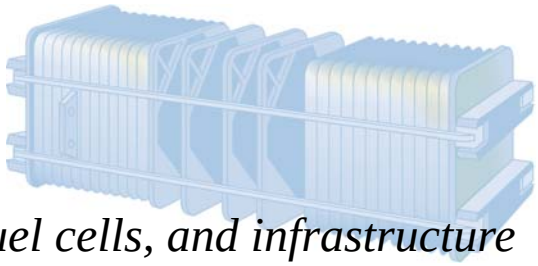
U.S. Department of Energy
Energy Efficiency and Renewable Energy

Module 2

Permitting Hydrogen Motor Fuel Dispensing Facilities



hydrogen, fuel cells, and infrastructure

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Contents

Module 2: Permitting Hydrogen Motor Fuel Dispensing Facilities

1.0 Introduction

1.1 Purpose

The purpose of this module is to guide permitting officials, code enforcement officials, and other parties involved in approving the implementation of hydrogen motor fuel dispensing facilities. The module facilitates the identification of

- the issues to be addressed in the permitting of a project as it progresses through the approval process
- the specific requirements associated with those issues
- the applicable (or potentially applicable) codes and standards by which to determine whether the specific requirements have been met.

In this module, a *hydrogen motor fuel dispensing facility* is a service station for 1) receiving hydrogen produced offsite and delivered to the station; 2) long-term storage of liquid hydrogen or compressed hydrogen gas or both; and 3) dispensing hydrogen (as a gas or liquid) to fuel cell vehicles and vehicles with hydrogen-powered internal combustion engines. Such a facility is analogous to a gasoline service station but stores and dispenses hydrogen (instead of gasoline and diesel fuel) to cars, buses, and trucks.

The module attempts to identify all applicable codes and standards relevant to the permitting requirements, regardless of the organizations that formulated them. Consequently, the codes and standards articulated include those formulated by the organizations such as the

- International Code Council (ICC)
- National Fire Protection Association (NFPA)
- American Society of Mechanical Engineers (ASME)
- Compressed Gas Association (CGA).

1.2 Background

Widespread market acceptance and penetration of vehicles that use hydrogen for fuel—whether fuel cell vehicles or vehicles with internal combustion engines—will eventually require hydrogen fueling stations. Just as there currently are corner gasoline stations, there will be a need for corner hydrogen fueling stations (or stations that provide both gasoline and hydrogen).

In the United States, only a small number of hydrogen fueling stations currently exist. Most were established to support demonstration or experimental hydrogen-powered vehicle projects. Because these stations are first-of-a-kind, they generally are overdesigned with respect to human health, safety, and fire prevention issues.

However, as automakers gear up to market fuel cell vehicles to American consumers (both to individuals and to fleet vehicle operators), the hydrogen and petroleum industries are gearing up to construct hydrogen fueling stations to service these vehicles.

As hydrogen fueling station projects are proposed, the building code and fire safety officials faced with having to permit them will require a good understanding of the issues that must be considered and the codes and standards that should be applied in the permitting process.

1.3 Structure of This Module

Section 2 provides a brief description of the basic installation of a stationary hydrogen motor fuel dispensing station that receives and stores liquid hydrogen, vaporizes the hydrogen and compresses it, and then dispenses hydrogen gas into vehicles.

Section 3 presents an overview of the safety requirements that a hydrogen fueling facility should meet, based on the lessons learned and experience gained from existing projects.

Section 4 provides the requirements for the systems, components, and other entities comprising a hydrogen motor fuel dispensing station. The information is intended to help enforcement officials develop permit conditions specifically for a hydrogen fueling facility.

Section 5 presents a case study with detailed but non-technical descriptions of representative hydrogen fueling facilities already in operation in the United States.

Specifically excluded from this edition of the module are

- new hydrogen motor fuel dispensing facilities where the hydrogen is produced onsite (e.g., by natural gas reforming or the electrolysis of water)
- hydrogen motor fuel dispensing facilities retrofitted into existing gasoline and/or compressed natural gas fueling stations
- multifuel fueling facilities where hydrogen and other fuels (e.g., compressed natural gas) are dispensed from the same fueling island
- service and repair facilities for hydrogen-fuel vehicles.

These types of facilities will be addressed in future versions of this module.

2.0 Hydrogen Motor Fuel Dispensing Facility Basics

Figure 2.1 shows the basic installation of a stationary hydrogen motor fuel dispensing facility that receives and stores liquid hydrogen, vaporizes the hydrogen and compresses it, and then dispenses hydrogen gas into vehicles at 3,600 to 5,000 psi. The basic elements of the installation include liquid hydrogen storage tanks (liquid hydrogen delivered to the site); cryogenic hydrogen compressors for high-pressure hydrogen supply; vaporizers; and gaseous high-pressure storage tanks.

Table 2.1 lists the physical properties of hydrogen and natural gas.

For hydrogen fueling to take place, several steps are required:

1. The hydrogen must be transported to the fueling station. Although hydrogen could be produced onsite, this module does not deal with onsite production. Fuel cell sites covered by this manual will have the fuel delivered to the site in some manner (truck, train or pipeline).

2. The hydrogen is stored onsite. The hydrogen can be stored as either a gas or liquid on the dispensing facility site.

3. The hydrogen is converted to its final form. The storage of the hydrogen may be in a different form than required for the final distribution and may be converted onsite. In the case study (included in this module), the fuel is converted from liquid to gas for final distribution to the vehicles.

4. The hydrogen is distributed to vehicles.

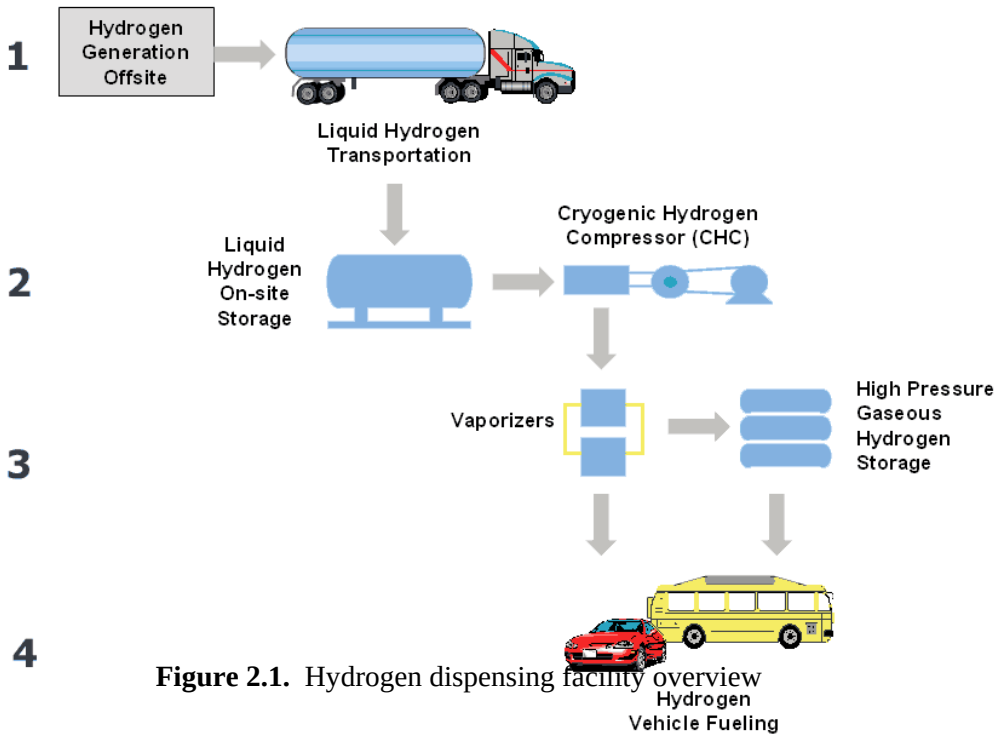

Figure 2.1. Hydrogen dispensing facility overview

Table 2.1. Properties of Hydrogen and Natural Gas

Property	Natural Gas	Hydrogen
Color	None	None
Specific gravity (air = 1)	0.424	0.07
Flammability range in air (%)	5.3 to 15	4 to 74
Ignition energy (millijoules)	0.29	0.02
Flame temperature (C^o)	2148	2050
Diffusion coefficient (cm^3/s)	0.15	0.61
Heat value (kJ/kg)	50,020	119,972
Energy density (MJ/nm^3)	35.882	10.783
See **Hydrogen Basics** section in **Overview**.		

3.0 Hydrogen Motor Fuel Dispensing Facility Requirements

The basic system components and the requirements that would apply to facilities for dispensing hydrogen motor fuel are summarized in this section. Two objectives underlie the various safety requirements described:

1. to reduce the probability of a release of hydrogen
2. to reduce the probability of an accident if there were a release.

Component and system materials requirements and piping requirements prevent unintended hydrogen releases. System separation distance requirements reduce the probability and severity of accidents.

For construction permitting, the requirements are organized so that they follow the chronological order of events involved in constructing a facility. The requirements for an operating permit are organized to follow, to the extent possible, the flow of hydrogen (whether as a liquid or gas) through the fueling process.

This organizational structure may not match the sequence for inspecting the system components. The same requirements are not listed in both the construction and operating sections. For example, the electrical requirements for classified areas would be found under the construction requirements. This arrangement is based on the assumption (for this version of the module) that the facility is new and does not involve retrofitting an existing gasoline or compressed natural gas fueling station to include hydrogen.

3.1 Construction Requirements for Gaseous Hydrogen Storage

Construction requirements for hydrogen motor fuel dispensing facilities fall into one of three categories:

1. site selection and system siting
2. storage system
3. dispensing system.

3.1.1 Site Selection and System Siting

Requirements for system siting should include a review of zoning requirements, review of method for transport of hydrogen to the site, and review of method for transfer of hydrogen from a transport vehicle or pipeline to the site storage system. Because hydrogen is classified as a hazardous material by the U.S. Department of Transportation (DOT), hazardous material storage and transportation requirements will apply. Hydrogen will be transported to the site (onsite production is not addressed in this module), so there must be a route to the site that does not restrict hydrogen shipment. It is also very important that prospective permit applicants meet with enforcement officials as soon as possible to address any special concerns relating to the proposed project location.

There also must be sufficient room at the site for a truck or other vehicle to unload. Buildings at the site must be positioned so that separation distance requirements are met. For example, whether the permitting official uses the ICC International Fire Code (IFC) or NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites 1999 Edition* in the permitting process, both sources require that gaseous hydrogen storage systems maintain certain separation distances from various exposures such as openings in nearby buildings.

3.1.2 Storage System

The storage system consists of five types of components:

- storage container
- connectors
- piping
- vents
- controlling devices.

