as a hydrogen-specific piping standard and might be more appropriate than ASME B31.3.

A.15.3.1.1.6.9 Filters or strainers should be provided to ensure reliable functioning of pressure regulators, flowmeters, flow monitors, control valves, and other components. [**86:**A.13.5.8.11]

A.15.3.1.1.7.2 Special precautions should be taken if aluminum piping is selected for hydrogen service or in the production of special atmospheres because of the low melting point of aluminum. The low melting point of aluminum subjects the piping to potential failure in fire situations. Other materials that are less subject to melting and failure under high-temperature conditions should be considered by system designers during the design process.

A.15.3.1.1.8.2 In cases where minimal operating states, such as safety ventilation, must be established to prevent a hazardous condition, it is recommended that the precision of the set point be confirmed. When precision is inadequate, the component should be either recalibrated or replaced. Frequency of this testing and calibration should be established based on the components' mean time between failure (MTBF) data and the component manufacturer's recommendations. [**86:**A.7.4.5]

A.15.3.1.1.9.1 This [code] addresses the protection needs of ovens, furnaces, and related equipment. Fire protection needs external to this equipment are beyond the scope of this [code]. The determination and extent of required fixed protection depends on the following:

(1) The construction and arrangement of the oven, furnace, or related equipment
(2) The material being processed
(3) Whether fixtures or racks are combustible or are subject to loading with excess combustible finishing materials, or whether an appreciable amount of combustible drippings from finishing materials accumulates in the oven or duct work.

[**86:**A.9.1]

Fixed protection should extend as far as necessary in the enclosure and ductwork if combustible material is processed or combustible buildup is likely to occur. This includes the potential for solvent condensation in ductwork as well as particle build-up. [**86:**A.9.1]

Fixed fire protection for the equipment can consist of sprinklers, water spray, carbon dioxide, foam, dry chemical, water mist, or steam extinguishing systems. [**86:**A.9.1]

Steam extinguishing (inerting) systems can be used to protect ovens where steam flooding is the only means available. Otherwise, the use of steam in ovens is not recommended. [**86:**A.9.1]

Hydrogen and other flammable gas fires are not normally extinguished until the supply of gas has been shut off because of the danger of re-ignition or explosion. Personnel should be cautioned that hydrogen flames are invisible and do not radiate heat. In the event of fire, large quantities of water should be sprayed on adjacent equipment to cool the equipment and prevent its involvement in the fire. Combination fog and solid stream nozzles should be used to allow the widest adaptability in fire control. [**86:**A.9.1]

Small flammable gas fires can be extinguished by dry chemical extinguishers or with carbon dioxide, nitrogen, or steam. Re-ignition can occur if a metal surface adjacent to the flame is not cooled with water or by other means. [**86:**A.9.1]

Dip tanks and drain boards included in oven enclosures should be protected by an automatic fire suppression system if flammable or combustible liquids are involved. NFPA 34 provides guidance for the design of fire suppression systems for dip tanks and drain boards. [**86:**A.9.1]

Refer to Chapter 6 of NFPA 86, for guidance on the proper design of a furnace or oven heating system.

Furnaces and ovens can be heated by a variety of techniques, including electrical resistance heating systems or radiant tube combustion systems.

A.15.3.1.1.10 Refer to the definitions for *special atmosphere* in 3.3.227. [**86:**A.13.5.10]

A.15.3.1.1.10.3 Special atmospheres containing hydrogen are typically found in Class C or D furnaces.

A Class C furnace is a furnace that is potentially hazardous because of the special atmosphere that has been added to the furnace for the treatment of materials in the furnace. Class C furnaces are further classified into a variety of types, each of which are comprised of different features and operating principles. Table 15.3.1.1.10.3 illustrates the various types of Class C furnaces.

A Class D furnace is a furnace that can contain a special atmosphere but that operates under vacuum for all or part of the furnace cycle. Class D furnaces generally are described as either cold-wall furnaces, hot-wall furnaces, or furnaces used for casting or melting of metal at high temperatures up to 5000°F (2760°C). There can be other special types.

Type I furnaces will be used as an example for describing the techniques for furnace operations. Refer to Chapter 12 of NFPA 86, for detailed guidance for the introduction and removal of special atmospheres from other Class C furnace types.

A.15.3.1.1.11.1(B) Failure to maintain positive pressure in a furnace can allow air infiltration. Air infiltration can occur at effluents, open ends, or the perimeter of doors. In addition, welds in a furnace shell can break, gasketed joints can fail, and radiant tube heaters can be breached, all of which could introduce additional sources of air infiltration. Furnaces should be designed to minimize sources of air infiltration. In addition, furnace shell joints and radiant tube heaters should be periodically evaluated or tested and repaired as needed. Should positive furnace pressure be lost in furnaces or chambers operating below 1400°F (760°C), air infiltration can lead to a flammable gas–air mixture that can result in an explosion. Loss of positive furnace pressure can be caused by an inadequate flow of carrier gases or loss of furnace heat, and loss of furnace heat will lead to the thermal contraction of the atmosphere volume. [**86:**A.13.5.11.1.2]

A.15.3.1.1.11.1(C) The character of the flame at furnace open ends and special [hydrogen] atmosphere effluents will be a function of the specific furnace. It is essential for the furnace operator to be trained to recognize the “established character” of these flames. In addition, the operator should be aware of the typical timing for flame to appear at open ends and effluent vents. [**86:**A.13.5.11.1.3]

A.15.3.1.1.11.1(D) The fluid in a bubbler can be water or oil. Bubblers might be provided to protect a furnace from overpressure or to maintain a minimum positive atmosphere pressure within the furnace. Bubblers also can control pressure within a bell furnace using an oil seal. Overpressure of the retort or heating chamber could blow the oil out of the seal ring. It is also possible to have water condensation accumulate in a bubbler bottle that can add to the liquid level and allow an increase in furnace pressure, which could increase furnace pressure to excessive levels and lead to the loss of oil seals. [**86:**A.13.5.11.1.4]

A.15.3.1.1.11.1(E) Where flammable atmosphere effluent is released unburned to the interior of a building, the accumulation of flammable gases could create a fire or explosion hazard. To avoid this hazard, effluent that will not reliably ignite upon contact with air should be captured by a hood and discharged to a safe outside location. See also A.15.3.1.1.11.10(C)(2), which addresses additional hazards. [**86:**A.13.5.11.1.5]

A.15.3.1.1.11.1(F) The use of plant air with reducing regulators is prohibited. Plant air lines can become slugged with water passing into the heated furnace resulting in abnormally high furnace pressures. Plant air lines can experience regulator failures resulting in high-pressure air admission into a furnace that contains a flammable atmosphere [**86:**A.13.5.11.1.6]

N **A.15.3.1.1.11.1(G)** The means to maintain furnace pressure below the static head pressure of the seal oil include the use of bubblers or manometers on vent lines. Other means might be possible. *[Also see A.15.3.1.1.11.1(D).]* [**86:**A.13.5.11.1.7]

A.15.3.1.1.11.2(B) Burn-off pilots using full premix (fuel–gas mixed with all the air needed to support full combustion) and glow plugs are examples of ignition sources meeting the intent of A.15.3.1.1.11.2(B). Full premix burn-off pilots have sufficient air (or, more precisely, sufficient oxygen in air) premixed with the fuel gas to maintain the burn-off pilot if the purge gas or special [hydrogen] atmosphere gas otherwise creates an oxygen-deficient atmosphere that would not support the burning of the burn-off pilot flame. [**86:**A.13.5.11.2.2]

A.15.3.1.1.11.2(C) Where loss of ignition of vent effluent creates either an environmental or a personal safety concern, the pilot flame should be monitored and an alarm generated to alert the operator to loss of flame. [**86:**A.13.5.11.2.3]

A.15.3.1.1.11.2(E) The ability to open doors manually in emergency situations is needed. Upon the simultaneous loss of furnace atmosphere and door pilot supervision, there will be a need to purge or manually open doors to burn-out vestibules that use an alternative source of ignition. [**86:**A.13.5.11.2.5]

A.15.3.1.1.11.2(G) If burn-off pilots were equipped with flame supervision interlocked to turn fuel gas off to the burn-off pilot upon loss of flame, the burn-off pilots would also be turned off in the event of a power failure. The loss of burn-off pilots at special atmosphere effluent points during a power failure is undesirable and would create a serious safety concern with reliably maintaining ignition of effluents. Where flame supervision is provided, it is for an alarm to draw attention to the need to relight the burn-off pilot or it is interlocked to prevent the opening of a furnace door. [**86:**A.13.5.11.2.7]

A.15.3.1.1.11.2(H) Burn-off pilots should be located where they will contact the effluent stream. For example, for a lighter-than-air effluent flowing from a furnace open end, the effluent most likely will be encountered at the top of the opening [**86:**A.13.5.11.2.8]

A.15.3.1.1.11.2(J) Burn-off pilots are not to be interrupted by any action other than closing of their individual manual shutoff valve or closing of the main equipment manual shutoff valve. [**86:**A.13.5.11.2.10]

A.15.3.1.1.11.3 Regarding items 15.3.1.1.11.3(2) and 15.3.1.1.11.3(5), once a door begins to open, it is intended that the door will be permitted to open completely. The interlock is only intended to prevent a closed door from opening. Flame curtains are often used to minimize the ingress of air into a furnace through an open furnace door to prevent process upset and not for the purpose of providing the ignition source for flammable atmosphere exiting from the door. [**86:**A.13.5.11.3]

A.15.3.1.1.11.3(2) It is recognized that maintaining a reliable source of ignition is critical to avoid explosion at an open door from which flammable atmosphere gas is flowing. Once a door begins to open or is full open, the flame curtain pilot flame supervision and flame curtain low and high gas interlocks can be ignored provided that flame curtain flame is sensed by an independent flame supervision system. [**86:**A.13.5.11.3(2)]

A.15.3.1.1.11.3(7) The manual override is provided for abnormal conditions to permit the manual removal of special [hydrogen] atmospheres from the furnace. [**86:**A.13.5.11.3.7]

A.15.3.1.1.11.6(A)(1) Purge effectiveness can be compromised by actions such as operating furnace doors, operating quench elevators, introducing work, and operating fans not included in the purge process. Purge effectiveness can also be compromised by not running fans required to effect the purge. Avoiding such actions can be accomplished by written operating procedures or interlocks. [**86:**A.13.5.11.6.1.1]

A.15.3.1.1.11.6(D) Verification of flammable special [hydrogen] atmosphere safety shutoff valves being closed can be accomplished by operator observation [**86:**A.13.5.11.6.4]

A.15.3.1.1.11.6(G) Flammable atmosphere–air interfaces occur at doors, open ends, effluents, and other locations where the flammable atmosphere contacts air. Active sources of ignition include door burn-off pilots, flame curtains, manual torches, door effluents above 1400°F (760°C), glow plugs, and hot door parts above 1400°F (760°C). Atmosphere–air interfaces can be avoided by a nitrogen seal. [**86:**A.13.5.11.6.7]

Where a furnace has open ends or doors, a flame of established character appearing at open ends or atmosphere effluents indicates that the atmosphere introduction has been completed or is being maintained. [**86:**A.13.5.11.6.7]

Furnaces without open ends or doors, such as bell furnaces and strip processing furnaces with sealed entrance and exit, might not have ignited effluent lines. As such, the operator might not know if or when the flammable atmosphere introduction is complete; however, because the furnace is sealed and positive pressure is maintained, this is not a safety concern. The operator is not using the effluent flame as an indicator for determining when to cycle loads or operate doors. [**86:**A.13.5.11.6.7]

The character of the flame at furnace open ends and special [hydrogen] atmosphere effluents is a function of the specific furnace. It is essential that the furnace operator be trained to recognize the “established character” of these flames [**86:**A.13.5.11.6.7]

A.15.3.1.1.11.6(H) The furnace volume includes chambers, zones, covers, and retorts that contain the flammable special [hydrogen] atmosphere within the furnace. Ductwork associated with recirculating fans such as jet coolers are considered part of the furnace volume, as are features such as large door housings or chambers and large pusher chain or mechanism housings that are exposed to the flammable special [hydrogen] atmosphere. [**86:**A.13.5.11.6.8]

A.15.3.1.1.11.6(K)(4) Oil level directly affects the volume of the vestibule. Flammable special [hydrogen] atmosphere introduction should not begin without quench oil being at the appropriate level. Atmosphere introduction should not be interrupted once started. [**86:**A.13.5.11.6.11(4)]

Δ **A.15.3.1.1.11.6(L)** The character of the flame at furnace open ends and special atmosphere effluents will be a function of the specific furnace. It is essential that the furnace operator be trained to recognize the “established character” of these flames. In addition, the operator should be aware of the typical timing for flame to appear at open ends and effluent vents.

Furnaces, such as heating-cover types, that have no open ends, doors, or effluent lines will have no features to provide indicators of visible flame. This is an acceptable arrangement and is addressed by the specific furnace design and operating instructions.

[**86:**A.13.5.11.6.12]

A.15.3.1.1.11.7(B)(1) Burn-in effectiveness can be compromised by actions that are not included in the burn-in operating instructions. Furnace doors, quench elevators, and fans should not be operated except in accordance with written burn-in operating instructions. Work should not be introduced into a furnace during the burn-in process. Burn-in effectiveness can also be compromised by running or not running fans in accordance with written burn-in instructions. [**86:**A.13.5.11.7.2.1]

A.15.3.1.1.11.7(C) The burn-in process is anticipated to reduce the oxygen level within the furnace to a point at or below 1 percent as the oxygen in air is consumed by the burn-in process. [**86:**A.13.5.11.7.3]

A.15.3.1.1.11.7(D) Any flammable atmosphere gas introduced into a chamber at or above 1400°F (760°C) will be reliably ignited by auto-ignition. An alternative method of atmosphere gas ignition, beyond just the burning flame front, might be needed where the burning atmosphere gas enters chambers below 1400°F (760°C). [**86:**A.13.5.11.7.4]

A.15.3.1.1.11.7(E) Long cooling tunnels can extinguish the burning atmosphere flame front by cooling the atmosphere gas as it moves along the length of the tunnel. [**86:**A.13.5.11.7.5]

A.15.3.1.1.11.7(F) In some furnace designs, such as the Type II furnace (integral quench batch furnace), manual torches might be needed as a means to reliably ignite flammable atmosphere gas as it flows into the cool vestibule chamber from the hot heating chamber. Written burn-in instructions for the specific furnace will outline the specific sequence to follow for burn-in. The following burn-in procedure for a Type II furnace is provided as one example:

(1) Atmosphere gas is introduced into the hot heating chamber and auto-ignites. Ignition is visually verified, and the inner heating chamber door is closed.
(2) A port in the closed inner door allows the atmosphere gas to flow from the heating chamber to the vestibule chamber. A manual torch placed at this port ignites the atmosphere gas.
(3) Once ignition is visually verified at the inner door port, the manual torch is removed and the outer vestibule door is closed, and the vestibule is allowed to burn-in.
(4) Burn-in of the vestibule is visually confirmed once a steady flame appears at the vestibule atmosphere effluent vent.

