



ANSI/CGA H-5—2020 STANDARD FOR BULK HYDROGEN SUPPLY SYSTEMS

THIRD EDITION



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NOTE—Technical changes from the previous edition are underlined.

NOTE—Appendix A (Informative) is for information only.

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1 Introduction

This standard contains minimum requirements for locating/siting, selecting equipment, installing, starting up, maintaining, and removing bulk hydrogen supply systems.

2 Scope

Two types of bulk hydrogen supply systems are covered in this standard: liquid and gaseous.

A bulk gas hydrogen supply system is one that contains more than 5000 scf (141.6 m³) of hydrogen. A bulk liquid supply system is one that contains more than 39.7 gal (150 L) of hydrogen. Requirements of this standard are limited to systems operating up to 15 000 psi (103.4 MPa).^{1, 2}

For the purpose of this standard, a liquid system is defined as one where hydrogen is delivered to the supply system and stored on-site in liquid form. Hydrogen is supplied in either liquid or gaseous form to the end user's requirement. When required, pumps and/or compressors are used to increase the hydrogen pressure before it is supplied to the end user. When required, coded vessels are used to store gaseous hydrogen before it is supplied to the end user. The system is considered to be a bulk liquid system instead of a bulk gaseous system because the hydrogen is delivered from the hydrogen supplier to the storage system in liquid form.

For the purpose of this standard, a gaseous system is defined as one where hydrogen is delivered to the supply system, stored, and is supplied to the end user's requirement in gaseous form.

See Figures A-1, A-2, A-3, A-4, A-5, and A-6 in Appendix A for typical gas and liquid system flow diagrams.

This standard applies to hydrogen supply systems containing any of the following equipment. Not all hydrogen systems include all the equipment listed. More details about hydrogen applications can be found in CGA G-5, *Hydrogen* and *Handbook of Compressed Gases*. [2, 3].

Hydrogen supply systems include:

- cryogenic hydrogen storage tank, either aboveground or belowground;
- gas storage vessels, either aboveground or belowground;
- heat exchangers (including vaporizers);
- valves including manual and automatic shutoff valves, and check valves;
- pressure control equipment including regulators and control valves;
- piping (pipe and tubing);
- cryogenic pumps;
- cryogenic and warm gas compressors;
- snubbers and pulsation dampeners; and
- monitoring and control systems including electrical and instrumentation.

The bulk hydrogen supply system terminates at the source valve or where the gaseous or liquid hydrogen supply first enters the supply line.

¹ kPa (MPa) shall indicate gauge pressure unless otherwise noted as (kPa, abs [MPa, abs]) for absolute pressure or (kPa, differential [MPa, differential]) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [1].

² References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3 Definitions

For the purpose of this standard, the following definitions apply.

Additional detailed definitions can be found in CGA H-4, *Terminology Associated with Hydrogen Fuel Technologies* [4].

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Bulk hydrogen compressed gas system

Assembly of equipment that consists of, but is not limited to, storage containers, pressure regulators, pressure relief devices (PRDs), compressors, manifolds, and piping, with a storage capacity of more than 5000 scf (141.6 m³) of compressed hydrogen gas that terminates at the source valve.

3.2.2 Bulk liquefied hydrogen system

Assembly of equipment that consists of, but is not limited to, storage containers, pressure regulators, PRDs, vaporizers, liquid pumps, compressors, manifolds, and piping, with a storage capacity of more than 39.7 gal (150 L) of liquefied hydrogen that terminates at the source valve.

3.2.3 Cavitation

Undesirable vapor bubble formation and subsequent bubble collapse of a saturated or slightly subcooled liquid in a pump that can cause loss of prime and damage the pump.

3.2.4 Combustible

Measure of how easily a substance will ignite.

3.2.5 Composite cylinder

Cylinder manufactured with a combination of metal and fiber with a protective resin matrix.