Examples of *controlling devices* include regulators to control volumetric flow rate in piping and ventilation for systems located inside buildings. All five of these component types are addressed in the International Fire Code (IFC), International Fuel Gas Code (IFGC), and NFPA 50A.

3.1.3 Dispensing System

The IFC has generic requirements for hydrogen and motor fuel dispensing, while NFPA 52, *Compressed Natural Gas (CNG) Vehicular Fuel Systems Code 2002 Edition*, gives requirements for CNG dispensing that have been applied to hydrogen dispensing. When the 2005 edition is issued, NFPA 52 will explicitly include hydrogen dispensing requirements. Hydrogen and natural gas have some similarities and some differences. It is important when using the requirements in NFPA 52 to consider how hydrogen differs from natural gas. However, most of the requirements are sufficiently generic that they could be applied to a hydrogen fueling system.

All components for the dispensing system must be listed for use with hydrogen, and any electrical equipment in the dispensing area must meet the requirements of the National Electric Code®. NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas 1997 Edition*, gives guidance on determining the electrical classification for an area and what equipment must be used in the area.

Safety interlocks are an important part of the dispensing system. The system must be constructed so that it will shut down to prevent overfilling or in the event of an accidental release.

3.2 Construction Requirements for Liquefied Hydrogen Storage

Both the IFC and NFPA 50B, *Standard for Liquefied Hydrogen Systems at Consumer Sites 1999 Edition*, give requirements for a liquefied hydrogen storage system. The schematic in Figure 2.1 for a generic dispensing facility includes both liquid hydrogen storage and gaseous hydrogen storage. Because the density of gaseous hydrogen is low, most stations to be constructed in the near term will include both liquid and gaseous storage.

The construction requirements for a liquefied hydrogen storage system are similar to those for a gaseous hydrogen storage system. However, because the density of liquid hydrogen is so much greater than that of gaseous hydrogen, the separation distances between liquid hydrogen storage systems and exposures are much larger. For example, based on NFPA 50A, a gaseous storage system in excess of 15,000 standard cubic feet must be at least 25 feet from an adjacent structure not having a sprinkler system. However, for a liquid system, based on NFPA 50B, this separation distance would have to be 75 feet. These distance requirements are being developed and verified, so changes to the specific distances may occur in the future.

3.3 Operating Requirements for a Hydrogen Motor Fuel Dispensing Facility

Typically, after a construction permit is issued defining construction conditions, an operating permit is issued to allow the facility to operate—the permit articulates conditions for safe operation. The conditions of the operating permit will also contain requirements for data collection and recordkeeping to give the inspector information to show that the facility has been operating safely on an ongoing basis. This information could be in the form of maintenance records, worker training records, operational data such as system pressure readings, or other information to show that the facility is meeting the safety conditions in its permit.

Several elements are part of operational safety. They can include

1. an emergency response plan
2. written operating procedures
3. staff training
4. equipment maintenance
5. ongoing documentation of safety checks
6. compliance records.

An emergency response plan is required because a facility must operate safely in routine and upset conditions. Written operating procedures help operating personnel perform tasks correctly and consistently, according to established standards. It is important that different workers not perform operations differently. These variations increase the probability of accidents and reduce the system reliability.

Staff training, reinforced by written operating procedures, is the means to ensure that operating personnel perform tasks correctly. It is important that staff be involved in developing and modifying operating procedures to ensure that they are usable. Equipment must be maintained according to the manufacturers' recommendations, and documentation of maintenance and safety checks must be maintained.

4.0 Codes and Standards Affecting Design, Installation, and Operation of a Hydrogen Motor Fuel Dispensing Facility

4.1 Overview

This section focuses on codes and standards (building regulations) that affect the design, installation, and operation of a hydrogen motor fuel dispensing facility and will therefore have an impact on its suitability for service to the public. The purpose of this section is to provide regulators, manufacturers, and designers some insight into the requirements that will need to be satisfied to deploy the technology and to provide code officials with a focus on the issues and criteria that will be relevant to them in considering and approving the technology.

4.2 Codes and Standards Tables

The applicable codes and standards identified in Table 4.1 provide a general guide to the regulations affecting the design of hydrogen motor fuel dispensing stations. More detail on the exact provisions for specific issues is provided in Table 4.2.

Table 4.1. Applicable Codes and Standards

Title of Code/Standard	Contact
ASME Boiler and Pressure Vessel Code (BPVC) Establishes rules of safety governing the design, fabrication, and inspection of boilers, pressure vessels, and nuclear power plant components during construction.	ASME
ASME B31.3 (2002) Process Piping Sets forth engineering requirements for the safe design and construction of piping installations typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals.	ASME
CGA C-7 (2000) Guide to Preparation of Precautionary Labeling and Marking of Compressed Gas Containers Covers use of precautionary labels to warn of principal hazards. Includes general principles and illustrative labels for several types of gases.	CGA
CGA G-5 (2002) Hydrogen Physical Properties Includes the physical properties and how hydrogen is made, used, contained and transported. CGA G-5 complements G-5.4 and G-5.5 to ensure safe and effective hydrogen installations.	CGA

Table 4.1. Applicable Codes and Standards (contd)

Title of Code/Standard	Contact
CGA G-5.4 (2001) Standard for Hydrogen Piping Systems at Consumer Locations Guides engineers, designers, and maintenance personnel through materials and components selection to install a safe and effective hydrogen supply system at consumer sites.	CGA
CGA G-5.5 (1996) Hydrogen Vent Systems Presents design guidelines for hydrogen vent systems for gaseous and liquid hydrogen installations at consumer sites, and provides recommendations for their safe operation.	CGA
CGA S-1.1 (1994) Pressure Relief Device Standards-Part 1-Cylinders for Compressed Gases Specifies requirements for pressure relief devices on DOT cylinders for compressed gases. Describes the various types of pressure relief devices, their limitations, design considerations, maintenance, testing, and application for various gases.	CGA
CGA S-1.2 (1995) Pressure Relief Device Standards-Part 2-Cargo and Portable Tanks for Compressed Gases Specifies minimum recommended requirements for pressure relief devices for use on cargo tanks (tank trucks) and portable tanks (skid tanks) designed to DOT specifications. Requirements are recommended for application to cargo and portable tanks that do not come within DOT or Canada Transport (TC) jurisdiction. Includes information on application, design, construction, testing, and maintenance of pressure relief devices.	CGA
CGA S-1.3 (1995) Pressure Relief Device Standards-Part 3-Stationary Storage Containers for Compressed Gases States the minimum recommended requirements for pressure relief devices for storage containers constructed in accordance with the ASME or API/ASME codes. Includes information on application, design, construction, testing, and maintenance for pressure relief devices.	CGA
ANSI/CSA NGV2 (2000) Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers Presents requirements for the material, design, manufacture, and testing of serially produced, refillable Type NGV2 containers intended only for the storage of compressed natural gas for vehicle operation. These containers are to be permanently attached to the vehicle. Type NGV2 containers shall not be over 1000 liters (35.4 cubic feet) water capacity.	CSA
DOTn 49 CFR, Parts 171-180 Regulations for Transportation Equipment and the Transport of Hazardous Materials Regulations related to transportation equipment and the transport of hydrogen are found in the various parts of Subtitle B, Chapter I, Subchapters A, B, and C in the various Parts cited.	DOTn

Table 4.1. Applicable Codes and Standards (contd)

Title of Code/Standard	Contact
2003 International Building Code (IBC) Establishes minimum requirements to safeguard public health, safety, and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment.	ICC
2003 ICC Electrical Code™ (ICC EC) Establishes administrative provisions that govern the design and construction of electrical systems and equipment. The electrical design and construction requirements of the International Residential Code or NFPA 70 are referred to as applicable therein.	ICC
2003 International Fire Code (IFC) Establishes minimum requirements consistent with nationally recognized good practice for providing a reasonable level of safety and property protection from the hazards of fire, explosion, or dangerous conditions in new and existing buildings, structures, and premises.	ICC
2003 International Fuel Gas Code (IFGC) Regulates the design, construction, installation, quality of materials, location, operation, and maintenance or use of fuel gas systems.	ICC
2003 International Mechanical Code (IMC) Regulates the design, construction, installation, quality of materials, location, operation, and maintenance of use of mechanical systems.	ICC
2003 International Residential Code (IRC) Provides minimum requirements for the construction, alteration, movement, replacement, repair, and equipment of one- and two-family dwellings and townhouses not more than three stories in height.	ICC
2002 National Electric Code (NFPA 70) Provides requirements for the inspection, design, review, alteration, modification, construction, maintenance, and testing of electrical systems and equipment, including electrical installations at special events.	NFPA
2003 NFPA 30A – Motor Fuel-Dispensing Facilities and Repair Garages Regulates the design, construction, maintenance, and testing of automotive and marine service stations, service stations located inside buildings, and fleet vehicle service stations.	NFPA

Table 4.1. Applicable Codes and Standards (contd)

Title of Code/Standard	Contact
1999 NFPA 50A – Gaseous Hydrogen Systems at Consumer Sites Covers the general principles recommended for the installation of gaseous hydrogen systems on consumer premises where the hydrogen supply to the consumer premises originates outside the consumer premises and is delivered by mobile equipment. 1999 NFPA 50B – Liquefied Hydrogen Systems at Consumer Sites Covers the general principles recommended for the installation of liquefied hydrogen systems on consumer premises where the liquid hydrogen supply to the consumer premises originates outside the consumer premises and is delivered by mobile equipment. (NFPA 50A and 50B will be combined in NFPA 55 in the next edition)	NFPA
2002 NFPA 52 – Compressed Natural Gas (CNG) Vehicular Fuel Systems Applies to the design and installation of CNG engine fuel systems on vehicles of all types, including a) original equipment manufacturers, b) vehicle converters, and c) vehicle fueling (dispensing) systems.	NFPA
2002 NFPA 54 - National Fuel Gas Code Natural Gas Systems Applies to the installation of fuel gas piping systems, fuel gas utilization equipment, and related accessories.	NFPA
2003 NFPA 5000 Building Construction and Safety Code Applies to the construction, protection, and occupancy features necessary to minimize danger to life and property.	NFPA
2003 NFPA 1 Uniform Fire Code Prescribes minimum requirements necessary to establish a reasonable level of fire and life safety and property protection from the hazards created by fire, explosion, and dangerous conditions.	NFPA
ASME = ASME International, Three Park Avenue, New York, NY 10016, 800-843-2763 or (973) 882-1167, www.asme.org **CGA** = Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151, (703) 788-2700, www.cganet.com **ICC** = International Code Council, Inc. 5203 Leesburg Pike, Suite 600, Falls Church, VA 22041, (703) 931-4533, www.iccsafe.org **NFPA** = National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269-9101 (800) 344-3555, www.nfpa.org **DOTn** = U.S. Department of Transportation, Research & Special Programs Administration, Office of Hazardous Materials Safety, 400 7th Street, SW, Washington, DC 20590, (800) 467-4922, http://hazmat.dot.gov	

Table 4.2 provides a listing of the codes and standards that affect the design, installation, and operation of a hydrogen motor fuel dispensing facility for service to the public. This table is designed as a reference for enforcement personnel to determine the codes and/or standards that govern the design, testing, and certification of the fuel dispensing and storage equipment itself, as well as the codes and standards that cover the installation and siting of the facility and its fuel dispensing and storage equipment. The data in Table 4.2 can be used also by the design and engineering community to determine how to document compliance with the various codes and standards.