[**86:**A.13.5.11.7.6]

A.15.3.1.1.11.7(G) To avoid adverse effects on the special [hydrogen] atmosphere in the heat zone and vestibule, the heating chamber fan is turned off when the inner door is open. One adverse effect could be the creation of atmosphere flow in the vestibule, that could draw in air around the steel-to-steel contact between the vestibule door and the furnace shell. Also, during initial furnace burn-in, the operator typically will be instructed to visually verify ignition of the special [hydrogen] atmosphere gas as it is introduced to the heating chamber. That requires both the heating chamber door and the vestibule door to be open and the heating chamber fan to be off to allow visual observation. [**86:**A.13.5.11.7.7]

A.15.3.1.1.11.7(H) During burn-in, cooling zone fans are to be turned off to avoid disrupting the flame front burning through the cooling chamber. If a furnace is being heated, the heat zone fans typically need to be kept in service to avoid thermal damage. In a cooling chamber, the only ignition source is the flame front, which is easily disrupted by fan circulation. In a heating chamber above 1400°F (760°C), the entire environment is an ignition source, and fans will not adversely affect the reliability of ignition. [**86:**A.13.5.11.7.8]

A.15.3.1.1.11.7(I)(2) The retort or inner cover of a Type VIII furnace and the cover of a Type IX furnace will be sealed to the base. Sand seals, oil seals, or rubber seals can be used. [**86:**A.13.5.11.7.9.2]

A.15.3.1.1.11.7(K) The character of the flame at furnace open ends and special [hydrogen] atmosphere effluents will be a function of the specific furnace. It is essential that the furnace operator be trained to recognize the "established character" of these flames. In addition, the operator should be aware of the typical timing for flame to appear at open ends and effluent vents. [**86:**A.13.5.11.7.11]

Furnaces, such as heating-cover types, that have no open ends, doors, or effluent lines will have no features to provide indicators of visible flame. This is an acceptable arrangement and is addressed by the specific furnace design and operating instructions. [**86:**A.13.5.11.7.11]

A.15.3.1.1.11.8(A)(1) Purge effectiveness can be compromised by actions such as operating furnace doors, operating quench elevators, introducing work, and operating fans not included in the purge process. Purge effectiveness can also be compromised by not running the fans required to effect the purge. Avoiding such actions should be addressed by written operating procedures or by interlocks. [**86:**A.13.5.11.8.1.1]

A.15.3.1.1.11.8(C) Oxidizing special atmosphere gases include air. [**86:**A.13.5.11.8.3]

A.15.3.1.1.11.8(D) The furnace volume includes chambers, zones, covers, and retorts that contain the flammable special [hydrogen] atmosphere within the furnace. Ductwork associated with recirculating fans such as jet coolers is considered part of the furnace volume, as is the space in the furnace steel shell but above the refractory arch if flammable special [hydrogen] atmosphere gas can permeate into that space. Flammable special [hydrogen] atmosphere gases such as hydrogen may migrate into an above-arch space during operation and may require special purging facilities to remove them during the purge-out process. [**86:**A.13.5.11.8.4]

A.15.3.1.1.11.8(E) Chambers include heating chamber, cooling chambers, vestibules, door housings, and other atmosphere containing volumes that would create a hazard if not specifically purged. [**86:**A.13.5.11.8.5]

A.15.3.1.1.11.9(B)(1) Burn-out effectiveness can be compromised by actions that are not included in the burn-out operating instructions. Furnace doors, quench elevators, and fans should not be operated except in accordance with written burn-out operating instructions. Work should not be introduced into a furnace during the burn-out process. Burn-out effectiveness can also be compromised by not running fans required to effect the burn-out. [**86:**A.13.5.11.9.2.1]

A.15.3.1.1.11.9(B)(2) Typically, where doors are present, the burnout procedure will begin with all inner and outer doors closed. The outermost chamber will be burned-out first. [**86:**A.13.5.11.9.2.2]

A.15.3.1.1.11.9(C) Burn-out can be accomplished by introducing air by a number of means, including open ends, vents, opening doors, header and feed pipes of burnout manifold systems, process air piping, and so forth. Uncontrolled admission of air can lead to excessive temperatures in some furnaces. Opening doors can create a draft through a furnace that can push ignited atmosphere out other openings, and instructions should be carefully developed to avoid such conditions. The written procedures required in 15.3.1.1.11.9(B) should provide step-by-step instructions for a controlled burn-out. [**86:**A.13.5.11.9.3]

With hot furnaces that contain soot, it is possible to re-form a flammable atmosphere that may require additional air introduction procedures to effect final burn-out. [**86:**A.13.5.11.9.3]

A.15.3.1.1.11.9(D) For Type IX furnaces (cover), visual observation of burn-out is not possible until the cover is removed. Written burn-out procedures will typically include the following actions:

(1) Release the mechanical clamping devices holding the heating cover to the base.
(2) Ignite the manual burn-off pilots or torches and place them in position at the heating cover to the base seal to ignite flammable gases that might be present inside the cover as the seal is broken.

[**86:**A.13.5.11.9.4]

A.15.3.1.1.11.9(D)(2)(a) The requirement for the furnace to be under positive pressure is to eliminate the concern that an indeterminate atmosphere might develop in furnace chambers under 1400°F (760°C). With some furnace burn-out procedures (e.g., opening doors), initiating the burn-out can cause the furnace pressure to immediately fall to atmospheric pressure. This is not an issue once the burn-out procedure has been initiated. [**86:**A.13.5.11.9.3.4(2)(a)]

A.15.3.1.1.11.9(G) During burn-out, fans are to be turned off to avoid disrupting the flame front burning back through to the special [hydrogen] atmosphere gas source. [**86:**A.13.5.11.9.7]

A.15.3.1.1.11.10 See Figure A.15.3.1.1.11.10.

[**86:**A.13.5.11.10]

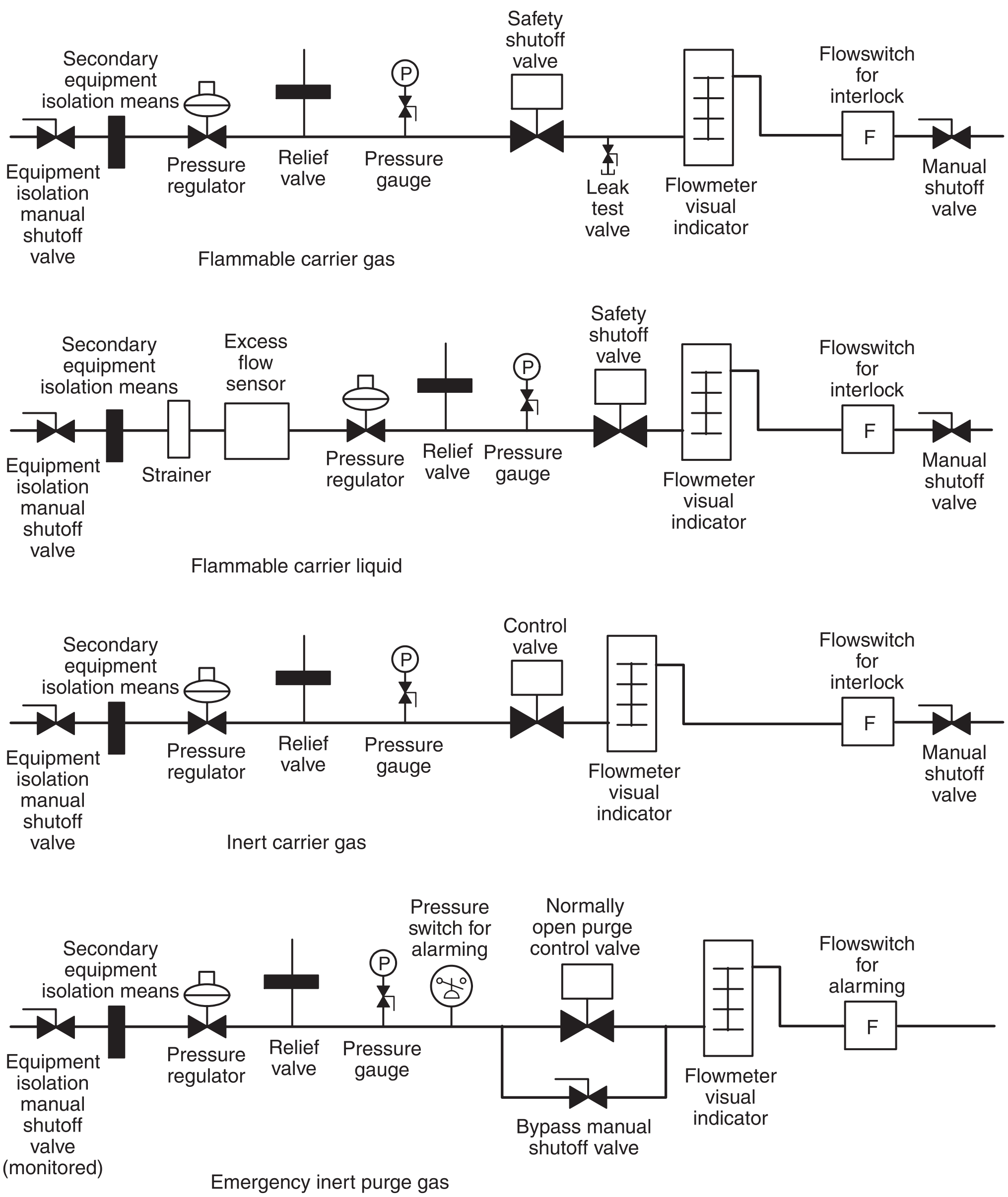

FIGURE A.15.3.1.1.11.10 Examples of Special Atmosphere Equipment Piping. [86:Figure A.13.5.11.10]

A.15.3.1.1.11.10(B)(1) One of the following secondary equipment isolation means should be provided immediately downstream of the equipment isolation manual shutoff valve so that no leakage of gas passing the equipment isolation manual shutoff valve can enter the downstream special [hydrogen] atmosphere piping:

(1) Removable spool piece
(2) Breakable flanges with loosely inserted blinding plate
(3) Blinding plate secured between flanges
(4) A second valve with venting of the intermediate space between this valve and the special [hydrogen] atmosphere manual isolation valve

[**86:**A.13.5.11.10.2.1]

Two manual shutoff valves in series without venting of the intermediate space would not be considered equivalent to the above choices. [**86:**A.13.5.11.10.2.1]

A.15.3.1.1.11.10(B)(6)(e) Lubricated plug valves require lubrication with the proper lubricant to shut off tightly. The application and type of gas used can require frequent lubrication to maintain the ability of the valve to shut off tightly when needed. [**86:**A.6.3.4.1.6]

A.15.3.1.1.11.10(C)(2) See A.15.3.1.1.3.1.

[**86:**A.13.5.11.10.3.2]

A.15.3.1.1.11.10(C)(4) Vent line sizing in accordance with 15.3.1.1.11.10(C)(4) is intended to avoid the operation of individual devices from affecting (cross-impulsing) other manifolded devices under normal operations. Under upset conditions in which a device diaphragm fails, the vent line will direct the release gas to a suitable location, but it would not necessarily avoid adverse control impact upon other manifolded devices. It should be noted that special [hydrogen] atmosphere gases typically operate at low pressure and utilize regulators with large diaphragms that are more sensitive to pressure pulses across interconnected vent lines. [**86:**A.13.5.11.10.3.4]

A.15.3.1.1.11.10(D)(1) Typically, relief valves would not be provided for generated special [hydrogen] atmosphere gases. Relief valves might not be needed for enriching gas where the fuel gas supply to the furnace is equipped with multiple pressure regulators and where the failure of any one pressure regulator would not introduce excessive pressures to the special [hydrogen] atmosphere system downstream of the failed pressure regulator. Relief valves might be needed for liquid special atmospheres or special [hydrogen] atmosphere gases provided from pressurized storage vessels. [**86:**A.13.5.11.10.4.1]

A.15.3.1.1.11.10(D)(2) Overpressurization of the liquid special atmosphere piping can occur if liquid is isolated in the piping between closed valves and exposed to an increase in temperature. Closed valves can include manual valves, automatic valves, or safety shutoff valves. Other means of controlling pressure could include an accumulator or an expansion tank. [**86:**A.13.5.11.10.4.2]

A.15.3.1.1.11.10(D)(3) See A.15.3.1.1.11.10(C)(2). Also, for atmosphere gases supplied in the liquid state, relief valves can be piped back to the liquid storage vessel. [**86:**A.13.5.11.10.4.3]

A.15.3.1.1.11.10(H) Atmosphere impingement on the temperature control thermocouple can result in overheating of the furnace or erroneous control readings on the over temperature thermocouple. [**86:**A.13.5.11.10.8]

A.15.3.1.1.12.8 The means can be either electrical or mechanical. Mechanical means would include the operation of valves in the special [hydrogen] atmosphere piping. For some applications, additional manual action might be required to bring the process to a safe condition. [**86:**A.13.5.11.11.8]

A.15.3.1.1.12.10(A) The removal of flammable special [hydrogen] atmospheres by burn-out, purge-out, or emergency purge-out can be caused by manual or automatic action. Table A.15.3.1.1.12.10(A) summarizes when the action should be automatic and when it can be automatic or manual. [**86:**A.13.5.11.11.10.1]

Part 3 addresses the condition where there is a low flow of carrier gas that will not maintain positive pressure within a chamber that is below 1400°F (760°C). If a chamber is above 1400°F (760°C), the low flow condition might allow furnace pressure to drop and might allow air infiltration; however, while this might lead to process issues, it is not a safety issue requiring the removal of the special [hydrogen] atmosphere. Following operating instructions, the operator can work to restore normal process conditions. [**86:**A.13.5.11.11.10.1]

It should be noted that Part 3 does not involve any measurement of the actual furnace pressure. Rather, it is based on comparing the actual carrier gas(es) flow with minimum allowable design flow rates. The actual carrier gas flow is measured with flow sensors. Furnace pressure is subject to fluctuation due to actions such as operating doors and loading or unloading work. The inadvertent shutdown of carrier gases due to a routine furnace pressure fluctuation is considered more of a potential safety hazard than the actual pressure fluctuation itself. [**86:**A.13.5.11.11.10.1]

A.15.3.1.1.12.11(B) Where exothermic generated special atmosphere gases are used for purging, the flammable content of the gas is maintained at a limited level that when mixed with air would not exceed 25 percent of LFL and therefore would not need a safety shutoff valve. See 15.3.1.1.15.1 for further guidance on monitoring of purge gases for flammable components. [**86:**A.13.5.11.11.11.2]

A.15.3.1.1.12.11(E) Refer to A.7.4.10 of NFPA 86 which provides a complete discussion of leak test options.

A.15.3.1.1.12.12(D) Normal shutdown of a furnace by burn-out is an example of a practice that causes a furnace chamber to lose positive pressure. However, this loss of positive pressure takes place along with the controlled introduction of air to effect the burn-out of the flammable atmosphere. Safety shutoff valves are to close in response to this action, but there is no safety issue with this intended case of furnace pressure loss. [**86:**A.13.5.11.11.12.4]

The unintended interruption of a furnace heating system, unintended loss of furnace temperature, unintended reduction of carrier gas flow, or unintended interruption of power are examples of conditions that can cause furnace chambers to lose positive pressure. These conditions, however, can lead to the uncontrolled infiltration of air into furnace chambers, which could rapidly lead to an unsafe condition (faster than operators might be able to respond) in some of or all the chambers. Chamber temperature will influence whether an unsafe condition can develop. [**86:**A.13.5.11.11.12.4]

Where chamber temperature is at or above 1400°F (760°C), the uncontrolled air infiltration could create process quality issues; however, it is not anticipated to create safety issues. This

Table A.15.3.1.1.12.10(A) Burn-out, Purge-out, and Emergency Purge-out Conditions and Responses

Part	Condition	Response
1	Normal furnace atmosphere burn-out initiated	Automatic or manual
2	Normal furnace atmosphere purge-out initiated	Automatic or manual
3	Low flow of carrier gas(es) that will not maintain a positive pressure in chambers below 1400°F (760°C) and positive pressure is not restored by the automatic transfer to another source of gas	Automatic
4	A furnace temperature below which any liquid carrier gas used will not reliably dissociate	Automatic
5	Automatic emergency inert gas purge initiated	Automatic
6	Manual operator emergency inert gas purge initiated	Automatic

[**86:**Table A.13.5.11.11.10.1]

code has no requirement to initiate the removal of the special [hydrogen] atmosphere in this case. Instead, the operator should follow written operating instructions and work to restore normal process conditions. The written operating instructions could include directions to implement a controlled furnace shutdown if certain specified conditions develop. [**86:**A.13.5.11.11.12.4]

Where chamber temperature is below 1400°F (760°C), the uncontrolled air infiltration could create an explosion hazard. Under these conditions, the safety shutoff valves for flammable special [hydrogen] atmospheres will close, and the actions specified in 15.3.1.1.12.10(B)(1) should automatically occur. [**86:**A.13.5.11.11.12.4]

Regarding 15.3.1.1.12.12(D), where a carrier gas generated by liquid dissociation is used, furnace temperatures need to be maintained above a temperature that will maintain reliable dissociation of the liquid. In earlier editions of NFPA 86, the minimum temperature was stated as 800°F (427°C). This specific value has been removed from the standard because there is more than one liquid used as a special atmosphere, and each liquid should be evaluated for the minimum temperature that will reliably dissociate that liquid in the furnace. Where a reliable dissociation temperature is not maintained, the special atmosphere liquid might no longer maintain a positive furnace pressure. Once positive furnace pressure is lost, air infiltration will be possible, and a furnace explosion hazard can develop. [**86:**A.13.5.11.11.12.4]