3.2.6 Cryogenic compressor

Power-driven machine that reduces the volume of cold gas vapor and increases its pressure to liquefy it or maintain it at a high pressure.

3.2.7 Cryogenic pump

Device for increasing the pressure of cryogenic fluids.

3.2.8 Electrically classified area

Location in which a combustible gas is or can be present in the atmosphere in sufficient concentrations to produce an ignitable mixture.

3.2.9 Flammability

Ability of a substance to ignite at some concentration in air.

3.2.10 Fire barrier wall

Wall used to reduce the minimum required separation distances between a bulk supply system and an exposure, normally with a 2 hr fire rating.

3.2.11 Fusible link

System designed to open an emergency shutoff valve due to a localized fire.

3.2.12 Fusible plug device

Nonreclosing device designed to function by the yielding or melting of a plug of material at a specified temperature.

3.2.13 Grounding

Practice of intentionally electrically connecting all exposed metallic items not designed to carry electricity in a room or building as protection from electric shock.

3.2.14 Hydrogen embrittlement

Process by which various metals, most importantly high-strength steel, become brittle and crack following exposure to hydrogen.

3.2.15 Inert gas

Gas that is noncombustible and nonoxidizing.

3.2.16 Instrument gas

Compressed gas, normally air or nitrogen, used to operate pneumatic components.

3.2.17 Intrinsically safe

Apparatus, circuit, or system that is incapable of causing ignition by a spark or thermal effect of a mixture of flammable or combustible material(s) in air.

3.2.18 Lower flammable limit (LFL)

Lowest concentration of a flammable gas in an oxidant that will propagate when ignited.

3.2.19 Low temperature embrittlement

Loss of ductility and strength of a material, making it brittle and of lower strength due to low temperature.

3.2.20 Low temperature protection (LTP)

System to stop or block flow when product temperature is at or below temperature set point.

3.2.21 Natural ventilation

Process of supplying and removing air through a space without using mechanical systems. It refers to the flow of external air to an indoor space because of pressure or temperature differences.

3.2.22 Source valve

Shutoff valve on the piping system serving a bulk gas supply system where the gas supply, at service pressure, first enters the supply line.

3.2.23 Pressure relief valve

Device designed to protect a vessel or piping from achieving pressures higher or lower (vacuum) than its design to avoid the failure of the pipe or vessel.

NOTE—Because these devices can have significant flow when activated, the discharge should be directed to a safe area.

3.2.24 Pressure vessel

Closed container designed to hold gases or liquids under pressure.

3.2.25 Process Hazards Analysis (PHA)

Set of organized and systematic assessments of the potential hazards associated with an industrial process.

NOTE—A PHA provides information intended to assist in making decisions for improving safety and reducing the consequences of unwanted or unplanned releases of hazardous chemicals.

3.2.26 Purge

Elimination of an undesirable contaminant by displacement with another fluid.

3.2.27 Rupture disk device

Nonreclosing PRD actuated by inlet static pressure and designed to function by the rupturing of a disk.

3.2.28 Storage vessel

Container mounted on a stationary foundation that is designed to store refrigerated liquid or cryogenic liquid.

3.2.29 Thermal relief valve

PRD used on piping systems to prevent overpressurization caused by the thermal expansion of a limited volume of trapped process fluid.

NOTE—Also known as thermal pressure relief valve.

3.2.30 Transfer pad

Area over which a delivery vehicle transfers product to stationary storage tanks.

3.2.31 Vaporizer

Piece of equipment used to provide heat to convert cryogenic fluids into a vapor or gaseous state.

NOTE—Heating is provided by the ambient environment or by other means.

3.2.32 Warm gas compressor

Power-driven machine that reduces the volume of warm gas vapor and increases its pressure to liquefy it or maintain it at a high pressure.