Table 4.2 is subdivided into five key sections that correspond to different aspects of a hydrogen motor fuel dispensing station:

1. **Fuel Supply and Storage** – Addresses either onsite storage in a storage vessel (e.g., hydrogen) or offsite storage and delivery of the fuel to the site via a piping system (e.g., natural gas) for onsite hydrogen generation.
   1.1. General
   1.2. Gaseous Hydrogen Storage
   1.3. Liquefied Hydrogen Storage

2. **General Station Siting Issues** – Addresses siting of the fuel dispensing station outdoors and indoors.
   2.1. General
   2.2. Outdoor Installations (not located within a building or structure; not enclosed by surrounding wall or roof construction; open to the outside environment)
   2.3. Indoor Installations (within a building or structure; enclosed by surrounding wall or roof construction; not open to the outside atmosphere)

3. **Fueling Station Piping and Equipment** – Provides codes and standards for the design of the piping and venting systems, compressors, pressure relief devices, shutoff valves, dispensing and electrical systems (e.g., those used for testing and listing the equipment).
   3.1. General
   3.2. Piping, Tubing and Fittings
   3.3. Pressure Relief Devices
   3.4. Vent Systems
   3.5. Vaporizers
   3.6. Compressors and Dispensing Equipment

4. **Fire Protection** – Addresses fire protection issues as they relate to the fuel dispensing station, including required safety precautions, fire protection systems, emergency shutdown equipment and controls.
   4.1.1.Type of Construction
   4.1.2.Fire Protection Systems
   4.1.3.Additional Safety Precautions, Emergency Shutdown Equipment and Controls

5. Operating and Maintenance – Addresses operational permitting, training for staff, dispensing operations, tank filling and vehicular movement onsite, equipment maintenance, fire extinguishers and signage.
   5.1. General
   5.2. Dispensing Requirements
   5.3. Operational Requirements.

Enforcement personnel can use the information in Table 4.2 during preliminary review of a hydrogen motor fuel dispensing facility to verify that each of the applicable provisions has been met. The number designated within Table 4.2 represents a major section heading within a code/standard or group of related codes/standards that covers a topic (e.g., Section 6.1, General). Please be aware that further subsections may be associated with each major section (e.g., Section 6.1.1) and further review by the user will be necessary.

The following information is included in Table 4.2:

- **Issue** – A generic description of the provision or specific title used in the code/standard.

- **Requirement Description** – A brief description of each of the primary code provisions is provided to give the user an overview of the code text.

- **What To Look For –** Guidance is provided to enforcement personnel on what to review for a hydrogen motor fuel dispensing facility submittal. The description includes the documentation that should be submitted (e.g., a label or listing) and where the information should be included in the plans or specifications.

- **Code/Standard** – The requisite code or standard that affects the design, installation, equipment specification or operation of the hydrogen motor fuel dispensing facility is listed in abbreviated form.

As technology evolves, so do codes and standards. This module was written based on information available at a specific point in time, so readers should be aware that codes and standards covered herein may have been revised and/or a new version of this document created. It is highly recommended that the user verify that the latest editions of this document and, more importantly, the relevant codes and standards are being used. In terms of systems design, it is suggested that manufacturers become involved in the codes and standards development process and, to the degree possible, remain aware not only of currently published documents but also of ongoing revisions and new documents under development.

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities

Issue	Requirement Description	What To Look For	Code/Standard
1.0 Fuel Supply and Storage			
1.1 General			
Identification and labeling of storage containers	Portable gaseous hydrogen containers and manifold gaseous hydrogen supply units shall be marked with the name "***HYDROGEN"*** or a legend such as "***This unit contains hydrogen"*** in accordance with CGA. Stationary liquefied hydrogen containers shall be marked as follows: ***LIQUEFIED HYDROGEN — FLAMMABLE GAS*** and in accordance with ASME BPVC.	Confirm marking of portable containers. For stationary, verify permanent nameplate information as follows: manufacturing specification, maximum allowable working pressure. The nameplate is intended to avoid any confusion about the operating pressures and materials being stored.	ASME BPVC CGA C-7 – §6.2.3, §6.6.3 CGA G-5 – §4.1, §4.2.5 IFC – §2703.2.4.2.1, §2703.5 §3003.2, §3203.4 NFPA 50A – §2-1.3, §2-5 NFPA 50B – §2-1.3
Charging of cylinders	Provides limitations such that cylinders are not charged in excess of the design pressure at the normal temperature. Protection from temperature extremes is also described.	DOT, Canada Transport (TC), and CSA NGV2 shall be charged as applicable. Other rules apply.	CGA G-5 – §6 CSA NGV2 IFC – §3003.5.4, §3003.5.6, §3005.7, §3503.1.2 NFPA 52 – §4-14.
Material-specific regulations	Indoor and outdoor use of flammable gases and cryogenic fluids shall comply with the appropriate material-specific provisions of the applicable fire code.	Consult and review material-specific provisions.	CGA G-5 – §2 IFC – §3005.9, §32, §3205.2, §35 IFGC – §705, §705.3 NFPA 195 NFPA 52

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Structural support	Permanently installed containers must be provided with substantial supports, constructed of noncombustible material securely anchored to firm foundations of noncombustible material. Compressed gas containers, cylinders, tanks, and systems shall be secured against accidental dislodgement.	Confirm supports are of noncombustible material. NFPA protects liquid container supports exceeding 18 inches (46 centimeters) in height with a 2-hour fire resistance rating.	IFC – §3003.3 NFPA 50A – §2-1.2, §2-4.5 NFPA 50B – §2-1.2
Distances from outdoor storage areas to exposures	Covers minimum separation distances (in feet) between storage equipment and features and a series of specified outdoor exposures. Other rules apply (see Sections 2.1 and 2.2).	Consult the separation distance charts as applicable. During plan review and field inspection, confirm the separation distances from various exposures.	IFC – §2209.3.1, T2209.3.1, Liq: §3203.6.1, T3203.6.1 Gas: §3504.2.1, T3504.2.1 NFPA 50A – §3-2, T3-2.1, T3-2.2 NFPA 50B – §3-2, T3-2.1, T3-2.2
Shutoff valves	A shutoff valve is required for containers and piping to equipment.	Verify the presence and operability of this shutoff device.	IFC – §2209.5.1 IFGC – §704.1.2.5 CGA G-5.4 §4
Electrical equipment and wiring	Fixed electrical equipment and wiring shall be installed in accordance with the applicable electrical code. Classified areas are defined in the applicable table.	Verify that electrical equipment, connections, and wiring compliance assessment are in accordance with NFPA 70. Classified areas may be reduced or eliminated as approved and by positive pressure ventilation in accordance with NFPA.	NFPA 50A – §4-1.2, §4-2.5 NFPA 50B – §4-12, T4-12 NFPA 70 – §501 NFPA 496: Standard for Purged and Pressurized Enclosures for Electrical Equipment

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Protection from impact	Guard posts or other approved means shall be provided to protect storage tanks and connected piping, valves, and fittings; dispensing areas; and use areas subject to vehicular damage. Container valves shall be protected from physical damage.	Confirm the presence and suitability of protection. The design of vehicle barrier systems shall be in accordance with the building code (as applicable). Confirm the presence of protective caps, collars, or similar devices for containers.	IFC – §2703.9.3, §2209.5.2, §3003.3, §3003.4, §3203.5, §3503.1.2 IFGC – §707.1 NFPA 50A – § 2-4.3
Security and access by authorized personnel	Areas used for the storage, use, and handling of compressed gas containers, cylinders, tanks, and systems shall be secured against unauthorized entry and safeguarded in an approved manner.	Evaluate access to equipment, valves, devices, etc., for maintenance. Safeguards shall protect operational controls and mechanisms from unauthorized operation. Inspect the storage site such that it is fenced and posted to prevent entrance by unauthorized personnel.	IFC – §2703.9.2, §3003.3, §3203.5 IFGC – §707.1 NFPA 50A – §2-4.3 NFPA 50B – §3-1.4
Containers	Hydrogen storage containers shall be designed, constructed, and tested in accordance with applicable requirements of the ASME Boiler and Pressure Vessel Code and Federal DOT regulations.	Hydrogen must be stored in containers allowed for service with hydrogen. The ASME container should have a nameplate, and DOT cylinders should be stamped.	ASME BPVC, §VIII CGA G-5 – §4.1, §5, §7 DOTn 49 CFR 171-190 IFC — §2703.2, §3503.1.2 NFPA 50A – §2-1
Cargo tanks (tank trucks) and portable tanks (skid tanks) designed to DOT specifications	Each mobile hydrogen supply unit used as part of a hydrogen system must be secured to prevent movement.	Inspect for wheel blocks and potential equipment shifting.	NFPA 50A — §2-4.5

