

CHAPTER 7

GASEOUS HYDROGEN SYSTEMS

SECTION 701 (IFGC) GENERAL

701.1 Scope. The installation of gaseous hydrogen systems shall comply with this chapter and Chapters 30 and 35 of the *International Fire Code*. Compressed gases shall also comply with Chapter 27 of the *International Fire Code* for general requirements.

701.2 Permits. Permits shall be required as set forth in Section 106 and as required by the *International Fire Code*.

SECTION 702 (IFGC) GENERAL DEFINITIONS

702.1 Definitions. The following words and terms shall, for the purposes of this chapter and as used elsewhere in this code, have the meanings shown herein.

HYDROGEN CUTOFF ROOM. A room or space which is intended exclusively to house a gaseous hydrogen system.

HYDROGEN-GENERATING APPLIANCE. A self-contained package or factory-matched packages of integrated systems for generating gaseous hydrogen. Hydrogen-generating appliances utilize electrolysis, reformation, chemical or other processes to generate hydrogen.

GASEOUS HYDROGEN SYSTEM. An assembly of piping, devices and apparatus designed to generate, store, contain, distribute or transport a nontoxic, gaseous hydrogen containing mixture having at least 95-percent hydrogen gas by volume and not more than 1-percent oxygen by volume. Gaseous hydrogen systems consist of items such as compressed gas containers, reactors and appurtenances, including pressure regulators, pressure relief devices, manifolds, pumps, compressors and interconnecting piping and tubing and controls.

SECTION 703 (IFGC) GENERAL REQUIREMENTS

703.1 Hydrogen-generating and refueling operations. Ventilation shall be required in accordance with Section 703.1.1, 703.1.2 or 703.1.3 in public garages, private garages, repair garages, automotive motor fuel-dispensing facilities and parking garages that contain hydrogen-generating appliances or refueling systems. For the purpose of this section, rooms or spaces that are not part of the living space of a dwelling unit and that communicate directly with a private garage through openings shall be considered to be part of the private garage.

703.1.1 Natural ventilation. Indoor locations intended for hydrogen-generating or refueling operations shall be limited to a maximum floor area of 850 square feet (79 m²) and shall communicate with the outdoors in accordance with Sections 703.1.1.1 and 703.1.1.2. The maximum rated output capacity of hydrogen generating appliances shall not exceed 4 standard cubic feet per minute (0.00189 m³/s) of

hydrogen for each 250 square feet (23.2 m²) of floor area in such spaces. The minimum cross-sectional dimension of air openings shall be 3 inches (76 mm). Where ducts are used, they shall be of the same cross-sectional area as the free area of the openings to which they connect. In such locations, equipment and appliances having an ignition source shall be located such that the source of ignition is not within 12 inches (305 mm) of the ceiling.

703.1.1.1 Two openings. Two permanent openings shall be provided within the garage. The upper opening shall be located entirely within 12 inches (305 mm) of the ceiling of the garage. The lower opening shall be located entirely within 12 inches (305 mm) of the floor of the garage. Both openings shall be provided in the same exterior wall. The openings shall communicate directly with the outdoors and shall have a minimum free area of 1/2 square foot per 1,000 cubic feet (1 m²/610 m³) of garage volume.

703.1.1.2 Louvers and grilles. In calculating the free area required by Section 703.1.1.1, the required size of openings shall be based on the net free area of each opening. If the free area through a design of louver or grille is known, it shall be used in calculating the size opening required to provide the free area specified. If the design and free area are not known, it shall be assumed that wood louvers will have 25-percent free area and metal louvers and grilles will have 75-percent free area. Louvers and grilles shall be fixed in the open position.

703.1.2 Mechanical ventilation. Indoor locations intended for hydrogen-generating or refueling operations shall be ventilated in accordance with Section 502.16 of the *International Mechanical Code*. In such locations, equipment and appliances having an ignition source shall be located such that the source of ignition is below the mechanical ventilation outlet(s).