4 Health hazards and safety considerations

For detailed information about the properties of hydrogen, see CGA G-5 [2]. Hydrogen suppliers' safety data sheets (SDS) also provide detailed information about hydrogen's properties and physical and chemical hazards. Main safety concerns about hydrogen are as follows:

- Hydrogen:
 - Is a flammable gas with a wide flammability range (4% to 75% in air) and a low ignition energy level (0.02 mJ), so it is much easier to ignite than other flammable liquids and gases
 - Has a wide detonation range of 18% to 59% in air
 - Burns with an almost invisible flame in daylight
 - Is an odorless, asphyxiant gas and can displace oxygen and
 - Is lighter than air and can accumulate in high spots;
- Flammable hydrogen mixtures can generate explosions particularly in the case of confinement and turbulence;
- Liquid hydrogen is a cryogenic liquid and presents the typical hazards of cryogenic liquids (frostbite, cryogenic burns);
- Certain metallic materials are susceptible to hydrogen embrittlement, particularly high-strength steels. Expertise shall be used when selecting and welding steel components for hydrogen service;

- Certain materials such as carbon steel are particularly susceptible to low temperature embrittlement and should not be used in liquid hydrogen service;
- The cold temperature of liquid hydrogen piping can cause air to liquefy. The nitrogen portion of the liquid air will vaporize before the oxygen portion and leave an oxygen-enriched atmosphere, which can promote enhanced combustion; and
- Liquid hydrogen spills will vaporize when allowed to contact warm surfaces, so diking is not recommended to contain spills. Vaporized hydrogen is lighter than air and will disperse rapidly. By contrast, containment of liquid hydrogen increases hazards because it slows down the rate of vaporization and allows the hydrogen to stay in the liquid phase for a longer time.

5 Site selection

5.1 General considerations

The location of a hydrogen storage system shall meet local codes and standards for hazardous materials. Local municipalities typically adopt one of these following sets of model fire codes and standards:

- International Code Council (ICC);
NOTE—There are other codes in the ICC family that are not listed below because they generally do not apply to hydrogen supply system installations.
 - International Fire Code® (IFC) has general requirements for industrial gases including flammable gases such as hydrogen [5].
- National Fire Protection Association (NFPA);
 - NFPA 1, *Fire Code* [6];
 - NFPA 2, *Hydrogen Technologies Code* [7] ; and
 - NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, for more specific site requirements for hydrogen systems (as well as other compressed gases and cryogenic liquids) [8].

NOTE—All requirements for siting hydrogen storage systems are located in and maintained by NFPA 55 [8]. Both NFPA 1 and NFPA 2 use the NFPA extract (copy and paste) policy to copy hydrogen storage system requirements so that an end user can find all the requirements in one document [6, 7]. Material copied from NFPA 55 into NFPA 1 or 2 has an extract tag identifying from which section of NFPA 55 the material is taken [8, 6, 7].

The first activity in selecting a suitable site is to determine how to meet required separation distances from on- and off-site exposures. Before taking measurements and selecting a site, the user shall determine if local codes have more stringent or additional requirements. In the absence of a local code, the supplier shall locate the hydrogen supply system to comply with NFPA 55 [8].

NFPA 55 lists minimum setback distances to exposures such as property lines, buildings, etc. NFPA 55 lists which distances can be reduced by the use of firewalls. The IFC, NFPA 1, and NFPA 2 refer to NFPA 55 for exposure distances [5, 6, 7, 8].

Setback distance tables in NFPA 55 are designed to cover a range of hazards. However, it is possible that a particular user site can have an exposure not specifically defined in NFPA 55 [8]. In such a case, the hydrogen supplier and the end user shall determine a reasonable distance and verify with the authority having jurisdiction (AHJ).

Exposure setback distances in NFPA 55 take into account:

- protection of people;
- protection of property; and
- access for emergency services.