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
1.2 Gaseous Hydrogen Storage			
Separation from hazardous conditions	Aboveground storage of flammable and combustible liquids or liquefied oxygen shall be located on ground higher than the hydrogen storage, except where diking, diversion curbs, grading, or a separating solid wall is provided to prevent liquids accumulation within 50 feet (15.2 meters) of the hydrogen container. Other hazardous conditions that pose exposure hazards also are addressed.	Separations from combustible waste, ledges and platforms, falling objects, and exposure to artificially created temperature extremes shall be evaluated during site inspection.	IFC – §2703.9.8, §3003.5, §3003.5, §3503.1.2 NFPA 50A – §3-1.4
Pressure relief devices (PRD)	Covers PRD requirements related to accessibility for maintenance, general sizing, installation, and device integrity.	See Section 3.3 for specific PRD requirements.	CGA G-5.4 – §4.3.1 IFC – §35 IFGC – §703.3 NFPA 50A – §2-2
Bonding and grounding	Stationary containers and mobile hydrogen supply units shall be electrically bonded to the facility before discharging hydrogen. Reference NFPA 70 – §250.90 for general bonding, §250.100 for bonding in hazardous locations and 250.104 (B) for bonding of "other metal piping." See also Section 3.1.	Bonding to eliminate ignition sources.	CGA G5.4 – §6.5 IFC – §2703.9.5, §3406.7 IFGC – §703.6, §704.4 NFPA 50A – §2-4.6 NFPA 70 – §250.90, §250.100, §250.104 API RP 2003: Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
1.3 Liquefied Hydrogen Storage			
Notices and placards	Sites shall be placarded as follows: "HYDROGEN — FLAMMABLE GAS NO SMOKING — NO OPEN FLAMES" All buildings, rooms, and areas containing flammable gases are to be properly marked.	Signs must be in English as the primary language and made of a durable material with the size, color, and lettering approved.	IFC – §2703.5 NFPA 50A – §2-5
Containers	Hydrogen storage containers shall be designed, constructed, and tested in accordance with applicable requirements of the ASME Boiler and Pressure Vessel Code and Federal DOT regulations.	Hydrogen must be stored in containers allowed for service with hydrogen. The ASME container should have a nameplate, and DOT cylinders should be stamped.	ASME BPVC, §VIII CGA G5.4 — §4.1, §8 DOT 49 CFR 171-190 IFC — §2703.2, §3203.1 NFPA 50B — §2-1
Cargo tanks (tank trucks) and portable tanks (skid tanks) designed to DOT specifications	Each mobile hydrogen supply unit used as part of a hydrogen system must be secured to prevent movement.	Inspect for potential equipment shifting.	NFPA 50B — §5-3 IFC — §3203.1.1
Adjacent flammable and combustible liquids or liquefied oxygen storage	Where hydrogen storage is located level with or below such hazardous materials, diking, diversion curbs, grading, or a separating solid wall is required to prevent liquids accumulation within 50 feet (15.2 meters) of the hydrogen container.	Where present, confirm the means and proximity of the measures to protect adjacent hydrogen storage.	IFC – §2703.9.8, §3203.1 NFPA 50B – §3-1.3

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Shutoff valves	A remotely controlled shutoff valve for liquid withdrawal lines serving containers >2000 gallons (7570 liters) is required.	Confirm conspicuous installation and operability. There shall be no connections, flanges, or other appurtenances allowed in the piping between the shutoff valve and its connection to the inner container.	IFC – §3203.2.6 NFPA 50B – §2-4.3
Pressure relief devices (PRD)	Covers PRD requirements related to accessibility for maintenance, general sizing, installation, and device integrity.	See Section 3.3 for specific PRD requirements.	CGA G-5.4 – §4.3.1 IFC – §3203.2 NFPA 50B – §2-2
Bonding and grounding	Liquefied hydrogen containers and associated piping shall be electrically bonded and grounded.	Liquefied hydrogen containers and associated piping must be properly bonded and grounded in order to prevent static discharges. It is critical that the piping be bonded so that it will discharge to ground. Bonding piping to something that is not grounded will not transfer the charge to ground.	CGA G5.4 – §6.5 IFC – §2703.9.5, §3406.7 IFGC – §703.6, §704.4 NFPA 50B – §2-8, §5-4 API RP 2003: Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents
Notices and placards	Sites shall be placarded as follows: “LIQUEFIED HYDROGEN FLAMMABLE GAS NO SMOKING — NO OPEN FLAMES” All buildings, rooms, and areas containing cryogenic fluids are to be properly marked.	Signs must be in English as the primary language and made of a durable material with the size, color, and lettering approved.	IFC – §2703.5, §3203.4.1 NFPA 50B – §3-1.4

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
2.0 General Station Siting			
2.1 General			
Installation	The building official is authorized to require construction documents to be prepared by a registered design professional. Personnel familiar with proper installation practices, construction, and use of such systems shall supervise installation of liquefied hydrogen systems.	At the time of permit application and at various intervals during the project, detailed technical information shall be submitted to the building official in accordance with state professional registration laws. No one person has the technical knowledge to evaluate all of the various operations, technologies, processes, products, materials, and uses from a safety standpoint. This section also provides the code official the authority to require the owner to provide a technical opinion safety report. It is critical that the preparer have the proper background and experience for the project because the credibility of the report depends on these qualifications.	CGA G-5 – §7.1, §8 CGA G-5.5 – §6.1 IBC – §106 IFC – §104.7, §105.6.40, §3005.1, §3205.1.1 IFGC– §701 NFPA 50A – §2-4.2 NFPA 50B – §2-4.2 NFPA 5000 - §1.7.6

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Adjacent flammable or combustible liquids	Covers circumstances in which the fueling station is within a minimum-specified distance (e.g., 50 feet or 15 meters) of above-ground storage of all classes of flammable and combustible liquids.	Assess the proximity of adjacent flammable or combustible liquids. Dikes, diversion curbs, grading, or separating solid walls may be used to prevent accumulation of these liquids under the station.	NFPA 50A – §3-1.2
Separation distances from equipment, features or exposures	Covers minimum separation distances (in feet) between fueling station equipment and features and a series of specified outdoor exposures. Separations between unloading connections for delivery equipment and exposures and between container fill connections and parked vehicles are specified. Other rules apply (see Section 2.2).	Consult the separation distance charts as applicable. During plan review and field inspection confirm that the separation distances from various exposures, including unloading connections and container fill connections are present. Appropriate separation reduces the opportunity for harmful impacts to the system and decreases the severity of a hydrogen release to life and property.	IBC – §302.1.1, T302.1.1 IFC – §2209.3.1, T2209.3.1, Liq: §3203.6.1, T3203.6.1 Gas: §3504.2.1, T3504.2.1 NFPA 50A – §3-2, T3-2.1, T3-2.2 NFPA 50B – §3-2, T3-2.1, T3-2.2
Location	Refueling station systems and equipment shall not be located beneath or where exposed to failure to any of the following: (a) Electric power lines (b) Piping containing all classes of flammable or combustible liquids (c) Piping containing other flammable gases or (d) Piping containing oxidizing materials.	Confirm and evaluate proximity of refueling station systems and equipment with respect to these features.	IFC – §2209.3.4 NFPA 50A – §3-1.2, §3-1.3 NFPA 50B – §3-1.4

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Electrical equipment	Any electrical equipment that is part of the facility shall be offset (in feet) as specified in Article 501 of NFPA 70, National Electrical Code®, for Class I, Division 2 locations. Electrical equipment within 15 feet (4.6 m) of gaseous hydrogen systems shall comply. Electrical equipment within 3 feet (1 m) of points of connection to liquefied hydrogen systems is Division 1; beyond 3 to 25 feet of the connection is Division 2. (Other exceptions apply.)	The proximity of ignition sources with respect to the electrical equipment shall be identified, so located and addressed.	ICC EC IFC – §3203.7, §2209.2.3 NFPA 50A – §4-1.2, §4-2.5, §4-3.5 NFPA 50B – §2-7, §4-2.4, §4-3.5 NFPA 70 – §501.4, Wiring; §501.5, Seals & Drainage; §501.6, Switches, Circuit Breakers, Motor controllers, Fuses; §501.8 Motors; §501.9, Luminaries; §501.12 Receptacles; §501.13 Conductor insulation; §501.14 Signal and communication; §501.16 Grounding
Separation distances from equipment, features or exposures	Hydrogen systems shall be located either outdoors, in a separate building, or in a “hydrogen cut-off room” (ICC) or a “special room” (NFPA). Rules, locations (in order of preference) and tables specifying minimum separation distances to specified exposures based on storage capacity apply and shall be consulted.	Consult the separation distance charts as applicable. During plan review and field inspection confirm that the separation distances from various exposures are present. Appropriate separation reduces the opportunity for harmful impacts to the system and decreases the severity of a hydrogen release to life and property.	IBC – §302.1.1, T302.1.1 IFC – §2209.3.1, T2209.3.1 NFPA 50A – §3-1, T3-2.1, T3-2.2 NFPA 50B – §3-1, T3-2.1, T3-2.2

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
2.2 Outdoor Installations			
Weather protection	Where walls, roofs, weather shelters, or canopies are provided, they shall be constructed of noncombustible materials. NFPA permits the use of limited-combustible materials (Other rules apply). Hazardous material storage or use can be considered outdoor storage or use where all of the following are met: 1. Structure supports do not obstruct more than 25% of the perimeter of the use area 2. The structure is located with respect to buildings, lot lines, public ways or means of egress as required for the hazardous material 3. The overhead structure is noncombustible construction and limited to 1,500 square feet (140 m^2).	Confirm construction type. Protective barriers can be installed to provide a greater measure of fire protection. The 1,500 ft^2 may be exceeded if either excess frontage or an automatic sprinkler system is provided.	CGA G-5 – §5, §8.2 IBC – §414.6 IFC – §2209.3.3, §2704.13 NFPA 50A – §4-1.1 NFPA 50B – §4-1.2

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Gas detection system (optional)	CGA offers an approved flammable gas detection system as optional equipment.	Review locations where detection is specified. Locations shall be the most likely to accumulate hydrogen or develop a flammable atmosphere in the event of a leak. Confirm or field test detectors such that they are set to alarm at 1% hydrogen (25% LFL) and to shut down at 2% hydrogen concentration.	CGA G-5.4 — §4.3.6 References as applicable: IFC – §2211.7 IFGC – §706.3.2 IMC – §502.16 NFPA 50A – §2-4.4, §4-2.2 NFPA 50B – §2-4.4
Roadway and yard surfaces	Identifies where surfaces are to be constructed of noncombustible materials.	Confirm material and surface conditions are present for sites incorporating liquefied hydrogen storage. Liquid air can drip from the transfer piping of the delivery vehicle, and could contribute to a hazardous condition.	CGA G-5 – §8.2 NFPA 50B – §5-3

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
2.3 Indoor Installations			
Ventilation and exhaust	Establishes requirements for providing ventilation exhaust and makeup air in repair garages servicing lighter-than-air fueled vehicles. The requirements are relevant and applicable to indoor installations of gaseous hydrogen systems. Establishes natural ventilation provisions for certain indoor locations intended for hydrogen generating or refueling operations. Relevant to residential applications where no more than three motor vehicles are stored or serviced. Requires ventilation to prevent the accumulation of gaseous hydrogen in cabinets or housings containing hydrogen control or operating equipment.	Review ventilation rates and details of interconnection and operation.	IFC – §2211.7 IFGC – §703.1.2, §706.3.2 IMC – §502.16 NFPA 50A – §3-2.4 IFGC – §703 NFPA 50A – §2-4.4 NFPA 50B – §2-4.4
Ventilation rate and operation	Establishes minimum continuous and uniform air movement of 1 cubic foot per minute per 12 cubic feet [0.00138 $m^3/(s \cdot m^3)$] of room volume as the baseline level of performance. Operational provisions for such ventilation systems need to be interlocked with a continuously monitoring, flammable gas detection system.	Confirm supply inlets are uniformly arranged in exterior walls near the floor. Exhaust outlets shall be uniformly arranged in exterior walls at the high point of the space. Additionally, NFPA requires inlet and outlet openings to be 1 ft^2 / 1000 ft^3 (1 m^2/ 305 m^3) of room volume.	IFC – §2211.7 IFGC – §706.3.2 IMC – §502.16 NFPA 50A – §2-4.4, §4-2.2 NFPA 50B – §2-4.4