703.1.3 Specially engineered installations. As an alternative to the provisions of Section 703.1.1 and 703.1.2, the necessary supply of air for ventilation and dilution of flammable gases shall be provided by an approved engineered system.

[F] 703.2 Containers, cylinders and tanks. Compressed gas containers, cylinders and tanks shall comply with Chapters 30 and 35 of the *International Fire Code*.

[F] 703.2.1 Limitations for indoor storage and use. Flammable gas cylinders in occupancies regulated by the *International Residential Code* shall not exceed 250 cubic feet (7.1 m³) at normal temperature and pressure (NTP).

[F] 703.2.2 Design and construction. Compressed gas containers, cylinders and tanks shall be designed, constructed and tested in accordance with the Chapter 27 of the *International Fire Code*, *ASME Boiler and Pressure Vessel Code* (Section VIII) or DOTn 49 CFR, Parts 100-180.

[F] **703.3 Pressure relief devices.** Pressure relief devices shall be provided in accordance with Sections 703.3.1 through 703.3.8. Pressure relief devices shall be sized and selected in accordance with CGA S-1.1, CGA S-1.2 and CGA S-1.3. See Chapter 27 of the *Phoenix Fire Code*.

[F] **703.3.1 Valves between pressure relief devices and containers.** Valves including shutoffs, check valves and other mechanical restrictions shall not be installed between the pressure relief device and container being protected by the relief device.

[F] **703.3.2 Installation.** Valves and other mechanical restrictions shall not be located between the pressure relief device and the point of release to the atmosphere.

[F] **703.3.3 Containers.** Containers shall be provided with pressure relief devices in accordance with the ASME *Boiler and Pressure Vessel Code* (Section VIII), DOTn 49 CFR, Parts 100-180 and Section 703.3.7.

[F] **703.3.4 Vessels other than containers.** Vessels other than containers shall be protected with pressure relief devices in accordance with the ASME *Boiler and Pressure Vessel Code* (Section VIII), or DOTn 49 CFR, Parts 100-180.

[F] **703.3.5 Sizing.** Pressure relief devices shall be designed and installed in accordance with Chapter 27 of the *Phoenix Fire Code*.

[F] **703.3.6 Protection.** Pressure relief devices and any associated vent piping shall be designed, installed and located so that their operation will not be affected by water or other debris accumulating inside the vent or obstructing the vent.

[F] **703.3.7 Access.** Pressure relief devices shall be located such that they are provided with ready access for inspection and repair.

[F] **703.3.8 Configuration.** Pressure relief devices shall be arranged to discharge unobstructed in accordance with Section 2209 of the *International Fire Code*. Discharge shall be directed to the outdoors in such a manner as to prevent impingement of escaping gas on personnel, containers, equipment and adjacent structures and to prevent introduction of escaping gas into enclosed spaces. The discharge shall not terminate under eaves or canopies.

Exception: This section shall not apply to DOTn-specified containers with an internal volume of 2 cubic feet (0.057 m³) or less.

[F] **703.4 Venting.** Relief device vents shall be terminated in an approved location in accordance with Section 2209 of the *International Fire Code*.

[F] **703.5 Security.** Compressed gas containers, cylinders, tanks and systems shall be secured against accidental dislodgement in accordance with Chapter 30 of the *International Fire Code*.

[F] **703.6 Electrical wiring and equipment.** Electrical wiring and equipment shall comply with the ICC *Electrical Code*.

SECTION 704 (IFGC) PIPING, USE AND HANDLING

704.1 Applicability. Use and handling of containers, cylinders, tanks and hydrogen gas systems shall comply with this section. Gaseous hydrogen systems, equipment and machinery shall be listed or approved.

704.1.1 Controls. Compressed gas system controls shall be designed to prevent materials from entering or leaving process or reaction systems at other than the intended time, rate or path. Automatic controls shall be designed to be fail safe in accordance with accepted engineering practice.