5.2 Electrical considerations

A key consideration for locating a hydrogen system is the effect on electrical equipment, both existing components and any hardware to be installed with the hydrogen system. Fire codes and standards listed in 5.1 specify what areas shall be electrically classified as hazardous areas in accordance with NFPA 70, *National Electric Code*[®], and meet requirements of articles 500 (Hazardous (Classified) Locations, Classes I, II, and III, Divisions 1 and 2) and 501 (Class I Locations), or 505 (Class I, Zone 0, 1, and 2 Locations) of NFPA 70 [9]. The site design and location of hydrogen equipment shall ensure that all existing ordinary electrical equipment or new equipment (such as lighting, control panels, etc.) meet minimum setback distances listed previously. It is mandatory to follow these distances. If the site layout requires that new or existing electrical components be located within the electrical classified area, then the equipment shall be made suitable per requirements of 8.10 of this standard.

Hydrogen is designated a Class I, Group B material per NFPA 70 [9]. The extent of the classified area for electrical equipment depends on the particular operation. At a minimum, the Division 1 and Division 2 locations are defined as follows.

5.2.1 For liquid hydrogen systems

- Class I, Division 1, Group B:
 - Within 3 ft (0.9 m) of the following (defined in NFPA 70 where ignitable concentrations of flammable gases can exist under normal conditions) [9]:
 - Tank fill connection and any vent outlet and
 - Any points where hydrogen is vented to the atmosphere under normal operation;
- Class I, Division 2, Group B:
 - Between 3 ft (0.9 m) and 25 ft (7.6 m) of the liquid tank fill connection
 - Between 3 ft (0.9 m) and 25 ft (7.6 m) of any vent outlet and
 - Within 25 ft (7.6 m) of any portion of the bulk supply system that contains liquefied hydrogen.

5.2.2 For gaseous hydrogen systems

- Class I, Division 1, Group B:
 - Within 3 ft (0.9 m) of the following (defined in NFPA 70 where ignitable concentrations of flammable gases can exist under normal conditions) [9]:
 - Any vent outlet and
 - Any points where hydrogen is vented to the atmosphere under normal operation;
- Class I, Division 2, Group B:
 - Between 3 ft (0.9 m) and 15 ft (4.6 m) of a vent outlet and
 - Within 15 ft (4.6 m) of any portion of the bulk supply system.

5.2.3 For liquid/gaseous hybrid systems

A hybrid system consists of components that contain liquid and gaseous hydrogen. An example is a liquid hydrogen supply system that also includes a gaseous hydrogen compressor and high pressure storage vessels. See 5.2.1 for those portions that contain liquid hydrogen and 5.2.2 for those portions that contain gaseous hydrogen.

6 Developing a suitable site for a hydrogen system

6.1 General

Once a location has been determined for the hydrogen system, it is necessary to develop the site.

6.2 Building codes

Design and install foundations per American Society of Civil Engineers (ASCE) 7, *Minimum Design Loads for Buildings and Other Structures* (wind and seismic forces) and building codes adopted by the AHJ [10]. Typical building codes are the ICC *International Building Code*® and NFPA 5000, *Building Construction and Safety Code*® [11, 12]. Include any buried utilities such as power and instrument gas if needed for the hydrogen system.

6.3 Bulk liquid system

Design and install a noncombustible product transfer pad for the trailer unloading area. This pad collects and vaporizes liquefied air, which drips from the uninsulated piping of the delivery vehicle. A typical product transfer pad is made of concrete. Asphalt is not allowed because the liquid air partially vaporizes and leaves an oxygen-enriched atmosphere, which enhances combustion of the asphalt.

Liquid hydrogen supply systems shall have a minimum 12 ft x 12 ft (3.7 m x 3.7 m) noncombustible product transfer pad.

6.4 Fencing and walls

Design and build a fence around the system for security. The hydrogen system shall be fenced to protect the system from access by unauthorized personnel. A minimum of two exit gates are required, one at the fill connection and another gate allowing for alternate egress in case of emergency. All gates shall provide unobstructed exit. All gates shall be locked when the fenced site is unoccupied and unlocked and open during operations by authorized personnel.