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Ventilation rate and operation (contd)		Verify that the detection system is installed, operational, and activates when the level of flammable gas exceeds 25%	

		of the lower flammability limit.	
Gas detection system	Requires indoor installations to be provided with an approved flammable gas detection system. NOTE: Indoor rooms exclusively housing a gaseous hydrogen system are constructed to requirements for a "Hydrogen cut-off room" in ICC or a "Special room" in NFPA. (Other rules apply).	The flammable gas detection system shall be of an approved type. Confirm or field test detectors such that they are set to alarm at 1% hydrogen (25% LFL) and to shut down at 2% hydrogen concentration.	CGA G-5.4 — §4.3.6 IFC – §706, §706.3.3, §2211.7 IFGC – §706.3.2 IMC – §502.16 NFPA 50A – §2-4.4, §4-2.2, §4-3 NFPA 50B – §2-4.4
3.0 Fueling Station Piping and Equipment			
3.1 General			
Insulation	Covers the design of piping systems and equipment to minimize the exposure of piping, surfaces and supports operating at cryogenic temperatures.	Inspect insulation levels and potential personnel exposure points. Insulation shall be noncombustible, vapor-tight and suitable for exposure to the environment.	CGA G-5.4 – §6.2.2, §6.3 CGA G5.5 – §6.11 NFPA 50B – §2-3.4, §3-1.3

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Bonding and grounding	Equipment, containers, and associated piping shall be electrically bonded and grounded. Floor and floor coverings must comply with provisions in CGA. Reference NFPA 70 – §250.90 for general bonding, §250.100 for bonding in hazardous locations and 250.104 (B) for bonding of "other metal piping." Reference NFPA 70 – §250.116 non-electric equipment (including containers and skid-mounted tanks), NFPA 70 – §250.118 for connection of any supplementary grounding electrode and NFPA 70 – §250.122 for grounding conductor sizing. Containers and systems: 1. Shall not be located where they could become part of an electrical circuit, and 2. Shall not be used for electrical grounding.	Hydrogen equipment, containers, and associated piping must be properly bonded in order to prevent static discharges. Verify the size of wire-type grounding conductors such that they penetrate moist soil and are not smaller than Table 250.122. The particular grounding system of choice (metal underground water or gas pipe systems, metal building frame, others) shall be confirmed and evaluated. Other rules apply. All metallic parts (piping, structure supports) within a classified hazardous area shall be at ground potential.	CGA G-5.4 – §6.5 CGA G5.5 – §6.10 NFPA 50B – §2-8 NFPA 70 – §250.90, §250.100, §250.104, §250.116, §250.118, §250.122 IFC – §3003.6, §3203.7, §3503.1.2

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Protection of structures and personnel	Means for minimizing exposure of personnel to piping operating at low temperatures and to prevent air or condensate from contacting surfaces not suitable for cryogenic temperatures. Uninsulated piping and equipment operating at liquefied hydrogen temperatures and cold vent piping shall not be installed above asphalt surfaces or other combustible materials. Containers shall be protected from contact with soil or unimproved surfaces, and the surface graded to prevent accumulation of water.	Inspect and confirm insulation on equipment operating at cryogenic temperatures Asphalt and bituminous paving are considered combustible materials. Other combustible materials, such those used with expansion joints shall be covered with noncombustible material. Evaluate surfaces underneath container storage.	CGA G-5.4 – §6.2.2 NFPA 50B – §2.3.4 OSHA CFR 29, Part 1910 CGA G-5.5 – §6.12 IFC – §3003.11, §3203.6.1.2 NFPA 50B – §2.3.5, §4-1.1
Protection from impact	Guard posts or other approved means shall be provided to protect storage tanks and connected piping, valves and fittings; dispensing areas; and use areas subject to vehicular damage.	Confirm the presence and suitability of protection. The design of vehicle barrier systems shall be in accordance with the building code (as applicable).	IBC – §1607.7.3 IFC – §2703.9.3, §3003.3, §3203.5, §3503.1.2 IFGC – §707.1 NFPA 50A – §2-4.3 NFPA 50B – §2-4.3 NFPA 5000

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Security and access by authorized personnel	Areas used for the storage, use, and handling of compressed gas containers, cylinders, tanks, and systems shall be secured against unauthorized entry and safeguarded in an approved manner. Containers, piping, valves, regulating equipment, and other accessories must be readily accessible and protected against physical damage and against tampering.	Devices and equipment must be accessed for maintenance. Areas such as yards, loading platforms, and any area where gas containers, cylinders, and tanks are used, handled, or stored are to be secured and safeguarded against unauthorized access.	CGA G-5.4 – §6 IFC – §2703.9.2, §3003.3, §3203.5, §3503.1.2, §3503.4 IFGC – §707.1 NFPA 50A – §2-4.3 NFPA 50B – §2-4.3
3.2 Piping, Tubing and Fittings			
Materials	Materials shall be approved for hydrogen service in accordance with ASME B31.3 for the rated pressure, volume, and temperature of the gas or liquid transported. Gray, ductile or malleable cast-iron pipe, valves, and fittings shall not be used. CGA specifies austenitic (300 series) stainless steels meeting ASME requirements for liquid and gaseous hydrogen service, and allows plastic under controlled conditions. IFGC specifies Type 304, 304L, or 316 stainless steel piping and tubing listed or approved for gaseous hydrogen service.	Hydrogen piping systems can consist of structural members, vacuum jackets, valve bodies and valve seats, electrical and thermal insulation, gaskets, seals, lubricants, and adhesives and will involve a multitude of materials. Hydrogen embrittlement involves many variables and can cause significant deterioration in the mechanical properties of certain metals. Thoroughly review material selection methods and bills-of-lading, quality control procedures, and material test reports employed during manufacture such that the materials are suitable for hydrogen service.	ASME B31.3 CGA G-5.4 – §4.2 CGA G-5.5 – §5.5 IFGC – §704.1.2, §708 IFC – §2209.5.4.1 (1), §3201 NFPA 50A – §2-3 NFPA 50B – §2-3.1, §2-3.2 ASME B31.3 CGA G-5.4 – §4.2.1.2 IFGC – §704.1.2, §708

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Joints	Joints on piping and tubing shall be listed for hydrogen service, including welded, brazed flared, socket, slip or compression fittings. Soft solder joints are not permitted. Threaded or flanged connections shall not be used in areas other than hydrogen cutoff rooms or outdoors.	Inspect several joining methods during construction to verify that they are of the approved type, suitable for hydrogen service. Mechanical joints must have electrical continuity or be connected with a bonding strap. Any gaskets or sealants shall be listed for use with hydrogen. CGA indicates graphite preferred. Specific sealant gasketing and packing materials are included in CGA G-5.4 and G-5.5.	CGA G-5.4 – §6.1.2, §6.1.4, §6.2.1 CGA G-5.5 – §6.4 - §6.10 IFGC – §704.1.2.4 NFPA 50A – §2-3.3 NFPA 50B – §2-3.3
Valve, gauge, regulator and piping component materials	All valves, gauges, regulators, and other piping components shall be listed or approved for hydrogen service for the rated pressure, volume , and temperature of the gas or liquid transported. Cast-iron valves and fittings shall not be used. The manufacturer or the hydrogen supplier shall recommend valves gauges, regulators, and other accessories for hydrogen service.	Confirm that mechanical fittings and special joints are used as required by ASME. Valves, gauges, and regulators used must be suitable for hydrogen service. CGA specifies use of safety glass and blowout plugs on pressure gauges. Also valve and seat types (e.g., metal-to-metal or metal-to-soft material) for various isolation, emergency isolation, and check valve types are discussed. Other rules apply.	CGA G-5.4 – §4.3.8, §4.3.1 CGA G-5.5 NFPA 50A– §2-4.1 NFPA 50B– §2-4.1

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Piping in floors, concealed locations and underground	Requirements for piping underground, in solid floors, and outdoors, including soil tests and welded construction (as applicable) and prohibition of valves, joints, and connections (for underground) are described.	Verify depth as required by fuel gas code (as applicable). Evaluate piping layout and need for protection from frost and surface loads with the casing ventilated to the outdoors. Review soil test results to determine need for cathodic protection.	IFGC – §704.1.2.3.5, §704.1.2.3.6 CGA G-5.4 – §6.3
Pressure regulators	Establishes design, installation, and protection for regulators.	Confirm the location of regulators and that their operation cannot be affected by freezing rain, sleet, snow, ice, mud, insects, or debris.	CGA G-5.4 CGA G-5.5 , CGA E-4 NFPA 50A– §2-4.3 NFPA 50B– §2-4.3 NFPA 52 – §4-7
Pressure gauges	Covers installation of gauges and the pressure variables that require monitoring to determine whether the system is functional.	Confirm the presence of and functionality of the gauges. Gauges shall report compression discharge pressure, storage pressure, and fuel supply container fill pressure.	CGA G-5 – §6.3 CGA G-5.5 CGA E-4 NFPA 50A– §2-3, §2-4 NFPA 50B–.§2-3, §2-4 NFPA 52 – §4-8
Shutoff valves	Piping to equipment shall be provided with an accessible, manual shutoff valve. Valves shall not be installed between the PRD and the container protected by the PRD and shall be conspicuous and readily accessible. (See also Sections 1.3 and 3.5.)	Inspect locations, accessibility, and operability of shutoff valves.	IFC – §2209.5.1, §3203.2.6 IFGC – §703.3.1, §704.1.2.5.1 NFPA 50B–.§2-4.3, §2-6.4

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Piping and hoses (general design and support)	Requirements for piping (including vent piping) and hoses cover design, protection, and support. Additional areas where there are requirements include hose electrical continuity and bonding, manifold connections, pipe thread joining materials, prohibited weakening of piping and tubing resulting from bending, access to joints, venting to safe points of discharge, limitations, on the use of hose connections and recycling of unused fuel.	Inspect direct runs and manifolds for support and provisions for expansion and vibration control. Review piping bending methods and inspect bends for visible signs of weakness. (Third party inspection of assembly methods may be necessary). 36-inch (910-millimeter) metallic hose lengths are permitted for flexibility (readily visible and protected from damage). (See also Section 3.4.)	CGA G-5.4 – §4.3.8, §6.1 CGA G-5.5 – §6.1, §6.2 NFPA 50A– §2-3, §2-4 NFPA 50B–.§2-3, §2-4 NFPA 52 – §4-9, §4-9.3
Testing	After installation, all field-erected piping tubing, and hose and hose assemblies shall be tested and proved hydrogen gas-tight for the rated pressure, volume, and temperature of the gas or liquid transported in that portion of the system.	A testing and purging procedure should be prepared and reviewed. While methods for testing hydrogen piping vary, an approved method such as outlined in ASME B31.3 often incorporate procedures that can be characterized as follows: 1) Perform a pressure test (CGA indicates a mix of at least 10% helium in inert gas preferred) at 1.5 times maximum working pressure, 30 minutes per 500 cubic feet of pipe volume.	ASME B31.3 CGA G-5.4 – §7.2 CGA G-5.5 – §6.13, §6.14 IFGC – §705, §705.3 NFPA 50A – §2-6 NFPA 50B – §2-5.1 NFPA 52 – §4-10.1