A.15.3.1.1.12.15 Vestibule explosion relief means usually consist of doors that remain in position under their own weight but are otherwise unrestrained from moving away from the door opening if an overpressure occurs within the furnace. [**86:**A.13.5.11.11.15]

A.15.3.1.1.12.16 Noncarrier special atmosphere gases can be flammable (e.g., enriching gas) or nonflammable (e.g., process air). Their introduction into the furnace should occur only after the carrier gases flow has been established. According to this [code], flammable special [hydrogen] atmosphere gases are equipped with safety shutoff valves. Nonflammable special atmosphere gases typically are equipped with solenoid valves. [**86:**A.13.5.11.11.16]

Δ **A.15.3.1.1.13** Furnace controls that meet the performance-based requirements of standards such as ANSI/ISA 84.00.01, *Functional Safety: Safety Instrumented Systems for the Process Industry Sector; IEC 61511, Functional Safety: Safety Instrumented Systems for the Process Industry Sector;* ISO 13849-1, *Safety of Machinery*; and IEC 62061, *Safety of Machinery — Functional Safety*, can be considered equivalent. The determination of equivalency will involve complete conformance to the safety life cycle, including risk analysis, safety integrity level selection, and safety integrity level verification, which should be submitted to the authority having jurisdiction. [**86:**A.8.2]

N **A.15.3.1.1.13(D)(4)** Multiple kinds of relays are labeled, listed, and sold as safety relays and not all of these are designed to produce a fail-safe reaction in the event of contact welding. As intended in this code, the safety relay should monitor its output contacts for failure to release and force a safe state if the contacts fail to release when commanded. Of concern is summarizing multiple interlocks with one relay; the relay is a single device whose failure can disable multiple safety functions. [**86:**A.8.2.14(4)]

Relays and contactors with force-guided contacts should be listed for safety service but on their own do not meet the requirements of a safety relay in this code. These relays or contactors by themselves do not perform contact diagnostics or provide a fail-safe action in the event of contact welding. [**86:**A.8.2.14(4)]

A.15.3.1.1.13(E) This [code] requires that the signal from the safety device be directly transmitted to the safety PLC input. Once the safety PLC processes the signal the resulting data can be used for any purpose except for the control of the process being protected. [**86:**A.8.2.15]

A.15.3.1.1.13(F) The control circuit and its non-furnace-mounted or furnace-mounted control and safety components should be housed in a dusttight panel or cabinet, protected by partitions or secondary barriers, or separated by sufficient spacing from electrical controls employed in the higher voltage furnace power system. Related instruments might or might not be installed in the same control cabinet. The door providing access to this control enclosure might include means for mechanical interlock with the main disconnect device required in the furnace power supply circuit. [**86:**A.8.2.16]

Temperatures within this control enclosure should be limited to 125°F (52°C) for suitable operation of plastic components, thermal elements, fuses, and various mechanisms that are employed in the control circuit. [**86:**A.8.2.16]

A.15.3.1.1.15 The NFPA 86 requirements for inert gas purge are found in 13.5.8, 13.5.10, 13.5.11, and 14.5.3 of NFPA 86.

N **A.15.3.1.2.2** Gas hazards can include asphyxiation, toxicity, corrosiveness, and flammability. The hazards associated with the release of these gases into the work environment should be assessed and mitigated appropriately. Accidental releases should be considered as part of the assessment. Mitigation strategies could include gas monitoring or ventilation of confined spaces or pits where such gases could accumulate. [**86:**A.14.2.2]

A.15.3.1.2.3.8 If a residual amount of air is retained in an external chamber, the inadvertent opening of a valve to an external system in the presence of a flammable atmosphere could create an explosive mixture. [**86:**A.14.5.3.1.8]

A.15.3.1.2.3.14 Cracking of a sight glass, which is not unusual, can admit air into the chamber or allow flammable gas to escape. [**86:**A.14.5.3.1.14]

A.15.3.1.2.11 In case of electric power failure, all the following systems could stop functioning:

(1) Heating system
(2) Flammable atmosphere gas system
(3) Vacuum pumping system

[**86:**A.14.5.3.16]

A.15.3.2 Large electrical generators have adopted the use of a hydrogen atmosphere within the casing to reduce windage drag, which improves the efficiency of the equipment, and to increase the cooling capability of the generator, thus allowing a higher energy density while minimizing thermal stresses on the machine. Hydrogen-cooled generators are supported by a number of subsystems, several of which can also contain hydrogen gas. Chapters 6 through 8 cover much of the overall system installation, and those provisions should be followed.

Traditionally, hydrogen gas for the generator is supplied either by a cylinder manifold (typically provided by the generator manufacturer) or a tube trailer (tied to the generator hydrogen system by the owner/operator). Such installations consist of piping, valves, and pressure regulation devices that should be installed in accordance with the provisions of Chapters 6 through 8. Recently, the traditional cylinder/tube trailer supply has been replaced on some installations with a local hydrogen generation unit, which lowers the cost of ownership, provides an assured supply of hydrogen, and offers a higher hydrogen purity capability within the generator envelope. Electrolyzer or reformer technology is typically the basis of these on-site hydrogen generation units, and the applicable provisions of Chapter 13 should be applied.

Other systems associated with hydrogen-cooled generators include hydrogen purity monitoring, control valves, hydrogen dew point sensors, gas dryers, liquid level detectors, and hydrogen detraining vessels. Active equipment, such as the purity monitoring and dew point equipment, will be purchased commercially and be suitably rated for exposure to hydrogen gas. Other items, such as level detectors and detraining vessels, do not contain ignition sources and require no special consideration other than the potential hazardous area surrounding them. Many of the items will include pressure relief or other venting elements that must be routed to an appropriate safe location as part of the power plant installation.

A.15.3.2.1.3.1 Although electric power generation facilities under the control of an electric utility are specifically excluded under 90.2(B)(5) of *NFPA 70*, many of the principles outlined in Articles 500 through 506 of *NFPA 70* can be successfully applied to a hydrogen-cooled generator to assure the overall safety of the equipment and personnel assigned to the facility.

A.15.3.2.2.1 Hydrogen-cooled generator installations can include acoustic walls to meet plant sound-pressure-level requirements. Although not considered a "building" for the purposes of 15.3.2.2.1, the effects of the acoustic walls on the ventilation airflow should be accounted for in the building ventilation design.

A.15.3.2.2.4 Given the low-ignition energy of hydrogen, the use of flares at the vent termination should be considered. If a flare is not used, the potential extent of hydrogen fires under worst credible conditions (e.g., generator purge) must be considered when establishing the vent termination point in relation to equipment and buildings.

A.15.3.2.3.2 See A.15.3.2.2.4.

A.15.4.1.1 Vaporizers used for safety purging to convert cryogenic liquids to the gas state should be ambient air heat transfer units so that flow from such vaporizers is unaffected by the loss of power.

The use of powered vaporizers is permitted where one of the following conditions is satisfied:

(1) The vaporizer has reserve heating capacity to continue vaporizing at least five furnace volumes at the required purge flow rate immediately following power interruption.
(2) Reserve ambient vaporizers are provided that are piped to the source of supply so that they are unaffected by a freeze-up or flow stoppage of gas from the powered vaporizer. The reserve vaporizers should be capable of evaporating at least five furnace volumes at the required purge flow rate.
(3) Purge gas is available from an alternative source that is capable of supplying five volume changes after interruption of the flow of the atmosphere gas to the furnace.

[**86:**A.13.5.5]

Vaporizers should be rated by the industrial gas supplier or the owner to vaporize at 150 percent of the highest purge gas demand for all connected equipment. Winter temperature extremes for the locale should be taken into consideration by the agency responsible for rating the vaporizers. [**86:**A.13.5.5]

The industrial gas supplier should be informed of additions to the plant that materially increase the inert gas consumption rate so that vaporizer and storage capacity can be resized for the revised requirements. [**86:**A.13.5.5]

A temperature indicator should be installed in the vaporizer outlet piping for use in evaluating its evaporation performance at any time. [**86:**A.13.5.5]

A device should be installed that prevents the flow rate of gas from exceeding the vaporizer capacity and thereby threatening the integrity of downstream equipment or control devices due to exposure to cryogenic fluids. A break in the downstream pipeline or failure (opening) of the supply pressure regulator could cause excessive flow. Exceeding the capacity of an atmospheric vaporizer leads to a gradual decrease in gas temperature that can be remedied by decreasing the demand on the vaporizer. [**86:**A.13.5.5]

In atmospheric vaporizers, in lieu of the flow-limiting device, a visual and audible alarm should indicate to operators in the vicinity of the furnace that the temperature of the vaporizer outlet gas has fallen below a minimum level, indicating a potential to exceed vaporizer capacity. [**86:**A.13.5.5]

A.16.1.2(2) The hazards of pilot plants are primarily based on the process, the chemistry, and the equipment, not the laboratory environment. Laboratories that have pilot plants within the laboratory unit should apply NFPA 45 to the laboratory portion. NFPA 45 should not be used to justify applying laboratory requirements, such as a general-purpose-area electrical classification, to the pilot plant itself. [**45:**A.1.1.3(2)]

A.16.2.1.1 A door to an adjoining laboratory work area or laboratory unit is considered to be a second means of access to an exit, provided that the laboratory unit is not of a higher fire hazard classification. [**45:**A.5.4.1]

A.16.2.2.1 A qualified design professional and owner safety officer should review the laboratory conditions through a hazard analysis and/or risk assessment to determine if a hazardous (ignitable) atmosphere could be developed within the laboratory work area, laboratory area, laboratory unit, and/or fume hood. If a hazardous atmosphere could be developed, these areas should be electrically classified per *NFPA 70*, Article 500. [**45:**A.5.5.2]

A.16.2.3.1.1.2 A series of fire tests in typical chemical laboratories was conducted to evaluate quick-response sprinkler technology and the use of quick-response sprinklers in chemical laboratories. Fire test results demonstrated that both standard response and quick-response sprinklers were effective in controlling fires. Additionally, fire test results of the quick-response sprinklers showed lower maximum temperatures at the 5 ft level consistent with what is considered acceptable tenability in the room of fire origin, as discussed in NFPA 13D, and evaluated by ANSI/UL 1626, Residential Sprinklers for Fire Protection Service. Also see NISTIR 89-4200, “Quick Response Sprinklers in Chemical Laboratories: Fire Test Results”, sponsored by the National Institutes of Health, Bethesda, MD. [**45:**A.6.1.1.2]

A.16.2.3.3.1 For laboratory buildings where trained personnel are available, Class III standpipe systems can be installed [**45:**A.6.2.1]

A.16.2.3.3.2 For additional information, see NFPA 25.

A.16.2.5.2 Maintenance procedures should include inspection, testing, and maintenance of the following:

(1) Utilities (steam, gas, electrical)
(2) Air supply and exhaust systems
(3) Fire protection equipment
(4) Detectors and alarms
(5) Compressed gas regulators and pressure relief valves
(6) Waste disposal systems
(7) Fire doors
(8) Emergency lighting and exit signs
(9) Electrically operated equipment

[**45:**A.6.5.2]

A.16.2.5.3 An emergency response plan should be prepared and updated. The plan should be available for inspection by the AHJ, upon reasonable notice. The following information should be included in the emergency plan:

(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 marking is provided for each storage area
(4) Location of posted emergency response procedures
(5) Safety Data Sheets (SDSs) for all hazardous materials stored on site
(6) A list of responsible personnel who are designated and trained to be liaison personnel for the fire department; these individuals should be knowledgeable in the site emergency response procedures and should aid the emergency responders with the following functions:
    (a) Pre-emergency planning
    (b) Identifying where flammable, pyrophoric, oxidizing, and toxic gases are located
    (c) Accessing MSDSs
(7) A list of the types and quantities of compressed and liquefied gases normally at the facility

[**45:**A.6.5.3]

A.16.2.5.3.2 Laboratory personnel should be thoroughly indoctrinated in procedures to follow in cases of clothing fires. The most important instruction, one that should be stressed until it becomes second nature to all personnel, is to immediately drop to the floor and roll. All personnel should recognize that, in the case of ignition of another person’s clothing, they should immediately knock that person to the floor and roll that person around to smother the flames. Too often a person will panic and run if clothing ignites, resulting in more severe, often fatal, burn injuries. [**45:**A.6.5.3.2]

Flame-resistant clothing is one option available to help reduce the occurrence of clothing fires. Refer to NFPA 2112 for performance requirements and test methods for flame-resistant clothing. [**45:**A.6.5.3.2]

It should be emphasized that the use of safety showers, fire blankets, or fire extinguishers are of secondary importance. These items should be used only when immediately at hand. It should be recognized that rolling on the floor not only smothers the fire but also helps to keep flames out of the victim’s face, reducing inhalation of smoke. [**45:**A.6.5.3.2]

A.16.3.2.1.1 NFPA 90A, and NFPA 91 contain additional requirements for general environmental ventilating systems. [**45:**A.7.1]

A.16.3.2.1.2.1 For additional information on laboratory ventilation, see ANSI/AIHA Z9.5, *Laboratory Ventilation*. For information on preventing the spread of smoke by means of utilizing supply and exhaust systems to create airflows and pressure differences between rooms or building areas, see NFPA 92. [**45:**A.7.2.1]

A.16.3.2.1.2.2 A minimum ventilation rate for unoccupied laboratories (e.g., nights and weekends) can be as low as four room air changes per hour with proper laboratory operations and storage of chemicals. Occupied laboratories typically operate at rates greater than six air changes per hour, consistent with the conditions of use for the laboratory. Occupied laboratories should determine their supply airflow rates based on cooling requirements, amount of exhaust air required for the hoods, or exhaust devices in the lab, whichever is greatest. Use of only an "air change per hour" criteria is not considered proper design. Adequate ventilation should be provided to ensure occupant safety and safe operation of exhaust devices inside the laboratory. [**45:**A.7.2.2.1]

Laboratory ventilation operating at lower rates should employ specific measures to monitor for potentially hazardous conditions and increase the ventilation automatically upon detection of any condition within 25 percent of the level of concern. If such a monitoring system is to be used, it should be fail-safe and be of such a nature that it will detect all potential leakage throughout the entire laboratory area. These systems should be reserved for locations where the anticipated contaminants can be measured reliably and activate the control system within a sufficiently rapid time period to provide occupant protection. In the event of a failure of the monitoring system or control components, the ventilation system should return to the designated occupied ventilation rate. Detailed analyses of flow paths, dead pockets, and failure modes under all credible scenarios should be performed to avoid exposure. [**45:**A.7.2.2.1]

It is not the intent of [this code] to require emergency or standby power for laboratory ventilation systems. [**45:**A.7.2.2.1]

A.16.3.2.1.2.3 Hoods having explosionproof electrical devices are sometimes referred to as *explosionproof hoods*. This term does not imply that they will contain an explosion, only that the electrical equipment will not provide a source of ignition. [**45:**A.7.2.3]

A.16.3.2.1.3.2 Special studies such as air-dispersion modeling might be necessary to determine the location of air intakes for laboratories away from the influence of laboratory exhaust and other local point source emissions. [**45:**A.7.3.2]

A.16.3.2.1.3.4 Room air current velocities in the vicinity of fume hoods should be as low as possible, ideally less than 30 percent of the face velocity of the fume hood. Air supply diffusion devices should be as far away from fume hoods as possible and have low exit velocities. [**45:**A.7.3.4]

A.16.3.2.1.4.1 Ductless chemical fume hoods that pass air from the hood interior through an absorption filter and then discharge the air into the laboratory are only applicable for use with nuisance vapors and dusts that do not present a fire or toxicity hazard. See ANSI Z9.5, *Laboratory Ventilation*, and other applicable standards for additional information for the proper use and application.