704.1.2 Piping systems. Piping, tubing, valves and fittings conveying gaseous hydrogen shall be designed and installed in accordance with Sections 704.1.2.1 through 704.1.2.5.1, Chapter 27 of the *International Fire Code*, and ASME B31.3. Cast-iron pipe, valves and fittings shall not be used.

704.1.2.1 Sizing. Gaseous hydrogen piping shall be sized in accordance with approved engineering methods.

704.1.2.2 Identification of hydrogen piping systems. Hydrogen piping systems shall be marked in accordance with ANSI A13.1. Markings used for piping systems shall consist of the name of the contents and shall include a direction-of-flow arrow. Markings shall be provided at all of the following locations:

1. At each valve.
2. At wall, floor and ceiling penetrations.
3. At each change of direction.
4. At intervals not exceeding 20 feet (6096 mm).

704.1.2.3 Piping design and construction. Piping and tubing materials shall be 300 series stainless steel or materials listed or approved for hydrogen service and the use intended through the full range of operating conditions to which they will be subjected. Piping systems shall be designed and constructed to provide allowance for expansion, contraction, vibration, settlement and fire exposure.

704.1.2.3.1 Prohibited locations. Piping shall not be installed in or through a circulating air duct; clothes chute; chimney or gas vent; ventilating duct; dumb-waiter; or elevator shaft. Piping shall not be concealed or covered by the surface of any wall, floor or ceiling.

704.1.2.3.2 Interior piping. Except for through penetrations, piping located inside of buildings shall be installed in exposed locations and provided with ready access for visual inspection.

704.1.2.3.3 Underground piping. Underground piping, including joints and fittings, shall be protected from corrosion and installed in accordance with approved engineered methods.

704.1.2.3.4 Piping through foundation wall. Under-ground piping shall not penetrate the outer foundation or basement wall of a building.

704.1.2.3.5 Protection against physical damage. In concealed locations, where piping other than stainless steel piping, stainless steel tubing or black steel is installed through holes or notches in wood studs, joists, rafters or similar members less than 1.5 inches (38 mm) from the nearest edge of the member, the pipe shall be protected by shield plates. Shield plates shall be a minimum of $\frac{1}{16}$ -inch-thick (1.6 mm) steel, shall cover the area of the pipe where the member is notched or bored and shall extend a minimum of 4 inches (102 mm) above sole plates, below top plates and to each side of a stud, joist or rafter.

704.1.2.3.6 Piping outdoors. Piping installed above ground, outdoors, shall be securely supported and located where it will be protected from physical damage. Piping passing through an exterior wall of a building shall be encased in a protective pipe sleeve. The annular space between the piping and the sleeve shall be sealed from the inside such that the sleeve is ventilated to the outdoors. Where passing through an exterior wall of a building, the piping shall also be protected against corrosion by coating or wrapping with an inert material. Below-ground piping shall be protected against corrosion.

704.1.2.3.7 Settlement. Piping passing through concrete or masonry walls shall be protected against differential settlement.

704.1.2.4 Joints. Joints in piping and tubing in hydrogen service shall be listed as complying with ASME B31.3 to include the use of welded, brazed, flared, socket, slip and compression fittings. Gaskets and sealants used in hydrogen service shall be listed as complying with ASME B31.3. Threaded and flanged connections shall not be used in areas other than hydrogen cutoff rooms and outdoors.

704.1.2.4.1 Brazed joints. Brazing alloys shall have a melting point greater than 1,000°F (538°C).

704.1.2.4.2 Electrical continuity. Mechanical joints shall maintain electrical continuity through the joint or a bonding jumper shall be installed around the joint.

704.1.2.5 Valves and piping components. Valves, regulators and piping components shall be listed or approved for hydrogen service, shall be provided with access and shall be designed and constructed to withstand the maximum pressure to which such components will be subjected.

704.1.2.5.1 Shutoff valves on storage containers and tanks. Shutoff valves shall be provided on all storage container and tank connections except for pressure relief devices. Shutoff valves shall be provided with ready access.