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Testing (contd)		2) After the pressure test, check for pressure decay. If some leakage is detected, use soap/water to find the local leaks (bubbles). 3) Energize the piping with hydrogen and check for local leaks with a "sonic tester" or a "sniffer" (hand-held combustibility tester). If the test "fails" the above procedure, purge the system, fix the leak, and repeat the process until it "passes." Sometimes a "sonic test" is used as part of yearly preventive maintenance.	
Purging	Covers purging with inert gas.	A testing and purging procedure should be prepared and reviewed. CGA refers to ASME B31.3 methods and requires residual oxygen to be reduced to less than 1%.	ASME B31.3 CGA G-5.4 – §7.3 IFGC – §705.3 NFPA 50A – §2-6 NFPA 50B – §2-5.1 NFPA 52 – §4-10.1
Cleaning	Before placing into hydrogen service, piping systems shall be cleaned.	Review CGA for details of cleaning procedures and visual and wipe tests to be performed.	CGA G-5.4 – §5 CGA G-5.5 – §6.9
3.3 Pressure Relief Devices (PRDs)			
Where required	Containers and portions of the system subject to overpressure shall be protected by pressure relief devices.	Inspect containers, equipment, and systems for location and operability of PRDs.	CGA G-5.4 – §4.3.1 IFC – §3203.2, §3503.1.2, NFPA 50A – §2-2 NFPA 50B – §2-2

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Sizing	Gaseous hydrogen containers and stationary and portable liquefied hydrogen containers shall be equipped with appropriately sizedPRDs. PRDs shall be designed and installed in accordance with the appropriate CGA (S-1.1 for cylinders, S-1.2 for cargo and portable tanks, S-1.3 for storage containers) or ASME BPVC utilizing commodity-based requirements, as applicable. Other rules apply.	PRDs shall be installed in accordance with the manufacturer's instructions and designed to operate properly. Review manufacturer's information to support sizing to the specifications of the container type such that the maximum design pressure of the container is not exceeded.	CGA G-5 – §4.2.2, §8.2 CGA G-5.4 – §4.3.1 CGA S-1.1 – §5, §5.4 CGA S-1.2 – §4.3.2, §5 CGA S-1.3 – §4.3.3, §5 IFC – §2209.5.4.1 (1), §3203.2.3 IFGC – §703.3, §703.4 NFPA 50A – §2-2 NFPA 50B – §2-2 DOTn 49 CFR , Pts 174-179

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirements	What To Look For	Code/Standard
Location of discharge	Covers unobstructed discharge to the outdoors, location and arrangement of escaping liquid or gas to protect containers, adjacent structures, and personnel. For pressure vessels, PRDs must be installed so they discharge in a vertical position.	Confirm arrangement of discharge and location.	CGA G-5 – §8.2 CGA G-5.4 – §4.3.1.4 CGA G-5.5 – §5.3.1 CGA S-1.1 – §5.1 CGA S-1.2 – §4.2 CGA S-1.3 – §4.2 IFC – §2209.5.4, §3203.7, §3005.5, §3503.1.2 IFGC – §703.3.3.8 NFPA 50A – §2-2.2 NFPA 50B – §2-2.3. §2-2.4 NFPA 52 – §6-6.1, §6-4.3.10
Obstructions	Addresses protection and location of the PRD so that moisture or other debris cannot interfere with proper operation of the device.	Verify the installation and positioning of PRDs. Ice formation on PRDs can render them inoperable.	CGA G-5 – §8.2, §8.3 CGA G-5.4 – §4.3.1.4 CGA G-5.5 – §6.16 CGA S-1.1 – §5.1 CGA S-1.2 – §4.2 CGA S-1.3 – §4.2 IFC – §2209.5.4, §3203.2.5 IFGC – §703.3.3.8 NFPA 50A – §2-2.3 NFPA 50B – §2-2.4 NFPA 52 – §4-6.2

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Fueling transfer system overpressure protection	Covers installation of an overpressure protection device (other than a rupture disc device) in the fueling transfer system.	The PRD shall be set no higher than 1.25 times the service pressure of the refueling nozzle. Consult the "marked set pressure" requirements for the PRD using the applicable CGA.	CGA G-5 – §4.2.2, §8.3 CGA S-1.1 – §4 CGA S-1.2 – §4.3, §4.3.2 CGA S-1.3 – §4.1.2 NFPA 52 – §6-6.3
3.4 Vent Systems			
General design	The vent structure must be designed to withstand ice, wind, and seismic loadings and located such that burning of the discharged hydrogen can proceed safely.	Evaluate structural support, height, and separation distances for the proposed vent outlet location.	CGA G-5.5 – §4.2, §4.3, §5.2, §5.3 IBC IFC – §2209.5.4.1 (2), T2209.5.4.1, §2209.5.4.2 NFPA 5000
Purging flow rate	Specifies the maximum purging flow to be equal to the PRD release rate in accordance with CGA using non-"engulfing fire" conditions or the maximum onsite production rate, whichever is larger. Also addresses manifolded vent sources to a common stack, miter cut exits, siting distances from exposures, and thermal/radiation impingement.	The flow rating shall be clearly specified (in cfm) at PRD rating pressure for the code official. The PRD rating pressure is the inlet static pressure at which the relieving capacity of the PRD is determined. Reductions to PRD flow requirements may be applied when the storage is protected from an "engulfing fire."	CGA G-5.4 - §4.3.1 CGA G-5.5 – §5.2, §5.3 CGA S-1.3 – §4.3.3, §5 IFC – §2209.5.4, §2209.5.4.2, §2209.5.4.3 NFPA 52 §6.12.1

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Materials and joining methods	Covers requirements for vent piping materials and joining methods. IFC specifies the associated PRD vent pipe system shall be designed for the maximum backpressure but not less than 335 psig (2310 kPa). CGA indicates that a system designed for 150 psig (1030 kPa) is sufficient. (See Section 3.2 for specific material and joining discussion.)	Thoroughly review material selection methods and bills-of-lading, quality control procedures, and material test reports employed during manufacture such that the materials and joining methods are suitable for hydrogen service.	ASME B31.3 CGA G-5.4 – §4.2, §4.3.1 CGA G-5.5 – §5.3.4, §5.4, §5.5 IFC – §2209.5.4.1
Obstructions	Vent piping shall be designed or located so that moisture or other debris cannot freeze or collect in a manner that would interfere with proper operation of the device.	Confirm that vent piping is present and that the protection is suitable for the intended protective function.	CGA G-5 – §8.2, §8.3 CGA G-5.4 – §4.3.1.4 CGA G-5.5 – §6.16 IFC – §2209.5.4, §3203.3 NFPA 50A – §2-2.3 NFPA 50B – §2-2.4 NFPA 52 – §6-9.2
Insulation	Covers the design of uninsulated, cold vent piping systems and equipment to minimize the exposure of piping, surfaces, and supports operating at cryogenic temperatures.	Inspect insulation levels and potential personnel exposure points. Insulation shall be noncombustible, vapor-tight, and suitable for exposure to the environment.	CGA G-5.4 – §6.2.2, §6.3 CGA G5.5 – §6.11 NFPA 50B – §2-3.4, §3-1.3

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Testing and cleaning (see Section 3.2 for testing and cleaning requirements)	After installation, all field-erected vents shall be tested and proved hydrogen gas-tight for the rated pressure, volume, and temperature of the gas transported. Before placing into hydrogen service, piping systems shall be cleaned.	A testing and purging procedure should be prepared and reviewed. Review CGA for details of cleaning procedures and visual and wipe tests to be performed.	ASME B31.3 CGA G-5.4 – §5, §7.2 CGA G-5.5 – §6.13, §6.14 IFGC – §705, §705.3 NFPA 50A – §2-6 NFPA 50B – §2-5.1 NFPA 52 – §6-10.1
Signage	Ice shall be prevented from forming on PRDs and making them inoperable.	Confirm the conspicuous placement of signage on the container near the pressure relief valve vent stack and on the vent stack that warns against spraying water on or in the vent opening.	NFPA 50B – §2-2.6
3.5 Vaporizers			
Vaporizers	General requirements for liquefied hydrogen vaporizers (summarized): 1. Supported on suitable foundations, 2. Anchored and accommodate the effects of expansion and contraction, 3. Protected on the hydrogen and heating media sections with PRDs, 4. Indirect heat (air, steam, water) shall be used for vaporization,	Confirm the presence of a suitable foundation, accommodations for expansion control. Verify the presence of PRDs. Assess their operability. Direct heating must be avoided to prevent ignition of hydrogen. Verify indirect source of heat. To prevent flow of liquefied hydrogen into system portions designed for gaseous hydrogen in the event of the loss of the heat source, a shutoff switch or automatic valve is required.	IFC – §3203.1.3, §3203.2.2, §3203.5 IFGC – §708 NFPA 50B – §2-6

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Vaporizer (contd)	5. A low-temperature shutoff switch or valve is required in the vaporizer	Confirm the presence of the equipment and operability.	

	discharge piping.		
3.6 Compressors & Dispensing Equipment			
Fuel dispensing devices	These sections provide requirements for listing, location, and installation of fuel dispensing devices (a.k.a., vehicle fueling appliances). Location and approval of emergency disconnect switches are also specified.	Evaluate manufacturer's listing and installation instructions for the dispensing device. Confirm installation in accordance with manufacturer's instructions. Verify location for dispensing devices.	IFC – §2203, §2209.2.2, §2209.3.3 NFPA 52 – §6-17
Temperature corrected fill pressure flow shutoff	A shutoff device required for stopping fuel flow automatically when a fuel supply container reaches the temperature-corrected fill pressure.	Verify the presence and operability of this automatic shutoff device. The device must be checked annually by manually tripping the hold-open linkage.	IFC – §2205.2.2 NFPA 52 – §6.11
Hoses and hose connections	Covers general requirements for hoses, including materials and selection, testing, protection and support, and limitations on the use of hose connections.	Hose and hose connections shall be listed for hydrogen service. Use of hoses shall be limited to vehicle fueling, inlet connection to compression equipment, and 36-inch (910-millimeter) metallic lengths in piping for flexibility (readily visible and protected from damage).	IFC – §2209.2.2 NFPA 52 – §4-10, §6-9.3