[**45:**A.7.4.1]

A.16.3.2.1.4.2 Consideration should be made of the potential contamination of the fresh air supply by exhaust air containing vapors of flammable or toxic chemicals when using devices for energy conservation purposes. [**45:**A.7.4.2]

Where fume hood exhaust is manifolded with general laboratory exhaust, energy recovery devices should be evaluated to ensure they would not recirculate contaminants through an active purge or filtration treatment. Energy recovery systems should be designed with a fail-safe alarm(s) and equipment interlocks to prevent cross contamination or recirculation from occurring, including shutdown of systems if needed. [**45:**A.7.4.2]

Enthalpy wheels, in particular, have potential for cross-contamination and should be carefully evaluated for all potential hazards and failure modes. [**45:**A.7.4.2]

A.16.3.2.1.4.4 Ducts should be sealed to prevent condensation, and so forth, from leaking into occupied areas. [**45:**A.7.4.4]

A.16.3.2.1.4.7 Laboratory fume hood containment can be evaluated using the procedures contained in ASHRAE 110, *Method of Testing Performance of Laboratory Fume Hoods*. Face velocities of 0.4 m/sec to 0.6 m/sec (80 ft/min to 120 ft/min) generally provide containment if the hood location requirements and laboratory ventilation criteria of this standard are met. [**45:**A.7.4.7]

Lower flow fume hoods (those with an average face velocity or 0.3 to 0.4 m/sec (60 to 80 ft/min) are often desirable for energy conservation. Lower hood face velocities are effective with hoods designed for lower face velocities. However, many circumstances can lead to inadequate contaminant containment. These include crowding, larger equipment, high thermal loads, internal circulation from equipment and numerous other issues. Hence the owner should carefully consider all potential applications when determining the face velocity to use. [**45:**A.7.4.7]

In addition to maintaining proper fume hood face velocity, fume hoods that reduce the exhaust volume as the sash opening is reduced should maintain a minimum exhaust volume to ensure that contaminants are diluted and exhausted from a hood. The chemical fume hood exhaust airflow should not be reduced to less than the flow rate recommended in ANSI/AIHA Z9.5, *Laboratory Ventilation*. [**45:**A.7.4.7]

A.16.3.2.1.4.9 Due to their low capture efficiency, canopy hoods should only be used for exhausting heat and nuisance odors and not for exhausting chemicals. It is not the intent of this standard to prohibit the use of ductless enclosures (often incorrectly called "ductless hoods"). However, the use of such devices requires careful hazard analysis and risk assessment of all potential failure modes (mechanical, breakthrough, contamination, off gassing, etc.), how the owner is able to control uses for which the enclosure will not be adequate, how the user can continuously verify that the adsorption media is working properly, and how the spent media is to be safely removed and replaced, among numerous other concerns. The committee does not believe these enclosures are a suitable replacement for a chemical fume hood except after careful and thorough analysis. [**45:**A.7.4.9]

A.16.3.2.1.4.11 Exhaust stacks should extend at least 3 m (10 ft) above the highest point on the roof to protect personnel on the roof. Exhaust stacks might need to be much higher to dissipate effluent effectively, and studies might be necessary to determine adequate design. Related information on stack height can be found in Chapter 14, Airflow Around Buildings, of the ASHRAE *Handbook of Fundamentals*. [**45:**A.7.4.11]

A.16.3.2.1.6.4 For informative material regarding spark-resistant fan construction, see ANSI/Air Movement and Control Association (AMCA) Standards for classification for spark-resistant construction. [**45:**A.7.7.4]

A.16.3.2.1.6.6 Exhaust fans should be tested to ensure they do not rotate backward in new installations or after repair on motors. [**45:**A.7.7.6]

A.16.3.2.1.7.1(A) Specifying the flame spread rating alone does not ensure that the liner will provide containment of a small fire. [**45:**A.7.8.1.1]

A.16.3.2.1.7.1(B) Baffles normally should be adjusted for the best operating position for general use. Only where high heat loads or the routine use of large quantities of light or heavy gases occur should compensating adjustment be made. In most cases, however, the low concentrations of heavier-than-air and lighter-than-air vapors take on the characteristics of the large volumes of air going through the hood. It is recommended that the total adjustment not exceed 20 percent of the total airflow. [**45:**A.7.8.1.3]

A.16.3.2.1.7.1(C) The means of containing minor spills might consist of a 6.4 mm (¼ in.) recess in the work surface, use of pans or trays, or creation of a recess by installing a curb across the front of the hood and sealing the joints between the work surface and the sides, back, and curb of the hood. [**45:**A.7.8.1.4]

A.16.3.2.1.7.2 A hood sash greatly enhances the safety provided by a chemical fume hood, and it is recommended that the hood design incorporate this feature. For example, a hood sash can be adjusted to increase the face velocity when working on high hazard material. The sash can be used as a safety shield. It can be closed to contain a fire or runaway reaction, and it can be closed to contain experiments when the hood is left unattended. [**45:**A.7.8.2]

Hoods without sashes or hoods with a side or rear sash in addition to a front sash do not offer the same degree of protection as do hoods with protected single face openings, and, thus, their use is not recommended. A small face opening can be desirable to save exhaust air and energy or to increase the maximum face velocity on existing hoods. [**45:**A.7.8.2]

A.16.3.2.1.7.3 Users should be instructed and periodically reminded not to open sashes rapidly and to allow hood sashes to be open only when needed and only as much as necessary. [**45:**A.7.8.3]

A.16.3.2.1.7.4 Locating services, controls, and electrical fixtures external to the hood minimizes the potential hazards of corrosion and arcing. [**45:**A.7.8.4]

A.16.3.2.1.7.7(A) Where a laboratory exhaust system can be overdrawn (as in a VAV system, for which it is assumed that all hoods are not at full capacity all the time — the so-called diversity factor) the hood alarm provides immediate warning to all users that their hood is no longer working properly. Hence, an indication that the exhaust system capacity has been breached is not required, although it might be desired by the owner. [**45:**A.7.8.7]

A.16.3.2.1.7.7(B) The intent of previous versions of this standard was to provide a local device that alerted users to improper hood performance. However, many commercially common installations showed face velocities that varied slightly, particularly during operation. This has led to frequent "alarms" even when the hoods were still within their design limits. Hence a Go/No Go-type sensor is actually preferred. ANSI/AIHA Z9.5, Laboratory Ventilation, recommends alarming if the average face velocity deviates by 20 percent or more; other sources and industry practice have suggested tighter limits of 10 percent. [**45:**A.7.8.7.1]

A.16.3.2.1.8.1 A person walking past the hood can create sufficient turbulence to disrupt a face velocity of 0.5 m/sec (100 ft/min). In addition, open windows or air impingement from an air diffuser can completely negate or dramatically reduce the face velocity and can also affect negative differential air pressure. [**45:**A.7.9.1]

A.16.3.2.1.8.3 Place low hazard activities (such as desks and microscope benches) away from the chemical fume hood. The term *directly in front of* does not include those areas that are separated by a barrier such as a lab bench or other large structure that would serve as a shield. [**45:**A.7.9.3]

A.16.3.2.1.9.1(A) A hazard and risk assessment should be conducted for fume hood operations. Circumstances exist where hood fire suppression systems might be appropriate as a stand-alone protection measure or as part of a more comprehensive strategy to reduce hazards and risks. This assessment should be reviewed when fume hood operations change. See the objectives of the NFPA 45 stated in Section 1.2. [**45:**A.7.10.1]

A.16.3.2.1.9.2(10) For further information, see report entitled "An Investigation of Chemical Fume Hood Fire Protection Using Sprinkler and Water Mist Nozzles" prepared by Factory Mutual Research Corporation. [**45:**A.7.10.2.1]

A.16.3.2.1.9.3 Subsection 4.2.2 of NFPA 91 states that incompatible materials shall not be conveyed in the same system. [Section] 16.3.2.1.5.7(B) allows exhaust ducts within a laboratory unit to be combined. The apparent inconsistency is due to the focus of both standards. NFPA 45 assumes that in normal routine laboratory operations, the amount of materials released into the exhaust system is small and will be diluted below any levels of concern. [**45:**A.7.5.10]

A.16.3.2.1.9.3(A) In 2001 at the University of California, a fire resulted in an injury and caused approximately $3.5 million in damage. Based on the investigation, it was concluded that the practice of not having fire dampers on the exhaust duct of the ventilation system at the shaft wall appears to have been beneficial in this fire scenario. The investigation observed that the exhaust system was effective at removing significant quantities of combustion products from the building during the fire, thereby reducing the amount of combustion products spreading to other areas of the building. The shutting down of the supply air by fire dampers did not significantly hinder the exhaust system because fresh air was provided though a broken window. However, if the window had not failed, the team concluded that the exhaust system probably would not have performed as well. [**45:**A.7.5.10.1.2]

A.16.3.2.1.9.3(C)(3) See Figure A.5.3 of NFPA 90A. [**45:**A.7.5.10.2.2(3)]

A.16.3.2.1.9.7 Installation of sprinklers in the void area or in the chemical fume hood is an acceptable method to prevent flame spread. [**45:**A.7.10.7]

A.16.3.2.1.10.1 Laboratory hoods in which radioactive materials are handled should be identified with the radiation hazard symbol. For information, see NFPA 801. [**45:**A.7.13.1]

A.16.3.2.1.11.1 The operating characteristics of some chemical fume hood designs, particularly auxiliary air chemical fume hoods, change at intermediate positions of sash height. It is, therefore, important to verify inward airflow over the face of the hood according to 16.3.2.1.11.1(5) at several sash heights from full open to closed. [**45:**A.7.14.1]

A number of test procedures for verifying performance of chemical fume hoods that have been installed in the field have been published. [**45:**A.7.14.1]

A test procedure is given in *Standard on Laboratory Fume Hoods*, by The Scientific Equipment and Furniture Association (SEFA), that uses a velometer and visible fume for checking hood performance. [**45:**A.7.14.1]

A standard has been issued by the American Society of Heating, Refrigerating, and Air Conditioning Engineers entitled ASHRAE 110, *Method of Testing Performance of Laboratory Fume Hoods*. [**45:**A.7.14.1]

The Environmental Protection Agency's *Procedure for Certifying Laboratory Fume Hoods to Meet EPA Standards* contains a test procedure utilizing sulfur hexafluoride as a test gas. [**45:**A.7.14.1]

A.16.3.2.1.11.5(A) The annual inspection of air supply and exhaust fans, motors, and components should ensure that equipment is clean, dry, tight, and friction-free. Bearings should be properly lubricated on a regular basis, according to manufacturers' recommendations. Protective devices should be checked to ensure that settings are correct and that ratings have been tested under simulated overload conditions. Inspections should be made by personnel familiar with the manufacturers' instructions and equipped with proper instruments, gauges, and tools. [**45:**A.7.14.5.1]

A.16.3.2.2.1.1 Hazard evaluations and risk assessments should be performed by a team of people who are familiar with hazardous chemicals, chemical reactions, equipment, and operational procedures prior to laboratory work. In particular, when new or existing experiments involve a scale-up, an increase in flow rate, changes in physical properties (such as temperature or pressure), changes in equipment or supplies, mixing of incompatible materials, or a potential for explosion, hazard evaluations and risk assessments should be performed prior to initiating research. The hazard evaluation and risk assessment team should include the stakeholders, such as the principal investigator, and representatives working in the laboratory, in addition to any experts on the design and controls of the chemical process.

The hazard evaluations and risk assessments should include understanding of the interactivity of materials, associated energies, side reactions, and temperature rise for worst-case reactions and side reactions. The evaluation should also consider evaluation with the materials and equipment associated with the laboratory operation.

Where the hazard evaluation identifies significant hazards, appropriate controls need to be implemented to mitigate the hazards to prevent fires or explosions. Mitigations could include adequate pressure relief/venting, limited size of vessels, shielding, controllers, and analyzers with automated shutdowns.

Reference sources include the following:

(1) NFPA 49, NFPA 325, and NFPA 491, which are contained in NFPA's *Fire Protection Guide to Hazardous Materials*.

(2) NFPA 551

(3) Chapter 4 of *Prudent Practices in the Laboratory*

(4) *Handbook of Chemical Health and Safety*

(5) A free tool for chemical reactivity, available at https://www.aiche.org/ccps/resources/chemical-reactivity-worksheet-40

[**45:**A.11.2.1]

A.16.3.2.2.1.1(D) When a new chemical is produced, it should be subjected to a hazard analysis as appropriate to the reasonably anticipated hazard characteristics of the material. Such tests might include, but are not limited to, differential thermal analysis, accelerating rate calorimetry, drop weight shock sensitivity, autoignition temperature, flash point, thermal stability under containment, heat of combustion, and other appropriate tests. [**45:**A.11.2.1.4]

A.16.3.2.2.1.1(E) In 2016, an experiment involving the use of a hydrogen, oxygen, and carbon dioxide gas mixture exploded in a laboratory, causing a serious injury and destroying the laboratory. [**45:**A.11.2.1.5]

A.16.3.2.2.1.2(D) Procedures might include chilling, quenching, cutoff of reactant supply, venting, dumping, and "short-stopping" or inhibiting. [**45:**A.11.2.8.4]

A.16.3.2.2.2.3(A) Pressure vessels require specialized design beyond the scope of normal workshop practice. For design of pressure vessels, see Section VIII, "Rules for Construction of Pressure Vessels," Division 1, ASME *Boiler and Pressure Vessel Code*. [**45:**A.11.3.5.1]

A.16.3.2.2.2.4(B) Hazards to personnel from high voltage, vapors or fumes, radiation, flames, flashbacks, and explosions should be minimized. [**45:**A.11.3.6.2]

A.16.3.2.3.1 The exhaust system should be identified "WARNING — Chemical Laboratory Exhaust" (or "Chemical Fume Hood Exhaust" or other appropriate wording). Exhaust system discharge stacks and discharge vents and exhaust system fans should be marked to identify the laboratories or work areas being served. [**45:**A.13.3]

A.16.4.1.2.1 For additional information, see the following:

(1) CGA Pamphlet P-1, *Standard for Safe Handling of Compressed Gases in Containers*
(2) ASME B31.1, *Power Piping* (including addendum)
(3) ASME B31.3, *Process Piping*
(4) National Safety Council Data Sheet 1-688-86, *Cryogenic Fluids in the Laboratory*

[**45:**A.10.2.1]

A.16.4.1.2.2 Additional shutoff valves, located in accessible locations outside of the areas in which the gases are used, are acceptable. [**45:**A.10.2.3]

A.16.4.1.2.3 Pressure relief should only be provided by devices designed and approved for this purpose. Providing pressure relief by use of a loosely attached plastic laboratory tubing, by leaving glass stoppers in a flask to pop off, or by other similar methods do not meet the requirements of this section. Failure of any device cannot be considered as pressure relief. [**45:**A.10.2.4.1]

A.16.4.1.2.3.1 Typically, relief devices are sized to provide the full flow rate at no more than 10 percent overpressure per ASME guidelines.

A safe location per 16.4.1.2.3.1 is into an exhaust duct, into the plenum of a laboratory hood, or into a vent that exits outside the building. [**45:**A.10.2.4.2]

A.16.4.1.2.4 It is recommended that each intermediate regulator and valve also be identified. The identification should conform to ANSI/ASME A13.1, *Scheme for the Identification of Piping Systems.* [**45:**A.10.2.5]

A.16.4.1.2.5 Great care should be taken when converting a piping system from one gas to another. In addition to the requirements of 16.4.1.2.5, thorough cleaning to remove residues might be essential. For example, inert oil-pumped nitrogen will leave a combustible organic residue that is incompatible with oxygen and other oxidizing agents. Similar incompatibilities can occur with other materials. [**45:**A.10.2.6]

A.16.4.1.3.1.2 Air can be condensed when it contacts containers or piping containing cryogenic fluids. When this occurs, the concentration of oxygen in the condensed air increases, thereby increasing the likelihood of ignition of organic material. [**45:**A.10.4.1.2]

A.17.3 The requirements for indoor parking of vehicles are located within the building and fire prevention codes adopted within a jurisdiction.

The fire hazard presented by self-propelled vehicles powered by GH_2 or LH_2 is sufficiently similar to those presented by vehicles fueled by liquid gasoline or diesel fuel that no additional requirements are warranted. Studies and fire tests performed have concluded that the combustible components common to all types of automobiles can cause a vehicle fire to spread from one parked vehicle to an adjacent one but that the presence or release of hydrogen (such as through activation of a thermal pressure relief device) is not a major cause of fire spread.

A.18.3.2.6 Defueling equipment provided by the vehicle manufacturer is recommended.

N **A.18.3.2.8.1** Defueling equipment provided by the vehicle manufacturer is recommended. Although intended for outdoor bulk hydrogen storage, Table 7.3.2.3.1.2(B)(a), Table 7.3.2.3.1.2(B)(b), and Table 7.3.2.3.1.2(B)(c) can provide general guidance on the separation distances for outdoor venting. Table 7.3.2.3.1.7.1 can provide recommendations for electrical area classifications distances that should be used when performing outdoor refueling from a vehicle.

A.18.3.2.9.5.4 Tanks mounted in vehicles meet this requirement provided the vehicle is secured from moving.

A.18.3.3.3(3) Exhaust systems that operate continuously are considered to have been activated for the purpose of this section.