- Main gate shall be at least 5 ft (1.5 m) wide; and
- Emergency exit gate(s) shall be at least 3 ft (0.9 m) wide.

If the site requires natural ventilation, fencing should be an open type to prevent undue restriction in ventilating the plot. Where fire barrier walls are used to reduce distances to exposures, the following requirements shall apply:

- Fire barrier walls shall have a minimum fire-resistance rating of 2 hours;
- Fire barrier wall shall interrupt the line of sight between the bulk hydrogen compressed gas system and the exposure;
- Configuration of the fire barrier shall allow natural ventilation to prevent accumulation of hazardous gas concentrations;
- Number of fire barrier walls used to separate individual systems shall be limited to three;
- Fire barrier wall shall not have more than two sides at 90 degrees (1.57 radian) directions or not more than three sides with connecting angles of 135 degrees (2.36 radian);
- Connecting angles between fire barrier walls shall be permitted to be reduced to less than 135 degrees (2.36 radian) for installations consisting of three walls when in accordance with CGA P-41, *Locating Bulk Storage Systems in Courts* [13];
- Fire barrier walls shall be designed and constructed as a structure in accordance with requirements of the building code without exceeding specified allowable stresses for materials of construction used. Structures shall be designed to resist overturning effects caused by lateral forces due to wind, soil, flood, and seismic events;

- Where clearance is required between the bulk hydrogen compressed gas system and the barrier wall for performance of service or maintenance-related activities, a minimum horizontal clearance of 5 ft (1.5 m) shall be provided between the structure and the system; and
- Fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area when the exterior building wall meets requirements for fire barrier walls.

6.5 Grounding

Design and build a grounding system with a maximum resistance to ground of 25 ohms to meet NFPA 70 grounding requirements [9]. The grounding system shall have stub-ups and ground connections located at ground connection points for all equipment, including tanks, vaporizers, pumps, compressors, equipment modules, receivers, tube trailers, vent stacks, and electrical control panels.

6.6 Design requirements

Install bumper posts or bollards at the fill connection and other parts of the hydrogen system that are exposed to vehicular traffic to protect the hydrogen system from vehicle impact.

Locate the system so water can drain away from the storage system. Avoid low spots where water can collect and present slipping hazards.

6.7 Site access

Provide access for installation, delivery, service vehicles, and personnel as required by the hydrogen supplier.

6.8 Utilities

Provide all of the following utilities as required by the hydrogen supplier:

- nitrogen;
- instrument gas;
- water; and
- electricity.

Adequate lighting shall be provided for night deliveries and maintenance of equipment.

7 Planning for compliance with OSHA and EPA regulations

7.1 Regulatory requirements

Depending on the amount of liquid and gaseous hydrogen contained in the hydrogen system and any user hydrogen storage, the liquid hydrogen installation may be subject to certain regulatory requirements that pertain to highly hazardous chemicals. Specifically, the following regulations could apply:

- Title 29 of the U.S. *Code of Federal Regulations* (29 CFR) Part 1910.119, "Process safety management of highly hazardous chemicals," referred to as OSHA Process Safety Management (PSM) [14]; and
- Title 40 of the U.S. *Code of Federal Regulations* (40 CFR) Part 68, "Chemical accident prevention provisions," referred to as EPA Risk Management Program (RMP) [15].

The responsibility for compliance with these regulations is typically that of the end user (i.e., the process owner). This position is taken because the user typically "operates" the liquid hydrogen supply systems daily and, more so than the gas supplier personnel, is the most likely to be involved in an incident involving a release. However, since industrial gas employees visit these installations periodically to perform maintenance and to deliver product into the system, the hydrogen supplier shall cooperate with users in fulfilling these regulation requirements. It is important that the user determine if these regulations apply to the hydrogen system so the user can address all requirements of regulations throughout the installation and startup phases. More details about the applicability of