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Breakaway devices	Establishes provisions for breakaway protection, their location, installation, arrangement, and separation forces.	Confirm listing and installation of these devices in accordance with the manufacturer's installation instructions such that in the event of a pull-away, hydrogen gas ceases to flow at any separation.	IFC – §2206.7.5, §2206.7.6, §2209.2.2 NFPA 52 – §6-11.7, §6-11.8 SAE 2600: Compressed Hydrogen Vehicle Fueling Connection Devices
Connector depressurization	Transfer systems must be capable of depressurizing to facilitate disconnection. Bleed connections shall lead to a safe point of discharge.	Confirm the presence and means for depressurization. Verify location of the point of discharge.	CGA G5 – §8.3 IFC – §2209.2.2 NFPA 52 – §6-14.7
Stray or impressed currents and bonding	Covers stray or impressed currents and where static protection (bonding) is not required.	Inquire whether stray currents are used or may be present. If YES, then verify the presence and continuity of protective measures (such as cathode protection). As relates to bonding required; inquire about the unloading of fuel, the coupling type (hose, tubing, or piping) and if both halves of the coupling are metallic and in direct contact. Other rules apply.	NFPA 52 – §6-13 CGA G5.4 – §6.5 IFC – §2703.9.5, §3406.7 IFGC – §703.6, §704.4 NFPA 70 – §250.90, §250.100, §250.104 API RP 2003: Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents
Shutoff valves	Shutoff valves for piping served by an outdoor compressor or storage system shall be located outside the building.	Inspect location, accessibility, proximity, and operability of shutoff valves.	NFPA 52 – §6-11.5

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Compressor self-closing valve	Specifies a self-closing valve at the inlet of the compressor.	Verify that the valve will shut off the gas supply to the compressor when • An emergency shutdown device is activated, or • A power failure occurs, or • The power to the compressor is switched to the off position. Verify presence and functionality of the valve(s).	NFPA 52 – §6-11.12
4.0 Fire Protection			
4.1 Type of Construction			
Rooms or spaces exclusively housing a gaseous hydrogen system	Protective walls or roofs shall be constructed of noncombustible materials. ICC permits 1- or 2-hour interior walls based on use group, interior openings with self-closing devices, or a source capture exhaust system and no operable windows. NFPA permits noncombustible and limited-combustible 2-hour interior walls (at least one wall shall be to the exterior), and no openings to other building areas. Explosion control is required.	These materials will provide greater protection in the event of a fire.	IBC – T302.1.1 IFC – §911, §2209.5.4, §3203.3, §3504.1.1 IFGC – §706.3 NFPA 50A – §4-2.3, §4-3.3 NFPA 50B – §4-3.3 NFPA 52 §6.15

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
4.2 Fire Protection Systems			
Weather protection and canopies > 1,500 ft^2 (140m^2)	The 1,500-ft^2 limitation for canopy area may be exceeded if either excess frontage or an automatic sprinkler system is provided.	Where a canopy exceeds this threshold, verify excess frontage or presence of an automatic sprinkler system.	IBC – §414.6 IFC – §2209.3.3, §2704.13 NFPA 50A – §4-1.1 NFPA 50B – §4-1.2 NFPA 30A - §12.4
Portable fire extinguishers	Covers general and specific requirements for the selection, installation, and maintenance of portable fire extinguishers.	Confirm the presence, extinguisher type, and location in accordance with the building code and NFPA 10. NFPA specifies a rating not less than 20-B:C. ICC specifies two 2-A:20-B:C and 75 feet from pumps, dispensers, and tank fill openings.	IFC – §906, §2205.5 NFPA 52 – §6-15
4.3 Additional Safety Precautions, Emergency Shutdown Equipment and Controls			
Container valve	Covers requirements for manually operated container valves on DOT and Canada Transport (TC) storage cylinders. A backflow valve at the container fill line is required to prevent flow back into the container. Other safety measures include the proximity of shutoff valve in manifolded container groups and precautions for the use of excess-flow valves (EFVs).	Review the presence, location, and operability of these preventive measures, means for shutoff, shutdown, and backflow prevention. For EFVs, verify that the closing flow is less than the flow rating of the piping system that would result from a pipeline rupture downstream.	CGA G-5.4 – §4.3.4 IFC – §911, §2209.5.4, §3203.3 IFGC – §706.3 NFPA 52 – §6-11.1 - 6-11.5

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Compressed gas controls	Controls shall be designed to prevent materials from entering or leaving process systems. Automatic controls shall be fail-safe.	Review the presence, location, and operability of these controls to prevent material entry or release. Verify control circuit operation, reset capabilities, and procedures to confirm that a safe condition is restored.	IFC – §3005.2, §3503.1.3
Emergency manual shutdown devices	Covers location and operation of emergency manual shutdown devices and control circuits. Such devices shall be conspicuous and distinctly marked.	Review the presence, location, and operability of these preventive measures and means for shutdown. Emergency manual shutdown devices shall be located in dispensing, generation, and compression areas. These devices, when activated, must shut off the power supply and gas supply to all storage, dispensing, generation, and compression equipment. Verify control circuit operation, reset capabilities, and procedures to confirm that a safe condition is restored.	CGA G-5.4 – §4.3.3 IFC – §2209.5.3, §3005.2, §3205.3.2, §3503.1.3 NFPA 52 – §6-11.6, §6-11.9
Fast-fill stations	Specifies locations for “quarter turn” manual shutoffs and shutoff conditions for lines between storage and dispenser(s).	Review the location of manual shutoffs between the storage system and the dispensing system.	NFPA 52 – §6-11.10, §6-11.11

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
5.0 Operating and Maintenance			
5.1 General			
Vehicle access	Storage containers shall be accessible to mobile supply equipment at ground level and to authorized personnel.	A site access survey could be utilized to evaluate turning radii, approach, and site circulation for the anticipated delivery vehicles.	IFC – §3205.4.2 NFPA 50A – §3-1.1 NFPA 50B – §3-1.1
Ignition source control	Ignition sources shall be identified and kept out of the fueling area. Storage and refueling areas must be kept clean and free of combustibles.	Identify and resolve ignition sources.	CGA G-5 – §8.4 IFC – §2205.4, §2205.7, §3503.1.4 IFGC – §707.1, §706.3.4 NFPA 50A – §4-2.3, §4-3.4, §6-2 NFPA 50B – §4-2.4, §4-3.4, §5-3 NFPA52 – §6-14.9
Warning signs	A warning sign with the words *"**STOP MOTOR, NO SMOKING, FLAMMABLE GAS**"* shall be posted at the dispensing station and in compressor areas.	Confirm such signage is conspicuous, within sight of the dispenser, and warns against 1) filling of unapproved containers, 2) smoking, and 3) shutting off the engine during the refueling process.	IFC – §2205.6 IFGC – §706.3.7 NFPA52 – §6-14.10

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Maintenance	Address the requirements for maintaining system components and safety equipment at dispensing operations. Repairs shall be by persons qualified to perform work on this equipment.	Equipment must be both properly installed and properly maintained. Conduct annual inspections as required.	CGA G-5.4 – §8 IFC – §107, §2205.2 IFGC – §707.1 NFPA 50A – §5-2 NFPA 50B – §5-2 NFPA52 – §6-16
Fire prevention and emergency planning	Requires a written fire prevention and emergency plan based on the size and location of the refueling station.	Reporting of emergencies, coordination with emergency response personnel, emergency plans and procedures for managing or responding to emergencies shall comply with these provisions.	IFC – §107, §404, §407, §2703.9 NFPA 5000
5.2 Dispensing Operations			
Fuel dispensing	Requirements for posting operating instructions and what information to post about the refueling process (e.g., turn off the vehicle, set the brake) are included.	Clearly understandable operating instructions for the use of the dispenser must be posted on the dispenser. The location shall be approved by the fire code official.	IFC – §2204.3.4 NFPA 52 – §6-14.4 - 6

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
5.3 Operational Requirements			
Required operational permits	General conditions requiring operational permits and collection of information demonstrating continued compliance with the unique requirements for particular operations. CGA requires that a permanent record of inspections and repairs shall be maintained.	This data collection and recording activity should be carried out by both the facility operator and the authority having jurisdiction.	CGA G-5.4 – §8 CGA G-5.5 – §7 IBC IFC – §105.6, §105.6.9, §105.6.11, §105.6.17, §105.6.40 NFPA 5000
Operator training	Covers required training for station employees and operating personnel who use and maintain the station.	Confirm the presence of and review the employee and operator training program.	IFC – §2209.4, §406 NFPA 5000
Safely transporting hydrogen (liquid or gaseous) from the production plant to the fueling station.	The fueling station shall be designed so that it is accessible to delivery equipment. There should be provisions for emergency equipment access (e.g., fire department equipment).	If there are restrictions on the access roads leading to the site with respect to transporting hydrogen (e.g., tunnels), the amelioration requirements should be specified.	Applicable local zoning code or ordinance relating to siting of fueling stations IBC– §506.2 NFPA 50A – §3-1.1 NFPA 50B – §3-1.1

Table 4.2. Codes and Standards for Hydrogen Motor Fuel DispensingFacilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Regular inspections (System components, containers and grounding)	Regular inspections of storage containers, system components, and grounding systems are specified.	Attend or verify the pressure testing of containers if out of service in excess of one year. The system and components (e.g., pressure relief devices) shall be checked to determine if they are operable and properly set.	CGA G-5.4 – §8 CGA G-5.5– §8 NFPA 50B – §2-5
Regular inspections (Hoses)	Covers re-inspection and leak tests required of hoses.	After the station is constructed, vehicle fueling hoses shall be examined visually at such intervals as are necessary to ensure that they are safe for use. Manufacturer's instructions are to be consulted for leak test requirements.	IFC – §2205.4, §2205.7 NFPA52 – §6-16.2
Regular inspections (Pressure Relief Devices, PRDs)	Stationary containers and portable tanks shall be tested every 5 years. Cylinders shall be examined at each refilling. When filling containers, PRDs shall be periodically examined externally for corrosion, damage, plugging of external channels, mechanical defects, and leakage.	Revisit for testing during operational permitting as called for. More frequent examinations may be warranted, depending on service condition or manufacturer's recommendations.	CGA S-1.1 – §8 CGA S-1.2 – §8.6 CGA S-1.3 – §8.6
Regular inspections (Pressure Relief Valves, PRVs)	PRVs shall be tested every 5 years. When filling containers, PRVs shall be periodically examined externally for corrosion, damage, plugging of external channels, mechanical defects, and leakage.	Revisit for testing during operational permitting as called for. More frequent examinations may be warranted, depending on service condition or manufacturer's recommendations.	NFPA 52 – §6-10.2, §6-16.4 IFC – §3203.2

Table 4.2. Codes and Standards for Hydrogen Motor Fuel Dispensing Facilities (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Maintenance and visual inspection (Hydrogen vent systems)	Provides for visual and physical inspections as well as manual venting operations and field repairs.	Revisit for testing during operational permitting annually. Visual inspections include looking for operational obstructions (nests, vegetation), inspecting the support systems, brackets wires, etc. Physically inspect the water drain device at the bottom of the stack. Qualified technicians shall check operation of vent system valves.	CGA G-5.5 – §7, §8

5.0 Case Study

5.1 Project Description

The Chicago Transit Authority (CTA), Ballard Power Systems, and Air Products and Chemicals, with funding support from the U.S. Department of Transportation Federal Transit Administration and the Regional Transportation Authority, successfully conducted a demonstration hydrogen fuel cell–powered mass transit bus project. The objective of the project was to run hydrogen fuel cell–powered buses on actual public transit routes in revenue service ***for two years*** to determine the technical feasibility, economic feasibility, and operating practicality of using them as an alternative to other alternative fuels (e.g., compressed natural gas, liquefied natural gas) being investigated to replace diesel power.