A.18.3.4.4.1 Electric heaters that are listed and labeled for Class I, Division 1 and 2, Group B (Class I, Zone 0, 1, and 2, Group IIC) are suitable for use with hydrogen. *(See NFPA 70.)* Other heaters that do not arc or spark; do not create static discharges; and do not have surface temperatures exceeding 752°F (400°C) could also be suitable.

Table 4.4.2 of NFPA 497 lists the AIT of hydrogen as 932°F (500°C).

A.18.6.1.2 Typically, fuel valves are closed when de-energized. De-energizing the fuel cell power system (FCPS) or other type of hydrogen-fueled engine will typically de-energize these valves. Preventing the FCPS or engine from restarting by removing a key, connector, or similar device will ensure that these fuel valves remain closed.

A.18.6.1.3 One standard for these FCPSs is UL 2267, *Fuel Cell Power Systems for Installation in Industrial Electric Trucks.*

A.18.6.2.2.1 Typically, fuel valves are closed when de-energized. Disconnecting the power to these valves will prevent them from opening during servicing. A lockout/tagout procedure in accordance with 29 CFR 1910.147 (OSHA) is recommended.

A.18.6.2.3 Service of the fuel storage containers includes repair, replacement, inspection, recertification, and similar activities that require direct access to containers. See 18.3.2 for requirements for the defueling equipment.

N **A.19.2.2** IEC 62282-4-101, *Fuel cell technologies—Part 4-101: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU)—Safety of electrically powered industrial trucks,* is similar to UL 2267, *Fuel Cell Power Systems for Installation in Industrial Electric Trucks.*

Annex B Administration

This annex is not a part of the requirements of this NFPA document unless specifically adopted by the jurisdiction.

The information in Annex B can be used to supplement the administrative requirements of Chapter 1.

B.1 Application.

B.1.1 This code shall apply to both new and existing conditions.

B.1.2 Referenced Standards.

Δ **B.1.2.1** Details regarding processes, methods, specifications, equipment testing and maintenance, design standards, performance, installation, or other pertinent criteria contained in those codes and standards listed in Chapter 2 of this *Code* shall be considered a part of this *Code*. [**1:**1.3.2.1]

B.1.2.2 Where no applicable codes, standards, or requirements are set forth in this code or contained within other laws, codes, regulations, ordinances, or bylaws adopted by the authority having jurisdiction (AHJ), compliance with applicable codes and standards of NFPA or other nationally recognized standards, as are approved, or approved performance-based options in accordance with Chapter 5, shall be deemed as prima facie evidence of compliance with the intent of this code.

B.1.2.3 Nothing herein shall diminish the authority of the AHJ to determine compliance with codes or standards for those activities or installations within the AHJ's responsibility. [**1:**1.3.2.3]

B.1.3 Conflicts.

Δ **B.1.3.1** When a requirement differs between this *Code* and a referenced document, the requirement of this *Code* shall apply. [**1:**1.3.3.1]

B.1.3.2 When a conflict between a general requirement and a specific requirement occurs, the specific requirement shall apply. [**1:**1.3.3.2]

B.1.4 Installations.

Δ **B.1.4.1** Buildings permitted for construction after the adoption of this *Code* shall comply with the provisions stated herein for new buildings.[**1:**1.3.6.1]

Δ **B.1.4.2** Buildings in existence or permitted for construction prior to the adoption of this *Code* shall comply with the provisions stated herein or referenced for existing buildings. *(see 10.3.2 of NFPA 1).* [**1:**1.3.6.2]

B.1.4.3 Repairs, renovations, alterations, and additions to existing hydrogen installations shall conform with NFPA 2 and the adopted building code.

Δ **B.1.4.4** Newly introduced equipment, materials, and operations regulated by this *Code* shall comply with the requirements for new construction or processes. [**1:**1.3.6.4]

Δ **B.1.4.5 Severability.** If any provision of this *Code* or the application thereof to any person or circumstance is held invalid, the remainder of the *Code* and the application of such provision to other persons or circumstances shall not be affected thereby. [**1:**1.3.7]

B.2 Equivalencies, Alternatives, and Modifications.

Δ **B.2.1 Equivalencies.** 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 to those prescribed by this *Code*, provided technical documentation is submitted to the AHJ to demonstrate equivalency and the system, method, or device is approved for the intended purpose. [**1:**1.4.1]

Δ **B.2.2 Alternatives.** The specific requirements of this *Code* shall be permitted to be altered by the AHJ to allow alternative methods that will secure equivalent fire safety, but in no case shall the alternative afford less fire safety than, in the judgment of the AHJ, that which would be provided by compliance with the provisions contained in this *Code*. [**1:**1.4.2]

Δ **B.2.3 Modifications.** The AHJ is authorized to modify any of the provisions of this *Code* upon application in writing by the owner, a lessee, or a duly authorized representative where there are practical difficulties in the way of carrying out the provisions of the *Code*, provided that, in the judgment of the AHJ, the intent of the *Code* shall be complied with, public safety secured, and substantial justice done. [**1:**1.4.3]

Δ **B.2.4** Buildings with equivalency, alternatives, or modifications, approved by the AHJ shall be considered as conforming with this *Code*. [**1:**1.4.4]

B.2.5 Each application for an equivalent, alternative, or modified fire protection feature should be filed with the AHJ and shall be accompanied by such evidence, letters, statements, results of tests, or other supporting information as required to justify the request. The AHJ shall keep a record of actions on such applications, and a signed copy of the AHJ's decision shall be provided for the applicant.

B.2.6 Approval. The AHJ should approve such equivalent, alternative, or modified construction systems, materials, or methods of design when it is substantiated that the standards of this code are at least equaled. If, in the opinion of the AHJ, the standards of this code are not equaled by the alternative requested, approval for permanent work can be refused. Consideration should be given to test or prototype installations.

B.2.7 Tests.

Δ **B.2.7.1** Whenever evidence of compliance with the requirements of this *Code* is insufficient or evidence that any material or method of construction does not conform to the requirements of this *Code*, or to substantiate claims for alternative construction systems, materials, or methods of construction, the AHJ shall be permitted to require tests for proof of compliance to be made by an approved agency at the expense of the owner or his/her agent. [**1:**1.4.7.1]

Δ **B.2.7.2** Test methods shall be as specified by this *Code* for the material in question. If appropriate test methods are not specified in this *Code*, the AHJ is authorized to accept an applicable test procedure from another recognized source. [**1:**1.4.7.2]

B.2.7.3 Copies of the results of all such tests shall be retained in accordance with Section B.7. [**1:**1.4.7.3]

B.3 Units.

Δ **B.3.1 International System of Units.** Metric units of measurement in this *Code* are in accordance with the modernized metric system known as the International System of Units (SI). [**1:**1.5.1]

Δ **B.3.2 Primary and Equivalent Values.** If a value for a measurement as given in this *Code* is followed by an equivalent value in other units, the first stated value shall be regarded as the requirement. A given equivalent value could be approximate. [**1:**1.5.2]

Δ **B.4 Enforcement.** This *Code* shall be administered and enforced by the AHJ designated by the governing authority. *(See Annex C for sample wording for enabling legislation.)* [**1:**1.6]

B.5 Authority.

Δ **B.5.1 Administration.** The provisions of this *Code* shall apply without restriction, unless specifically exempted. [**1:**1.7.1]

Δ **B.5.2 Minimum Qualifications to Enforce this Code.** The AHJ shall establish minimum qualifications for all persons assigned the responsibility of enforcing this *Code*. [**1:**1.7.2]

B.5.3 Interpretations.

Δ **B.5.3.1** The AHJ is authorized to render interpretations of this *Code* and to make and enforce rules and supplemental regulations in order to carry out the application and intent of its provisions. [**1:**1.7.3.1]

Δ **B.5.3.2** Such interpretations, rules, and regulations shall be in conformance with the intent and purpose of this *Code* and shall be available to the public during normal business hours. [**1:**1.7.3.2]

Δ **B.5.4 Enforcement Assistance.** Police and other enforcement agencies shall have authority to render necessary assistance in the enforcement of this *Code* when requested to do so by the AHJ. [**1:**1.7.4]

Δ **B.5.5 Delegation of Authority.** The AHJ shall be permitted to delegate to other qualified individuals such powers as necessary for the administration and enforcement of this *Code*. [**1:**1.7.5]

B.5.6 Inspection.

Δ **B.5.6.1** The AHJ shall be authorized to inspect, at all reasonable times, any [hydrogen installation or operation] for dangerous or hazardous conditions or materials as set forth in this *Code*. [**1:**1.7.7.1]

Δ **B.5.6.2** The AHJ shall have authority to order any person(s) to remove or remedy such dangerous or hazardous condition or material. Any person(s) failing to comply with such order shall be in violation of this *Code*. [**1:**1.7.8.1]

B.5.6.3 To the full extent permitted by law, any AHJ engaged in fire prevention and inspection work shall be authorized at all reasonable times to enter and examine any building, structure, marine vessel, vehicle, or premises for the purpose of making fire safety inspections [of hydrogen installations and/or operations]. [**1:**1.7.7.2]

B.5.6.4 Before entering, the AHJ shall obtain the consent of the occupant thereof or obtain a court warrant authorizing entry for the purpose of inspection except in those instances where an emergency exists. [**1:**1.7.7.3]

Δ **B.5.6.5** As used in B.5.6.4, emergency means circumstances that the AHJ knows, or has reason to believe, exist and that can constitute imminent danger.

B.5.6.6 Persons authorized to enter and inspect buildings, structures, marine vessels, vehicles, and premises as herein set forth shall be identified by credentials issued by the governing authority. [**1:**1.7.7.5]

Δ **B.5.7** Where conditions exist and are deemed hazardous to life or property by the AHJ, the AHJ shall have the authority to summarily abate such hazardous conditions that are in violation of this *Code*. [**1:**1.7.8.2]

Δ **B.5.8 Interference with Enforcement.** Persons shall not interfere or cause conditions that would interfere with an AHJ carrying out any duties or functions prescribed by this *Code*. [**1:**1.7.9]

B.5.9 Impersonation. Persons shall not use a badge, uniform, or other credentials to impersonate the AHJ. [**1:**1.7.10]

B.5.10 Investigation.

B.5.10.1 Authority. The AHJ shall have the authority to investigate the cause, origin, and circumstances of any fire, explosion, [or uncontrolled release of hydrogen gas or liquid]. [**1:**1.7.11.1]

B.5.10.2 Evidence. The AHJ shall have the authority to take custody of all physical evidence relating to the cause of the fire, explosion, [or uncontrolled release of hydrogen gas or liquid]. [**1:**1.7.11.2]

B.5.10.3 Limiting Access. The AHJ shall have the authority to limit access to emergencies or other similar situations. [**1:**1.7.11.3]

Δ **B.5.10.4 Trade Secret.** Information that could be related to trade secrets or processes shall not be made part of the public record except as could be directed by a court of law.

B.5.11 Plans and Specifications.

B.5.11.1 The AHJ shall have the authority to require plans and specifications to ensure compliance with applicable codes and standards. [**1:**1.7.12.1]

B.5.11.2 Plans shall be submitted to the AHJ prior to construction unless otherwise permitted by B.5.11.4. [**1:**1.7.12.2]

B.5.11.3 The construction documents for each phase shall be complete in themselves, so that review and inspection can properly be made. Preliminary plans of the total building shall be submitted with the construction documents, and with sufficient detail, so that proper evaluation can be made. Areas and items not included in the phase to be permitted shall be shown as not included. [**5000:**1.7.6.3.3.3]

B.5.11.4 The AHJ is authorized to exempt detached one- and two-family dwellings and accessory structures from the submittal of plans. [**1:**1.7.12.4]

B.5.11.5 Plans shall be submitted to the AHJ prior to the change of occupancy of any existing building. [**1:**1.7.12.5]

B.5.11.6 Plans shall be submitted to the AHJ prior to the alteration of the means of egress or fire protection systems of any existing building. [**1:**1.7.12.6]

B.5.11.7 Plans shall be submitted to the AHJ for other conditions as deemed necessary by the AHJ to determine compliance with the applicable codes and standards. [**1:**1.7.12.7]

B.5.11.8 The AHJ shall be authorized to require permits for conditions listed in B.5.11.2, B.5.11.5, and B.5.11.6, unless otherwise permitted by B.5.11.9. [**1:**1.7.12.8]

B.5.11.9 The AHJ is authorized to exempt detached one- and two-family dwellings and accessory structures from the permit requirement of B.5.11.8. [**1:**1.7.12.9]

B.5.11.10 No construction work shall proceed until the AHJ has reviewed the plans for compliance with the applicable codes and standards and the applicable permits have been issued. [**1:**1.7.12.10]

B.5.12 Inspection of Construction and Installation.

B.5.12.1 The AHJ shall be notified by the person performing the work when the installation is ready for a required inspection. [**1:**1.7.13.1]

B.5.12.2 Whenever any installation subject to inspection prior to use is covered or concealed without having first been inspected, the AHJ shall have the authority to require that such work be exposed for inspection. [**1:**1.7.13.2]

B.5.12.3 When any construction or installation work is being performed in violation of the plans and specifications as approved by the AHJ, a written notice shall be issued to the responsible party to stop work on that portion of the work that is in violation. [**1:**1.7.13.3]

B.5.12.4 The notice shall state the nature of the violation, and no work shall be continued on that portion until the violation has been corrected. [**1:**1.7.13.4]

B.5.13 Certificate of Occupancy. If the adopted building code requires a certificate of occupancy, the certificate of occupancy shall not be issued until approved by the AHJ for the adopted fire code enforcement.

Δ **B.5.14 Stop Work Order.** The AHJ shall have the authority to order an operation, construction, or use stopped when any of the following conditions exists:

(1) Work is being done contrary to provision of this *Code*.
(2) Work is occurring without a permit required by B.8.
(3) An imminent danger has been created.

[**1:**1.7.15]

B.5.15 Imminent Dangers and Evacuation.

B.5.15.1 When, in the opinion of the AHJ, an imminent danger exists, the AHJ shall be authorized to order the occupants to vacate, or temporarily close for use or occupancy, a building, the right-of-way, sidewalks, streets, or adjacent buildings or nearby areas. [**1:**1.7.16.1]

N **B.5.15.2** When, in the opinion of the AHJ, an imminent danger exists, the AHJ shall be authorized to order the immediate disconnection of utilities to a structure or property. [**1:**1.7.16.2]

B.5.15.3 The AHJ shall be authorized to employ the necessary resources to perform the required work in order to mitigate the imminent danger. [**1:**1.7.16.3]

B.5.15.4 Costs incurred by the AHJ in the performance of emergency work shall be the responsibility of the property owner or other responsible party creating such imminent danger. [**1:**1.7.16.4]

B.6 Fire Code Board of Appeals.

B.6.1 Establishment of Fire Code Board of Appeals. A Board of Appeals shall be established to rule on matters relating to the fire code and its enforcement. [**1:**1.10.1]

B.6.1.1 Membership.

B.6.1.1.1 The members of the Board of Appeals shall be appointed by the governing body of the jurisdiction. [**1:**1.10.1.1.1]

B.6.1.1.2 The Board of Appeals shall consist of five or seven principal members and one ex officio member representative of the AHJ. Each principal member shall be permitted to have an alternate with similar experience to serve in his or her stead when necessary. [**1:**1.10.1.1.2]

B.6.1.1.3 Members and alternate members shall be appointed based on their education, experience, and knowledge. [**1:**1.10.1.1.3]

B.6.1.1.4 Members and alternates shall be appointed to a 3-year term. [**1:**1.10.1.1.4]

B.6.1.1.5 Members and alternates shall be composed of individuals experienced in the following fields or professions:

(1) Engineering or architectural design
(2) General contracting
(3) Fire protection contracting
(4) Fire department operations or fire code enforcement
(5) Building code enforcement
(6) Legal
(7) General public

[**1:**1.10.1.1.5]

B.6.1.1.5.1 Members and alternates shall not be employees, agents, or officers of the jurisdiction. [**1:**1.10.1.1.5.1]

B.6.1.1.5.2 Members and alternates shall be residents of the jurisdiction. [**1:**1.10.1.1.5.2]

B.6.1.1.5.3 No more than one member shall represent the same field or provision listed in B.6.1.1.5. [**1:**1.10.1.1.5.3]

B.6.1.1.6 The representative of the AHJ shall be an ex officio member and shall be entitled to participate in all discussions. The ex officio member shall not be entitled to a vote. [**1:**1.10.1.1.6]

B.6.1.1.7 No member of the Board of Appeals shall sit in judgment on any case in which the member holds a direct or indirect property or financial interest in the case. [**1:**1.10.1.1.7]

B.6.1.1.8 The board shall select one of its members to serve as chair and one member to serve as vice chair. [**1:**1.10.1.1.8]

Δ **B.6.2 Rules and Procedures of the Board of Appeals.** The Board of Appeals shall have the authority to establish rules and regulations for conducting its business that are consistent with the provisions of this *Code*. [**1:**1.10.2]

B.6.3 Authority of the Board of Appeals.