The project began in September 1997 and was completed successfully in March 2000.

Case Study Location

Chicago, Illinois

Project Partners

- Chicago Transit Authority (CTA)
- Ballard Power Systems, which supplied the hydrogen fuel cell-powered buses
- Air Products and Chemicals, which provided the hydrogen fuel and the refueling station.

Facilities and Equipment

- three city transit buses outfitted with polymer electrolyte membrane (PEM) fuel cells
- hydrogen fueling station at CTA's Chicago/Pulaski Avenue Garage – The station also serves as the hydrogen storage facility.
- Chicago Avenue Garage Hydrogen Bus Storage Area – CTA modified the Chicago/Pulaski Avenue Garage to accommodate the hydrogen buses. Each hydrogen bus has its own storage section with walls of noncombustible materials on either side.

5.2 Installation Type

The hydrogen fueling station for the CTA Hydrogen Bus Project was designed and constructed by Air Products and Chemicals. They adapted the industrial hydrogen distribution and supply technology base to design and construct the fueling facility at the CTA Bus Garage for fueling the demonstration fleet of three Ballard buses—each powered by a polymer electrolyte membrane (PEM) fuel cell that drives an electric propulsion system. The fuel for the fuel cells was compressed hydrogen gas stored in roof-mounted lightweight composite tanks.

CTA's fueling station has facilities for receiving, storing, processing, and dispensing hydrogen to the buses. It consists of two major systems:

- a hydrogen receiving and long-term storage system to receive and store liquid hydrogen, vaporize liquid hydrogen to create gaseous hydrogen, and compress and store compressed hydrogen for fueling operations
- a hydrogen transfer system for fueling the buses for revenue operation.

Both systems are located at the Chicago/Pulaski Avenue Bus Garage but are physically detached from it for safety purposes. The garage is a CTA facility for conducting bus maintenance; housing buses; fueling and washing buses; and servicing the fuel cell buses in a special vented area. Figure 5.1 is a schematic of the hydrogen fueling facility.

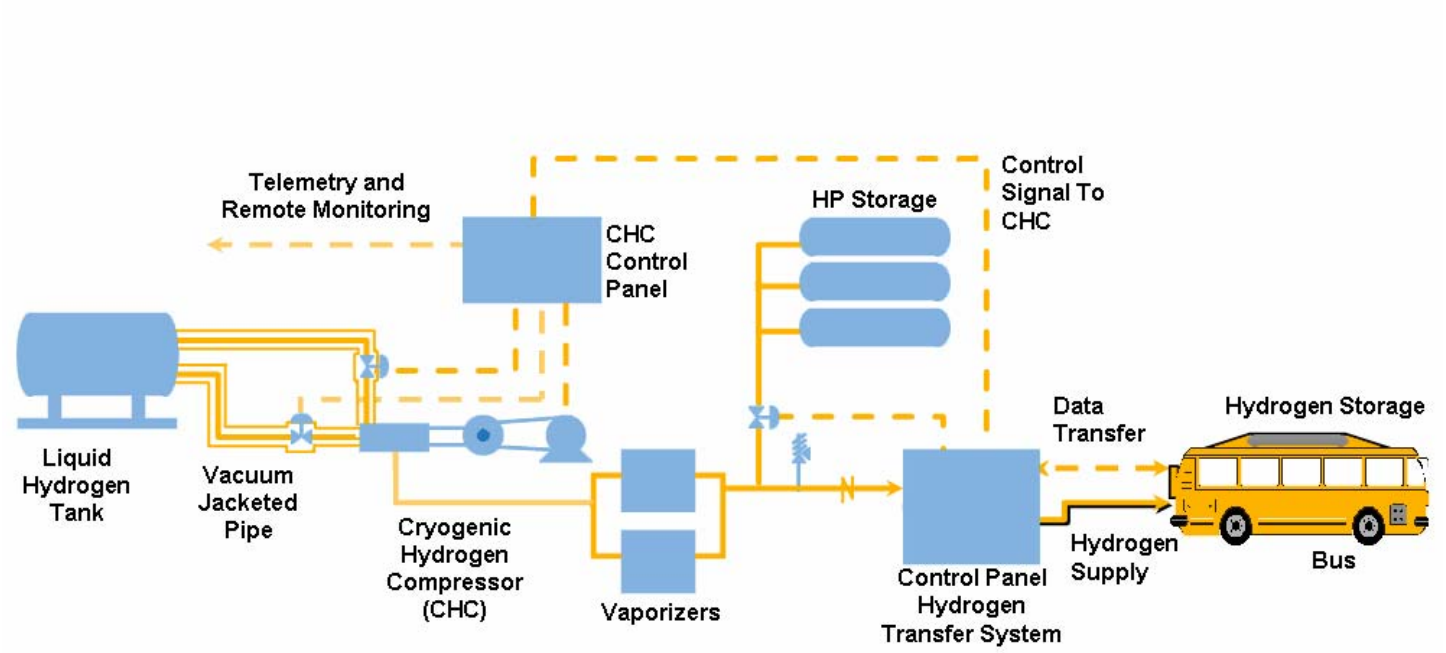

Figure 5.1. Hydrogen Fueling Facility

The project included making modifications to the garage—specifically, designing and installing hydrogen detection and evacuation systems, explosion-proof lighting, and fire suppression systems.

5.2.1 Hydrogen Receiving and Long-Term Storage System

For CTA, it proved to be most economical to have liquid hydrogen delivered, vaporize it at the facility, and compress it to achieve the high storage pressure needed for the gaseous hydrogen on the buses. Liquid hydrogen is transported to the bus garage in tanker trailers from an Air Products plant. The hydrogen is stored on the site in an insulated tank. A pump then moves liquid hydrogen from the storage tank (150 psi) through a vaporizer for refueling the buses with gaseous hydrogen at 3600 psi.

Typically, a bus can be completely filled within 15 to 20 minutes, depending upon the starting pressure of the bus. The single cryogenic hydrogen compressor (CHC) pump system is capable of fueling two to three buses per hour on a continuous basis. However, it takes about 2 hours to move all three vehicles into place, fuel them, and move them out again, because there is only one fueling dispenser.

5.2.2 Hydrogen Transfer System

The hydrogen transfer system receives pressurized hydrogen gas from, and operates synchronously with, the hydrogen receiving and long-term storage system. An automatic control system communicates with the person who is fueling the bus, the bus itself, and with the hydrogen source during the fueling process. The system measures the quantity of fuel in the vehicle tanks and stops the flow of fuel when the tanks are full or if an abnormal condition is detected (e.g., the bus is not grounded).

5.2.3 Installation Operation

Fueling is performed only by operators who have completed the hydrogen transfer system training program and while wearing fire-resistant clothing, gloves, and eye protection.

Multiple levels of protection were designed into the fueling station to ensure that the bus did not move during refueling. In addition to the breakaway fitting within the fuel hose, the traction motors of the bus were de-energized when the fuel door on the bus was opened. Also, a small depression was made in the pavement at the fueling station to accommodate the left front tire of the bus—again, to prevent movement.

Equipment	Specifications
Bus	Ballard Series 5900
PEM Fuel Cell	XCELLIS 205 kW
Fuel Source	Hydrogen from natural gas
Hydrogen Fuel Storage on Bus	Roof-mounted composite tanks at 250 bar (3300 psi)
Hydrogen Transportation Method	Liquid tanker truck (15,000 gallons)
Hydrogen Transportation Distance	Approximately 300 miles, from Air Products plant to CTA
Hydrogen Storage Onsite	Double-walled vacuum-insulated tank with liquid capacity of 9000 gallons (pressure 150 psi)
Cryogenic Hydrogen Compressor (CHC)	CHC-6000 single-stage reciprocating, positive displacement pump unit, driven by a 30-kW ac motor
Fueling Time	15 minutes Required a maximum delivery rate capacity of 2000 Nm^3 of hydrogen per hour to achieve a final settled storage pressure of 250 bar at ambient conditions (188 to +38° C).
Fuel Consumption	Approx. 400-500 Nm^3 hydrogen per day per bus

5.3 Codes and Standards

CTA worked with the Chicago Fire Department and the Department of Environment to address codes and standards issues. Codes and standards considered in the project included

- NFPA 50A: *Standard for Gaseous Hydrogen Systems at Consumer Sites*
- NFPA 50B: *Standard for Liquefied Hydrogen Systems at Consumer Sites*
- NFPA 54: *National Fuel Gas Code*
- NFPA 70: *National Electric Code*
- NFPA 88A: *Standard for Parking Structures*
- NFPA 88B: *Standard for Repair Garages*
- NFPA 497A: *Recommended Practice for Classification of Class I Hazardous Locations for Electrical Installations in Chemical Process Areas.*

The CTA Emergency Response Plan complies with 1) the National Response Team, Guidance for an Integrated Emergency Response Plan, 1996; 2) the requirements of the Occupational Safety and Health Administration (OSHA) 29 CFR 1910 for Hazardous Waste Operations and Emergency Response; and 3) the Metropolitan Water Reclamation District of Greater Chicago for Spill Prevention, Containment and Countermeasures Plan 40 CFR 403 8(f2)v.

5.4 Additional Resources

The experiences of CTA in planning and executing its hydrogen fuel cell bus project were used by the U.S. Department of Transportation in generating the following report:

Clean Air Program: Design Guidelines for Bus Transit Systems Using Hydrogen as an Alternative Fuel (DOT-FTA-MA-26-7021-98-1), Office of Research, Demonstration and Innovation, Federal Transit Agency, U.S. Department of Transportation, Washington, D.C., October 1998.