Δ **B.6.3.1** The Board of Appeals shall provide for the reasonable interpretation of the provisions of this *Code* and issue rulings on appeals of the decisions of the AHJ. [**1:**1.10.3.1]

Δ **B.6.3.2** The ruling of the Board of Appeals shall be consistent with the letter of the *Code* or when involving issues of clarity, ensuring that the intent of the *Code* is met with due consideration for public safety and fire fighter safety. [**1:**1.10.3.2]

Δ **B.6.3.3** The Board of Appeals shall have the authority to grant alternatives or modifications through procedures outlined in Section B.2 of the *Code*. [**1:**1.10.3.3]

Δ **B.6.3.4** The Board of Appeals shall not have the authority to waive the requirements of the *Code*. [**1:**1.10.3.4]

B.6.3.5 The Board of Appeals decisions shall not be precedent setting. [**1:**1.10.3.5]

B.6.4 Means of Appeals.

Δ **B.6.4.1** Any person with standing shall be permitted to appeal a decision of the AHJ to the Board of Appeals when it is claimed that any one or more of the following conditions exist:

(1) The true intent of the *Code* has been incorrectly interpreted.
(2) The provisions of the *Code* do not fully apply.
(3) A decision is unreasonable or arbitrary as it applies to alternatives or new materials.

[**1:**1.10.4.1]

Δ **B.6.4.2** An appeal shall be submitted to the AHJ in writing within 30 calendar days of notification of violation. The appeal shall outline all of the following:

(1) The *Code* provision(s) from which relief is sought
(2) A statement indicating which provisions of B.6.4.1 apply
(3) Justification as to the applicability of the provision(s) cited in B.6.4.1
(4) A requested remedy
(5) Justification for the requested remedy stating specifically how the *Code* is complied with, public safety is secured, and fire fighter safety is secured

[**1:**1.10.4.2]

B.6.4.3 Documentation supporting an appeal shall be submitted to the AHJ at least 7 calendar days prior to the Board of Appeals hearing. [**1:**1.10.4.3]

B.6.4.3.1 No additional information should be submitted to review by the Board of Appeals without the information submitted to the AHJ for their review prior to the hearing date. Additional information submitted after the filing of the appeal to the Board and AHJ should be made available to the Board and AHJ in a time frame that permits adequate review before the hearing date. [**1:**A.1.10.4.3]

B.6.5 Meetings and Records.

B.6.5.1 Meetings of the Board of Appeals shall be held at the call of the chair, at such other times as the board determines, and within 30 calendar days of the filing of a notice of appeal. [**1:**1.10.5.1]

B.6.5.2 All hearings before the Board of Appeals shall be open to the public. [**1:**1.10.5.2]

B.6.5.3 The Board of Appeals shall keep minutes of its proceedings showing the vote of each member on every question or, if the member is absent or fails to vote, these actions shall be recorded. [**1:**1.10.5.3]

B.6.5.4 The Board of Appeals shall keep records of its examinations and other official actions. [**1:**1.10.5.4]

B.6.5.5 Minutes and records of the Board of Appeals shall be public record. [**1:**1.10.5.5]

B.6.5.6 A quorum shall consist of not less than a simple majority of appointed members or alternates.

Δ **B.6.5.7** In varying the application of any provision of this *Code*, or in modifying an order of the AHJ, a two-thirds vote of the quorum shall be required. [**1:**1.10.5.7]

B.6.6 Decisions.

B.6.6.1 Every decision of the Board of Appeals shall be entered in the minutes of the board meeting. [**1:**1.10.6.1]

Δ **B.6.6.2** A decision of the Board of Appeals to modify an order of the AHJ shall be in writing and shall specify the manner in which such modification is made, the conditions upon which it is made, the reasons therefore, and justification linked to specific *Code* sections. [**1:**1.10.6.2]

B.6.6.3 Every decision shall be promptly filed in the office of the AHJ and shall be open for public inspection. [**1:**1.10.6.3]

B.6.6.4 A certified copy shall be sent by mail or delivered in person to the appellant, and a copy shall be publicly posted in the office of the AHJ for 2 weeks after filing. [**1:**1.10.6.4]

B.6.6.5 The decision of the Board of Appeals shall be final, subject to such remedy as any aggrieved party might have through legal, equity, or other avenues of appeal or petition. [**1:**1.10.6.5]

Δ **B.6.6.6** If a decision of the Board of Appeals reverses or modifies a refusal, order, or disallowance of the AHJ, or varies the application of any provision of this *Code*, the AHJ shall take action immediately in accordance with such decision. [**1:**1.10.6.6]

B.7 Records and Reports.

B.7.1 A record of examinations, approvals, equivalencies, and alternates shall be maintained by the AHJ and shall be available for public inspection during business hours in accordance with applicable laws. [**1:**1.11.1]

N **B.7.2** Documents requested from a property owner for fire protection systems with deficiencies shall be maintained by the AHJ. [**1:**1.11.1.1]

B.7.3 The AHJ shall keep a record of all fire prevention inspections, including the date of such inspections and a summary of any violations found to exist, the date of the services of notices, and a record of the final disposition of all violations. [**1:**1.11.2]

N **B.7.4** The AHJ shall keep a record of all permits and plans reviewed, including the dates of such reviews and a summary of any comments, denials, or approvals. [**1:**1.11.3]

B.8 Permits and Approvals.

B.8.1 The AHJ shall be authorized to establish and issue permits, certificates, and approvals pertaining to conditions, operations, or materials hazardous to life or property pursuant to Section B.8. [**1:**1.12.1]

B.8.2 Applications for permits shall be made to the AHJ on forms provided by the jurisdiction and shall include the applicant's answers in full to inquiries set forth on such forms. [**1:**1.12.2]

B.8.2.1 Applications for permits shall be accompanied by such data as required by the AHJ and fees as required by the jurisdiction. [**1:**1.12.2.1]

B.8.2.2 The AHJ shall review all applications submitted and issue permits as required. [**1:**1.12.2.2]

B.8.2.3 If an application for a permit is rejected by the AHJ, the applicant shall be advised of the reasons for such rejection. [**1:**1.12.2.3]

B.8.2.4 Permits for activities requiring evidence of financial responsibility by the jurisdiction shall not be issued unless proof of required financial responsibility is furnished. [**1:**1.12.2.4]

B.8.3 Conditions of Approval.

B.8.3.1 Any conditions of the initial approval by the AHJ of a use, occupancy, permit, or construction shall remain with the use, occupancy, permit, or construction unless modified by the AHJ. [**1:**1.12.3.1]

B.8.3.2 The AHJ shall be permitted to require conditions of approval be memorialized via recording in the public records, as part of the plat, permit, or other method as approved by the AHJ. [**1:**1.12.3.2]

B.8.4 Approvals by Other AHJs.

B.8.4.1 The AHJ shall have the authority to require evidence to show that other regulatory agencies having jurisdiction over the design, construction, alteration, repair, equipment, maintenance, process, and relocation of structures have issued appropriate approvals. [**1:**1.12.4.1]

B.8.4.2 The AHJ shall not be held responsible for enforcement of the regulations of such other regulatory agencies unless specifically mandated to enforce those agencies' regulations. [**1:**1.12.4.2]

B.8.5 Misrepresentation.

Δ **B.8.5.1** Any attempt to misrepresent or otherwise deliberately or knowingly design; install; service; maintain; operate; sell; represent for sale; falsify records, reports, or applications; or other related activity in violation of the requirements prescribed by this *Code* shall be a violation of this *Code*. [**1:**1.12.5.1]

B.8.5.2 Such violations shall be cause for immediate suspension or revocation of any related approvals, certificates, or permits issued by this jurisdiction. [**1:**1.12.5.2]

B.8.5.3 Such violations shall be subject to any other criminal or civil penalties as available by the laws of this jurisdiction. [**1:**1.12.5.3]

B.8.6 Permits.

Δ **B.8.6.1** A permit shall be predicated upon compliance with the requirements of this *Code* and shall constitute written authority issued by the AHJ to maintain, store, use, or handle materials; to conduct processes that could produce conditions hazardous to life or property; or to install equipment used in connection with such activities. [**1:**1.12.6.1]

Δ **B.8.6.2** Any permit issued under this *Code* shall not take the place of any other approval, certificate, license, or permit required by other regulations or laws of this jurisdiction. [**1:**1.12.6.2]

B.8.6.3 Where additional permits, approvals, certificates, or licenses are required by other agencies, approval shall be obtained from those other agencies. [**1:**1.12.6.3]

B.8.6.4 The AHJ shall have the authority to require an inspection prior to the issuance of a permit. [**1:**1.12.6.4]

Δ **B.8.6.5** A permit issued under this *Code* shall continue until revoked or for the period of time designated on the permit. [**1:**1.12.6.5]

B.8.6.6 The permit shall be issued to one person or business only and for the location or purpose described in the permit. [**1:**1.12.6.6]

B.8.6.7 Any change that affects any of the conditions of the permit shall require a new or amended permit. [**1:**1.12.6.7]

B.8.6.8 The AHJ shall have the authority to grant an extension of the permit time period upon presentation by the permittee of a satisfactory reason for failure to start or complete the work or activity authorized by the permit. [**1:**1.12.6.8]

B.8.6.9 A copy of the permit shall be posted or otherwise readily accessible at each place of operation and shall be subject to inspection as specified by the AHJ. [**1:**1.12.6.9]

Δ **B.8.6.10** Any activity authorized by any permit issued under this *Code* shall be conducted by the permittee or the permittee's agents or employees in compliance with all requirements of this *Code* applicable thereto and in accordance with the approved plans and specifications. [**1:**1.12.6.10]

Δ **B.8.6.11** No permit issued under this *Code* shall be interpreted to justify a violation of any provision of this *Code* or any other applicable law or regulation. [**1:**1.12.6.11]

B.8.6.12 Any addition or alteration of approved plans or specifications shall be approved in advance by the AHJ, as evidenced by the issuance of a new or amended permit. [**1:**1.12.6.12]

B.8.6.13 Permits shall be issued by the AHJ and shall indicate the following:

(1) Operation, activities, or construction for which the permit is issued
(2) Address or location where the operation, activity, or construction is to be conducted
(3) Name, address, and phone number of the permittee
(4) Permit number
(5) Period of validity of the permit
(6) Inspection requirements
(7) Name of the agency authorizing the permit (AHJ)
(8) Date of issuance
(9) Permit conditions as determined by the AHJ

[**1:**1.12.6.13]

Δ **B.8.6.14** Any application for, or acceptance of, any permit requested or issued pursuant to this *Code* shall constitute agreement and consent by the person making the application or accepting the permit to allow the AHJ to enter the premises at any reasonable time to conduct such inspections as required by this *Code*. [**1:**1.12.6.14]

B.8.7 Revocation or Suspension of Permits.

Δ **B.8.7.1** The AHJ shall be permitted to revoke or suspend a permit or approval issued if any violation of this *Code* is found upon inspection or in case any false statements or misrepresentations have been submitted in the application or plans on which the permit or approval was based. [**1:**1.12.7.1]

B.8.7.2 Revocation or suspension shall be constituted when the permittee is duly notified by the AHJ. [**1:**1.12.7.2]

Δ **B.8.7.3** Any person who engages in any business, operation, or occupation, or uses any premises, after the permit issued therefore has been suspended or revoked pursuant to the provisions of this *Code*, and before such suspended permit has been reinstated or a new permit issued, shall be in violation of this *Code*. [**1:**1.12.7.3]

B.8.7.4 Permits shall be required when the amount of GH_2 exceeds 200 ft^3 (5.7 m^3) or LH_2 exceeds 1 gal (3.8 L) inside a building or 60 gal (230 L) outside a building.

B.9 Plan Review.

B.9.1 Where required by the AHJ for new construction, modification, or rehabilitation, construction documents and shop drawings shall be submitted, reviewed, and approved prior to the start of such work as provided in Section B.9. [**1:**1.14.1]

B.9.2 The applicant shall be responsible to ensure that the following conditions are met:

(1) The construction documents include all of the fire protection requirements.
(2) The shop drawings are correct and in compliance with the applicable codes and standards.
(3) The contractor maintains an approved set of construction documents on site. [**1:**1.14.2]

B.9.3 It shall be the responsibility of the AHJ to promulgate rules that cover the following:

(1) Criteria to meet the requirements of Section B.9
(2) Review of documents and construction documents within established time frames for the purpose of acceptance or providing reasons for nonacceptance

[**1:**1.14.3]

Δ **B.9.4** Review and approval by the AHJ shall not relieve the applicant of the responsibility of compliance with this *Code*. [**1:**1.14.4]

B.9.5 Where required by the AHJ, revised construction documents or shop drawings should be prepared and submitted for review and approval to illustrate corrections or modifications necessitated by field conditions or other revisions to approved construction documents.

B.10 Technical Assistance.

B.10.1 The AHJ shall be permitted to require a review by an approved independent third party with expertise in the matter to be reviewed at the submitter's expense.

B.10.2 The independent reviewer shall provide an evaluation and recommend necessary changes of the proposed design, operation, process, or new technology to the AHJ. [**1:**1.15.2]

B.10.3 The AHJ shall be authorized to require design submittals to bear the stamp of a registered design professional. [**1:**1.15.3]

Δ **B.10.4** The AHJ shall make the final determination as to whether the provisions of this *Code* have been met. [**1:**1.15.4]

B.11 Notice of Violations and Penalties.

Δ **B.11.1 Where Required.** Whenever the AHJ determines violations of this *Code*, a written notice shall be issued to confirm such findings. [**1:**1.16.1]

B.11.2 Serving Notice of Violation.

Δ **B.11.2.1** Any order or notice of violation issued pursuant to this *Code* shall be served upon the owner, operator, occupant, registered agent, or other person responsible for the condition or violation by one of the following means:

(1) Personal service
(2) Mail to last known address of the owner, operator, or registered agent

[**1:**1.16.2.1]

B.11.2.2 For unattended or abandoned locations, a copy of such order or notice of violation shall be posted on the premises in a conspicuous place at or near the entrance to such premises, and the order or notice shall be disseminated in accordance with one of the following:

(1) Mailed to the last known address of the owner, occupant, or registered agent
(2) Published in a newspaper of general circulation wherein the property in violation is located

[**1:**1.16.2.2]

B.11.2.3 Refusal of an owner, occupant, operator, or other person responsible for the violation to accept the violation notice shall not be cause to invalidate the violation or the notice of violation. When acceptance of a notice of violation is refused, valid notice shall have deemed to have been served under this section provided the methods of service in B.11.2.1 or B.11.2.2 have been followed. [**1:**1.16.2.3]

Δ **B.11.3 Destruction or Removal of Notice.** The mutilation, destruction, or removal of a posted order or violation notice without authorization by the AHJ shall be a separate violation of this *Code* and punishable by the penalties established by the AHJ. [**1:**1.16.3]

B.11.4 Penalties.

Δ **B.11.4.1** Any person who fails to comply with the provisions of this *Code*, fails to carry out an order made pursuant to this *Code*, or violates any condition attached to a permit, approval, or certificate shall be subject to the penalties established by the AHJ. [**1:**1.16.4.1]

B.11.4.2 Where the AHJ has not adopted a separate penalty schedule, or if state laws or rules do not specify a penalty, violations of this code can be subject to a $100.00 penalty per day for each violation.

B.11.4.3 Failure to comply with the time limits of an order or notice of violation issued by the AHJ can result in each day that the violation continues being regarded as a separate offense and can be subject to a separate penalty.

B.11.4.4 A separate notice of violation should not be required to be served each day for a violation to be deemed a separate offense.

B.11.4.5 Abatement. Where a violation creates an imminent danger, the AHJ is authorized to abate such hazard in accordance with B.5.15. [**1:**1.16.5]

Annex C Sample Ordinance Adopting NFPA 2

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.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 2, *Hydrogen Technologies Code*, 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 NFPA 2, *Hydrogen Technologies Code*, 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 failed 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 or 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 2, *Hydrogen Technologies Code*, 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 D Physical Properties of Hydrogen

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Δ **D.1 Physical Properties (Informative).** 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.

Δ **D.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.

Δ **D.1.2** Hydrogen remains a gas even at high pressures. It is liquefied when cooled to its boiling point of −423°F (−253°C).

Δ **D.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.

Δ **D.2 Physical Properties.** Liquefied hydrogen is transparent, odorless, and not corrosiveor noticeably reactive. The boiling point at atmospheric pressure is −423°F (−253°C). It is only $\frac{1}{14}$ as heavy as water. Liquefied hydrogen converted to gaseous hydrogen at standard conditions expands approximately 850 times.

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Annex E Explanation of Methodology Utilized to Develop Separation Distances

This annex is not part of the requirements of this NFPA document but is included for informational purposes only.

E.1 Separation Distances Tables Methodology History. 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 for the 2010 edition of NFPA 55.

In the 2016 edition of NFPA 2, exposures were grouped in Table 7.4.3.2.3.1.1(A)(a) based upon the rationale for determining the associated hazard, as shown in Table E.1(a) and Table E.1(b). Table E.1(a) is cross-referenced to Table 7.4.3.2.3.1.1(A)(a) by exposure group number and row letter. 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 E.1(b). The performance criteria and design scenarios have been extracted from NFPA 1 as indicated in the extracts provided. [1] For each exposure, the effects of a release 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 in NFPA 1.

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 used to analyze each exposure.

Studies by Houf and Schefer of Sandia National Laboratories (Sandia) 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 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 were then used to determine distances that were believed to be appropriate based on the consequence of a release. The consequence approach is referred to as a deterministic approach because distances are determined based on consequence alone. Another consequence-based approach, found in a project 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 should have a bearing on determining a reasonable level of safety.

The work of the task group integrated the efforts of Sandia's risk and reliability department, as part of the US Department of Energy Hydrogen, Fuel Cells & Infrastructure Technologies Program.

Researchers at Sandia developed benchmark experiments and a defensible analysis strategy for risk and consequence assessment of unintended releases from gaseous hydrogen systems. This work included 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 was incorporated into engineering models that were used for assessment of different hydrogen release scenarios and for input into quantitative risk assessments (QRA) of hydrogen facilities.

The QRAs were 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. [4]

To evaluate risk, the history of leakage data from high-pressure compressed gas systems was needed. Hydrogen-specific leak data were provided by one of the major suppliers through the use of a 5-year documented collection of leak data from both industrial and fueling uses. These data were augmented with data from other sources after being reviewed for applicability, and representative values were selected. The source documents considered in augmentation of hydrogen-specific data included the following publications:

(1) "Determination of Safety Distances," European Industrial Gases Association, IGC Doc 75/07/E, 2007.
(2) A. W. Cox, F. P. Lees, and M. L. Ang, "Classification of Hazardous Locations," Institution of Chemical Engineers, May 2003.
(3) C. H. Blanton and S. A. Eide, "Savannah River Site Generic Data Base Development," WSRC-TR-93-262, Westinghouse Savannah River Company, June 30, 1993.
(4) J. Spouge, "New Generic Leak Frequencies for Process Equipment," *Process Safety Progress* (Vol. 24, No. 4), December 2005.

A hierarchy was developed that gave hydrogen-specific data the highest priority, followed by non-gas-specific data where available for high-pressure components. Piping and instrumentation drawings (P&IDs) were then prepared to define a standard bulk supply system in terms of modules that might be found in the typical system. The P&IDs can be found in A.3.3.95.9.1 of NFPA 55. 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 (i.e., 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 and combined to quantify a probability for failure on a component-by-component basis [e.g., hoses (pigtails), valves, instruments, joints, pipe]. 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. The technical approach and supporting details can be found in the articles listed in Annex H of NFPA 55 and informational articles found in Section I.2 of NFPA 55. The advantage of the Bayesian approach is that it can combine data from different sources to include uncertainty. This approach is contrary to what has been done in other sources. For example, judgment can be used as a means to determine risk; however, that method does not provide for uncertainty. Such methods are qualitative at best. By comparison, the use of specific leak data results in a quantitative approach.

The tables developed for inclusion in Chapter 10 of the 2010 edition of NFPA 55 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 GH_2 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 associated with the operation of a single gasoline station has been reported to be approximately 2E-5/yr. [5] Other key decisions of the group included the parameters given in Sections E.2 through E.5.

E.2 Lower Flammable Limit — 4 Percent H_2 by Volume. In scenarios where the concern is that a plume of unignited GH_2 from a release might reach an ignition source, the separation distance was determined using a computational fluid dynamics (CFD) model to determine the distance required to reduce the GH_2 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.

E.3 Use of 3 Percent of Internal Area as Leak Size. A detailed description of the process used and the results achieved are provided in a technical article included in Annex H of NFPA 55. [6] This process follows guidance by the Fire Protection Research Foundation published in March 2007 that encourages NFPA Technical Committees to use risk concepts in their decision-making process. [7] The risk-informed approach

Table E.1(a) Hazard Scenario

Row	Group 1 Exposures greater of a or b	Hazard Scenario Rationale[c]
(a)	Lot lines	1, 2, 3, 4, 5
(b)	Air intakes (HVAC, compressors, other)	1
(c)	Operable openings in buildings and structures	1, 2
(d)	Ignition sources such as open flames and welding	3, 5
Row	**Group 2 Exposures[d]**	**Hazard Scenario Rationale[c]**
(a)	Exposed persons other than those involved in servicing of the system	4
(b)	Parked cars	4
Row	**Group 3 Exposures[e]**	**Hazard Scenario Rationale[c]**
(a)	Buildings of noncombustible non-fire-rated construction	2
(b)	Buildings of combustible construction	2
(c)	Flammable gas storage systems above or below ground	2
(d)	Hazardous materials storage systems above or below ground	6, 7, 8, 9
(e)	Heavy timber, coal, or other slow-burning combustible solids	2
(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	2
(g)	Unopenable openings in buildings and structures	1, 2
(h)	Encroachment by overhead utilities (horizontal distance from the vertical plane below the nearest overhead electrical wire of building service)	2, 10
(i)	Piping containing other hazardous materials	6, 7, 8, 9
(j)	Flammable gas metering and regulating stations such as natural gas or propane	6, 7, 8, 9

[a]Unignited jet concentration decay distance to 4 percent mole fraction (volume fraction) hydrogen.
[b]Drad – radiation heat flux level of 1577 W/m^2.
[c]See Table E.1(b) of NFPA 55 for explanation of notes.
[d]Drad for heat flux level of 4732 W/m^2 exposure to employees for a maximum of 3 minutes.
[e]The greater of Drad for combustible heat flux level of 20,000 W/m^2 or the visible flame length.

included two considerations: the frequency of hydrogen system leakage and the risk from leakage events.

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.

Δ Table E.1(b) Hazard Scenario Rationale Notes to Table E.1(a) of NFPA 55

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]

(continues)

Δ Table E.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]

E.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, *Pressure Relieving and 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 might 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]

E.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 especially true for large systems typically encountered in commercial applications. Small systems using small-diameter tubing were accounted for by the use of tables that allow the user to calculate the benefit from the use of small-diameter systems.

E.6 Updates to the Separation Distances Tables. Since the publication of the two codes, several hydrogen storage systems have been installed in accordance with the risk-informed separation distances. These recent installations have provided an opportunity to examine how these requirements work in actual project applications. The project applications have been reviewed and found to meet an acceptable level of safety such that conservative assumptions made in the previous analysis could be reexamined. In addition, there was interest from the committees to perform a similar risk-based process to calculate separation distances for liquid bulk hydrogen storage systems. In 2014, the NFPA 2 and NFPA 55 Technical Committees created a task group with the following objectives:

(1) Evaluate the risk criteria used to develop the separation distances for bulk gaseous hydrogen storage and make recommendations for changes in these distances based on the revised criteria.
(2) Develop revised separation distances for bulk liquefied hydrogen storage based on a risk-informed methodology parallel to the process used in the previous update of the gaseous requirements.

Objective 1 is discussed in Section E.7, and objective 2 is discussed in Section E.8.

E.7 Updates to the Gaseous Hydrogen Separation Distance Tables. For each of the exposures listed in Table E.1(a), potential hazard scenarios associated with ignited and unignited hydrogen jets were identified. Harm criteria, including heat flux levels and a 4 percent mole fraction of hydrogen which represents the potential for a flash fire given delayed ignition, were chosen depending on the scenario. Three risk criteria thresholds that were used in the 2010 edition of NFPA 55 were reexamined: lower flammable limit, leak size, and heat flux levels.

Lower Flammable Limit — 8 Percent H_2 by Volume.

The task group reviewed the hydrogen concentration threshold. Based on work done at Sandia National Laboratories Combustion Research Facility, the task group concluded that there would not be sustained ignition at hydrogen concentrations of 8 percent or less. [16] There could be localized hydrogen ignition, but it would not develop into sustained combustion.

Use of 1 Percent of Internal Pipe Diameter (ID) as Leak Size

The cumulative probability for different leak sizes was calculated to determine what range of leaks represents the most likely leak sizes, as discussed in Section E.3. The system leakage frequency corresponds to the largest internal pipe downstream of the highest pressure source in the system. 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, however the risk resulting from this small leak size significantly exceeded the 2 × 10-5/yr risk guideline set by the task group. At the same time, the use of a leak size between 1 percent and 10 percent of the component flow area results in risk estimates that are reasonably close to the risk guideline.

Based on the results of both the system leakage frequency evaluation and the associated risk assessment, the task group decided that adjusting to a diameter of 1 percent value, instead of a 3 percent, would remove excess conservatism from the input assumption to the model. The 1 percent value still accounts for 95 percent of the leakage frequency from the example systems and does not exceed the 2 × 10-5/year risk guideline established in the previous analysis. This results in more permissive separation distance requirements with no change in risk.

Selected Heat Flux Values

The task group reviewed the heat flux values discussed in Section E.4 and determined that the use of a "no harm" criteria was overly conservative. This heat flux assumes exposed persons will not take protective actions, such as moving away from the fire scene. The task group deemed it reasonable to assume that exposed personnel will relocate away from a fire scene within a few minutes and therefore the "no harm" criteria is not appropriate for establishing separation distances. Exposures that were analyzed based on this heat flux value were updated to reflect the harm distance for a radiation heat flux level of 4.7 kW/m^2. The task group decided not to change the three other heat flux values.

Table E.7 shows the revised separation distances for the four storage pressure ranges based on the task group's recommended changes in risk criteria and exposures grouped by the harm criteria that the distance is based upon. The safety distances in the table are rounded to the nearest whole number and a safety factor of 1.5 has been added to the values. The significance of these potential changes can be shown in the high-pressure column for the Group 1 Exposures. The reduction in separation distances from 34 feet to 16 feet for bulk gaseous systems would allow these systems to be placed in more locations, including existing gasoline fueling stations and other space constrained locations.

Δ **E.8 Separation Distances for Bulk Liquefied Hydrogen Storage Based on a Risk-Informed Methodology.** The steps based on a risk-informed methodology are as follows:

(1) Define a representative bulk liquefied hydrogen storage system.
(2) Perform a risk analysis on the system to determine the release scenarios with the highest risk.
(3) Evaluate the risk criteria for each of the highest risk release scenarios by using a scientific model that predicts the extent of specific hydrogen concentrations and heat fluxes.
(4) Acquire leak frequency data from the discharge points from the highest risk release scenarios.
(5) Perform an integrated analysis of releases and leak frequencies to estimate the system separation distances using the risk threshold of 2×10^{-5} fatalities/yr.

The task group decided to use the liquefied hydrogen system described in the Compressed Gas Association, Inc. (CGA) P-28, *OSHA Process Safety Management and EPA Risk Management Plan Guidance Document for Bulk Liquid Hydrogen Systems*, as the representative system. The representative system contains a liquid hydrogen storage tank, a pressure buildup circuit and economizer, vaporizer, and pump. CGA P-28 also contained a representative hazard and operability study (HAZOP) that was performed on the representative bulk liquid hydrogen system. The process was divided into seven segments, called nodes, which were as follows:

(1) Delivery trailer, hose, and fill line to the storage vessel
(2) Storage tank
(3) Pressure buildup circuit and economizer
(4) Hydrogen line — liquid through the vaporizer to the final line
(5) Hydrogen pump
(6) Vent stacks
(7) General items

In CGA P-28, each node was examined based on deviations from normal operating parameters that could have potentially hazardous consequences. The task group started with this division of the system and analyzed each node deviation to come up with event likelihood and hazard severity. Event likelihood was the annual probability that the deviation may occur for each node, with the highest level expecting the deviation to occur once per year or more and the lowest level expected to occur once per 10,000 years, documented in Table E.8(a). Hazard severity classified the consequence from the node deviation. The hazard severity ranged from negligible to catastrophic, documented in Table E.8(b). The task group estimated the event likelihood and severity based on industry experience and subject matter expertise and had to agree with the levels given to each node deviation.

Δ **Table E.7 Updated Values to 2016 NFPA 2 and NFPA 55 Tables with 1.5 Safety Factor**

Exposures		Separation Distance >0.10 to 1.7 MPa (>15 to 250 psig)	>1.7 to 20.7 MPa (>250 to 3000 psig)	>20.7 to 51.7 MPa (>3000 to 7500 psig)	51.7 to 103.4 MPa (7500 to 15000 psig)
Group 1	2010 edition	12 m (40 ft)	14 m (46 ft)	9 m (29 ft)	10 m (34 ft)
	2019 edition	5 m (16 ft)	6 m (20 ft)	4 m (13 ft)	5 m (16 ft)
Group 2	2010 edition	6 m (20 ft)	7 m (24 ft)	4 m (13 ft)	5 m (16 ft)
	2019 edition	5 m (16 ft)	6 m (20 ft)	3 m (10 ft)	4 m (13 ft)
Group 3	2010 edition	5 m (17 ft)	6 m (19 ft)	4 m (12 ft)	4 m (14 ft)
	2019 edition	4 m (13 ft)	5 m (16 ft)	3 m (10 ft)	4 m (13 ft)

Notes:

(1) Group 1 Exposures include: lot lines, air intakes, operable openings in buildings and structures, and ignition sources. Group 1 separation distances are based on the higher value of radiation heat flux of 4.7 kW/m^2 or the unignited jet concentration decay distance of 8percent hydrogen volume fraction concentration. In this instance, the separation distance is higher for the concentration value than the heat flux value.
(2) Group 2 Exposures include parked cars, exposed persons other than those servicing the system. Group 2 separation distances are based on the higher value of the incident radiation heat flux of 4.7 kW/m^2 exposure to employees for a maximum of 3 minutes or the visible flame length.
(3) Group 3 Exposures include everything else (e.g., buildings of combustible construction, ordinary combustibles, openings in buildings and structures, etc.). Group 3 separation distances are based on the higher value of the radiant heat flux for noncombustible equipment of 25.2 kW/m^2 or the visible flame length.

Based on the level of likelihood and severity, the node deviation was given a risk ranking, documented in Figure E.8. A few assumptions were made for this analysis. First, the task group assumed an NFPA 55 and a CGA H-5 code-compliant system. The scenarios would only have a single failure, and cascading failures would not be analyzed. The current setback distances did not provide any credit during this analysis and tornadoes were not included in the natural disaster considerations.

After the task group had prioritized all 102 node deviations, the risk-ranked results were reviewed and discussed. Two scenarios were added, based on feedback from the task group, which analyzed high and normal flow from a trailer vent stack. In total, the task group chose nine scenarios with the highest risk to analyze further. The first six scenarios listed occur during liquid hydrogen (LH_2) transfer operations from a tanker truck to the bulk LH_2 storage tank. The two scenarios that the task group added are included in this list. The other three scenarios occur during normal system operations. For each of the scenarios, the task group decided upon the inputs to liquid hydrogen models and the risk criteria for analysis.

Sandia developed a cryogenic hydrogen integral jet and plume model, called COLDPLUME, which is intended to be used to predict release characteristics from various real-world hydrogen storage states. [17] Sandia is also developing a network flow model that accounts for internal system flows from the storage vessel to the release plane, called NETFLOW, which will be suitable for liquid and multiphase cryogen flows. [18] These models are currently under development and experimental validation. Once modeling results are available, the hydrogen exposure risk criteria used for the bulk gaseous separation distances will be used to develop the new liquid separation distance table. *[See Table E.8(c).]*

N **E.9 Determination of Separation Distances for Bulk Gaseous Hydrogen Systems.** This section is a paper by William Houf and Robert Schefer titled "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).

This paper has been provided for historical reference to how the separation distance tables for bulk gaseous hydrogen systems were calculated.

Table E.8(a) Event Likelihood Classification Table

Level	Annual Probability	Probability Description
1	Frequent > 1.0	Expected to occur once per year or more frequently.
2	Reasonably probable 1.0 to 0.1	Expected to occur once per 10 years.
3	Occasional 0.01 to 0.1	Expected to occur once per 100 years.
4	Remote 0.001 to 0.01	Expected to occur once per 1000 years.
5	Extremely remote 0.0001 to 0.001	Expected to occur once per 10,000 years.
6	Improbable < 0.0001	Expected to occur less than once per 10,000 years. Extremely unlikely to occur.

Table E.8(b) Hazard Severity Classification Table

Level	Description	Potential Consequences
1	Catastrophic	Could cause fatality to nonassociated members of the public
2	Critical	Could cause severe injury to nonassociated members of the public, fatality or serious injury to works of the public, fatality or serious injury to workers of persons conducting business at a refueling site or significant damage to equipment/facilities
3	Marginal	Could cause minor injury, or minor system damage
4	Negligible	Will not result in injury or system damage

N **E.9.1 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 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 percent 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.9.1(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.9.1(a) for that pressure range, then the values listed in the separation distance table can be used, or alternately the formulas at the bottom of the table can 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 the 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.9.1(a).

Table E.8(c) HAZOP Scenarios and Modeling Notes

		HAZOP Number and Description	Modeling Notes	Separation Distance Driver
Release scenarios during liquid transfer to bulk storage tank	1.18	High-flow gaseous hydrogen from trailer vent stack due to venting excess pressure after LH_2 transfer	Sandia's NETFLOW and COLDPLUME models will characterize the temperature and concentration from the trailer vent stack. The task group would like to model an estimate of up to 50 kg of cold, gaseous hydrogen.	
	1.19	Normal flow from trailer vent stack due to venting excess pressure after LH_2 transfer	Sandia's NETFLOW and COLDPLUME models will characterize the temperature and concentration from the trailer vent stack. The task group would like to model an estimate of up to 50 kg of cold, gaseous hydrogen.	Modeling results will be used to calculate separation distance from air intakes and overhead utilities because this is the highest frequency release and the release point is in closest proximity to these exposures.
	1.6	High flow from line rupture, valve or component failure during transfer process	Sandia's NETFLOW and COLDPLUME models will characterize the temperature and concentration from the release to the air. A model is needed to characterize pooling and evaporation effects.	
	1.4	High temperature caused by external fire will cause high flow venting through tank vent stack	Sandia's NETFLOW and COLDPLUME models will characterize the temperature and concentration from the trailer vent stack. This is the worst case venting scenario from the pressure relief device to a high ambient temperature.	
	1.8	Reverse flow during transfer process caused by human error and pressure mismanagement	Sandia's NETFLOW and COLDPLUME models will characterize the temperature and concentration from the release to the air. A model is needed to characterize pooling and evaporation effects.	
	1.16	Loss of containment from external impacts, consider all causes	The task group postulated a vehicle crash into the tanker during transfer. This causes a transfer hose rupture with NETFLOW and COLDPLUME models characterizing the release to the air. A model is needed to characterize pooling and evaporation effects.	
Release scenarios during normal system operation	4.15	Loss of containment from pipe leading from tank to vaporizer or vaporizer itself caused by thermal cycles or ice falling from vaporizers	Sandia's NETFLOW and COLDPLUME models will characterize the temperature and concentration from the release to the air. A model is needed to characterize pooling and evaporation effects.	Modeling results of hydrogen concentration plume and heat flux from a subsequent fire will be used for all other separation distance exposures because this is the highest risk priority during normal operations.
	6.15	Misdirected flow caused by operator error resulting in large low-level release of cold gaseous hydrogen through bottom drain valve of vent stack during normal tank venting process	Sandia's NETFLOW model will capture how much gas is going out of the drain vent and vent stack. Sandia's COLDPLUME model can characterize the temperature and concentrations from the releases to the air. A model is needed to characterize pooling and evaporation effects.	
	2.1	High pressure because of a leak in inner vessel allowing hydrogen into the vacuum area	Sandia's NETFLOW and COLDPLUME models can characterize the flow out of the casing vent (a large hole instead of a pipe orifice).	

		Likelihood					
		1	2	3	4	5	6
Severity	1	1	1	1	2	3	4
	2	1	1	2	3	3	4
	3	2	2	3	3	4	4
	4	4	4	4	4	4	4

1: High risk
2: Moderate risk
3: Low risk
4: Routine risk

FIGURE E.8 Risk Ranking Table.

The formulas are based on performing curve-fits to hazard distance calculations performed over a range of pipe diameters (assuming 3 percent flow area leak) and pressures using the hazard models discussed in Section E.9.2. 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, and 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.9.1(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.

N **Table E.9.1(a) Pressure Ranges for Separation Distances Table and the Associated System Characteristic Pipe Diameter**

Storage Pressure Range		Characteristic Pipe Diameter (I.D.)	
kPa (gauge)	**psig**	**mm**	**in.**
>103 to ≤ 1724	>15 to ≤250	52.50	2.067
>1724 to ≤ 20684	>250 to ≤3000	18.97	0.75
>20684 to ≤ 51711	>3000 to ≤7500	7.92	0.312
>51711 to ≤ 103421	>7500 to ≤15000	7.16	0.282

N **Table E.9.1(b) Hazard Parameters for Separation Distances Tables**

Hydrogen unignited jet	Distance to point where concentration has decayed to 4 percent 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 $Btu/hr \cdot ft^2$)
Hydrogen jet flame	Distance to radiation heat flux level of 4732 W/m^2 (1500 $Btu/hr \cdot ft^2$) 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 $Btu/hr \cdot ft^2$)
Hydrogen jet flame	Distance to non-combustible equipment heat flux level of 25,237 W/m^2 (8000 $Btu/hr \cdot ft^2$)

N **E.9.2 Description of Engineering Hazard Models: Nomenclature.** See Table E.9.2 for specification of the parameters used in engineering hazard models.

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.9.2. The distances of importance 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 nondimensional 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.9.2. 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.

N **E.9.2.1 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 following form:

[E.9.2.1a]

$$X_{rad} = S_{rad} / m_{fuel}\Delta H_c$$

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 following form (Sivathanu and Gore, 1993):

[E.9.2.1b]

$$q_{rad}(x, r) = C^*(x/L_{vis})S_{rad} / 4\pi r^2$$

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* can 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.9.2.1(a) shows typical profiles of C* 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.9.2.1b 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 percent CO/43 percent H_2 mixture. A plot of the radiant fraction data from Turns and Myhr (1991) along with the radiant fraction data for large-scale

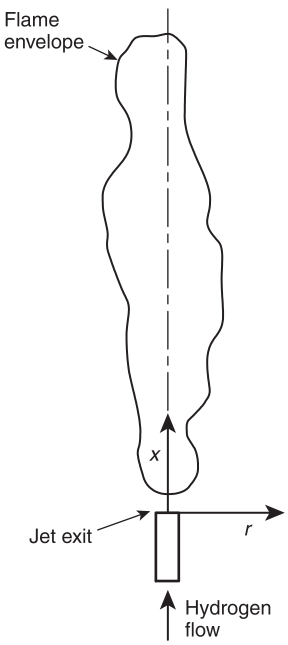
N **Table E.9.2 Parameters Used in Hazard Models**

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
$p\infty$	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 (2390 K)
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

(continues)

N **Table E.9.2** ***Continued***

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
$(\rho_j/\rho\infty)$	Ratio of jet gas density to ambient gas density
$\rho\infty$	Density of the ambient fluid, kg/m^3
$\bar{\eta}$	Volume fraction (mole fraction) along the centerline of the jet
τ_f	Global flame residence time, sec



N **FIGURE E.9.2 Coordinate System for Turbulent Jet Flame and Unignited Jet.**

H_2 flames is shown in Figure E.9.2.1(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 following form:

[E.9.2.1c]

$$\tau_f = \left(\rho_f W_f^2 L_{vis} f_s\right) / \left(3\rho_j d_j^2 u_j\right)$$

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, 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 follows:

[E.9.2.1d]

$$Fr_f = \frac{u_j f_s^{3/2}}{\left(\rho_j / \rho_\infty\right)^{1/4} \left[\frac{\Delta T_f}{T\infty} g d_j\right]^{1/2}}$$

where u_j is the jet exit velocity, f_s is the mass fraction of fuel at stoichiometric conditions, $(\rho_j/\rho\infty)$ 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 $(\rho_j/\rho\infty)$ are included in Fr_f. Further, a non-dimensional flame length, L*, can be defined as follows:

[E.9.2.1e]

$$L^* = \frac{L_{vis} f_s}{d_j \left(\rho_j / \rho\infty\right)^{1/2}} = \frac{L_{vis} f_s}{d^*}$$

where L_{vis} is the visible flame length and d* is the jet momentum diameter. Figure E.9.2.1(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 following expression:

[E.9.2.1f]

$$L^* = \frac{13.5 Fr_f^{2/5}}{\left(1 + 0.07 Fr_f^2\right)^{1/5}} \text{ for } Fr_f < 5$$

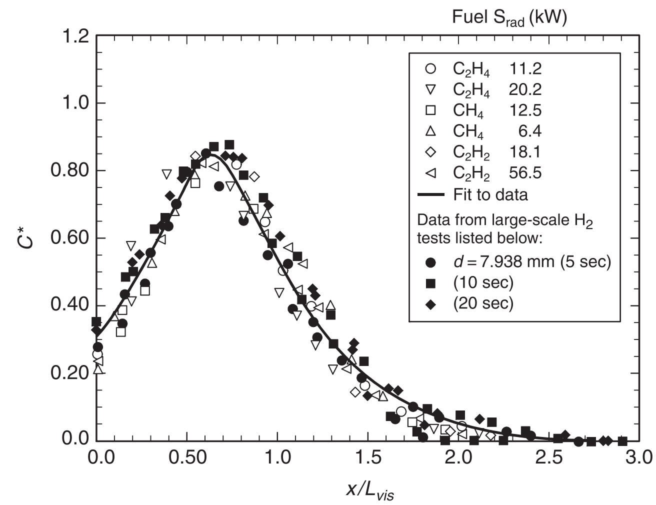
and in the momentum-dominated regime by the following expression:

[E.9.2.1g]

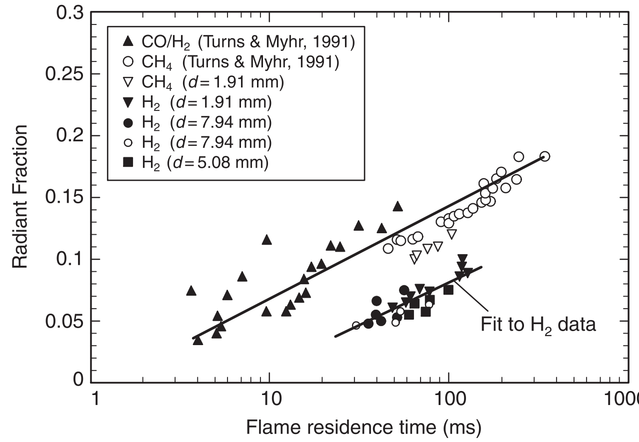
$$L^* = 23 \text{ for } Fr_f > 5$$

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 Equations E.9.2.1f and E.9.2.1g. For choked flow conditions, the concept of a notional expansion and effective source diameter *(see E.9.2.2)* was used to reduce the hydrogen flame length

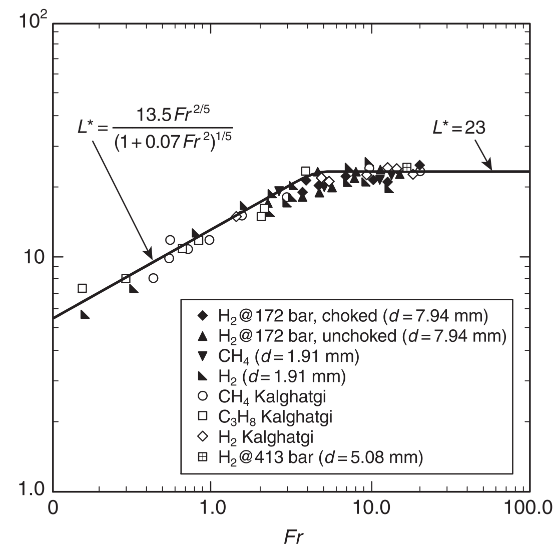
 Shaded text = Revisions. Δ = Text deletions and figure/table revisions. • = Section deletions. N = New material.



N **FIGURE E.9.2.1(a) Axial Variation of Normalized Radiative Heat Flux.**



N **FIGURE E.9.2.1(b) Radiant Fraction as a Function of Flame Residence Time (Lab H_2 Flame Data for Diameters of 1.905 mm and 3.75 mm, Large-Scale H_2 Flame Test Data at Diameter of 7.94 mm).**



N **FIGURE E.9.2.1(c) Variation of Dimensionless Visible Flame Length with Flame Froude Number.**

measurements for plotting in terms of L* in Figure E.9.2.1(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 Equations E.9.2.1f and E.9.2.1g.

If the jet exit velocity and density of a hydrogen flame are known, then Equation E.9.2.1d can be used to calculate the flame Froude number and Equation E.9.2.1e and both Equation E.9.2.1f and Equation E.9.2.1g 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 $W_f = 0.17L_{vis}$ and used in Equation E.9.2.1c 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.9.2.1(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.9.2.1(a), Equation E.9.2.1b can be used to compute the radiant heat flux from the hydrogen flame at any axial position, x, and radial position r.

N **E.9.2.2 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.9.2. 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, η_{cl}, (or mean mole fraction) along the centerline of the jet is given by an expression of the following form:

[E.9.2.2a]

$$\eta_{cl}(x) = \frac{Kd_j}{x + x_o}\left(\frac{\rho\infty}{\rho_{gas}}\right)^{1/2}$$

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., Equation E.9.2.2a) 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 as follows:

[E.9.2.2b]

$$d_{eff} = \left(\frac{\rho_j u_j}{\rho_{gas} u_{eff}} \right)^{1/2} d_j$$

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 following form:

[E.9.2.2c]

$$u_{eff} = u_j + \left(P_j - P\infty \right) / \left(\rho_j u_j \right)$$

where p_j is the jet exit pressure and $p\infty$ is the ambient pressure. Equations E.9.2.2b and E.9.2.2c 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 Equation E.9.2.2a and centerline concentration decay equation becomes the following:

[E.9.2.2d]

$$\eta_{cl}(x) = \frac{K d_{eff}}{x + x_o} \left(\frac{\rho\infty}{\rho_{gas}} \right)^{1/2}$$

At each axial position, x, the radial variation of the concentration is computed from the following expression:

[E.9.2.2e]

$$\eta(x, r) = \eta_{cl}(x) e^{-K_c (r/x + x_o)^2}$$

where the value of K_c = 57 for a round jet (Chen and Rodi, 1980). Equations E.9.2.2b, E.9.2.2c, E.9.2.2d, and E.9.2.2e 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).

N **E.9.3 Comparison of Models with Experimental Data.**

N **E.9.3.1 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 following form:

[E.9.3.1]

$$p = \frac{\rho R_{H_2} T}{(1 - b\rho)}$$

where the values of R_{H2} = 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.9.3.1(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 percent scatter occurs in the data around the L* correlation *[see Figure E.9.2.1(c)]* used in the model, an uncertainty analysis was performed where the L* correlation was increased and then decreased by 10 percent from its nominal value. Calculations are shown in Figure E.9.3.1(a) for the nominal L* correlation, and an increase in L* of 10 percent and a decrease in L* of –10 percent. Predictions from the model are found to be in good agreement with the measured hydrogen flame lengths.

Figure E.9.3.1(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 percent scatter occurs in the data around the L* correlation *[see Figure E.9.2.1(c)]*, the C* correlation *[see Figure E.9.2.1(a)]*, and the radiant fraction correlation *[see Figure E.9.2.1(b)]*, X_{rad}. Hence, an uncertainty analysis was performed where model calculations were performed with the nominal values of these correla-