704.2 Upright use. Compressed gas containers, cylinders and tanks, except those with a water volume less than 1.3 gallons (5 L) and those designed for use in a horizontal position, shall be used in an upright position with the valve end up. An upright position shall include conditions where the container, cylinder or tank axis is inclined as much as 45 degrees (0.79 rad) from the vertical.

704.3 Material-specific regulations. In addition to the requirements of this section, indoor and outdoor use of hydrogen compressed gas shall comply with the material-specific provisions of Chapters 30 and 35 of the *International Fire Code*.

704.4 Handling. The handling of compressed gas containers, cylinders and tanks shall comply with Chapter 27 of the *International Fire Code*.

SECTION 705 (IFGC) TESTING OF HYDROGEN PIPING SYSTEMS

705.1 General. Prior to acceptance and initial operation, all piping installations shall be inspected and pressure tested to determine that the materials, design fabrication and installation practices comply with the requirements of this code.

705.2 Inspections. Inspections shall consist of a visual examination of the entire piping system installation and a pressure test. Hydrogen piping systems shall be inspected in accordance with this code. Inspection methods such as outlined in ASME B31.3 shall be permitted where specified by the design engineer and approved by the code official. Inspections shall be conducted or verified by the code official prior to system operation.

705.3 Pressure tests. A hydrostatic or pneumatic leak test shall be performed. Testing of hydrogen piping systems shall utilize testing procedures identified in ASME B31.3 or other approved methods, provided that the testing is performed in accordance with the minimum provisions specified in Sections 705.3.1 through 705.4.1.

705.3.1 Hydrostatic leak tests. The hydrostatic test pressure shall be not less than one-and-one-half times the maximum working pressure, and not less than 100 psig (689.5 kPa gauge).

705.3.2 Pneumatic leak tests. The pneumatic test pressure shall be not less than one-and-one-half times the maximum working pressure for systems less than 125 psig (862 kPa gauge) and not less than 5 psig (34.5 kPa gauge), whichever is greater. For working pressures at or above 125 psig (862 kPa gauge), the pneumatic test pressure shall be not less than 110 percent of the maximum working pressure.

705.3.3 Test limits. Where the test pressure exceeds 125 psig (862 kPa gauge), the test pressure shall not exceed a value that produces hoop stress in the piping greater than 50 percent of the specified minimum yield strength of the pipe.

705.3.4 Test medium. Deionized water shall be utilized to perform hydrostatic pressure testing and shall be obtained from a potable source. The medium utilized to perform pneumatic pressure testing shall be air, nitrogen, carbon dioxide or an inert gas; oxygen shall not be used.

705.3.5 Test duration. The minimum test duration shall be $\frac{1}{2}$ hour. The test duration shall be not less than $\frac{1}{2}$ hour for each 500 cubic feet (14.2 m³) of pipe volume or fraction thereof. For piping systems having a volume of more than 24,000 cubic feet (680 m³), the duration of the test shall not be required to exceed 24 hours. The test pressure required in Sections 705.3.1 and 705.3.2 shall be maintained for the entire duration of the test.

705.3.6 Test gauges. Gauges used for testing shall be as follows:

1. Tests requiring a pressure of 10 psig (68.95 kPa gauge) or less shall utilize a testing gauge having increments of 0.10 psi (0.6895 kPa) or less.
2. Tests requiring a pressure greater than 10 psig (68.98 kPa gauge) but less than or equal to 100 psig (689.5 kPa gauge) shall utilize a testing gauge having increments of 1 psi (6.895 kPa) or less.
3. Tests requiring a pressure greater than 100 psig (689.5 kPa gauge) shall utilize a testing gauge having increments of 2 psi (13.79 kPa) or less.

Exception: Measuring devices having an equivalent level of accuracy and resolution shall be permitted where specified by the design engineer and approved by the code official.

705.3.7 Test preparation. Pipe joints, including welds, shall be left exposed for examination during the test.

705.3.7.1 Expansion joints. Expansion joints shall be provided with temporary restraints, if required, for the additional thrust load under test.

705.3.7.2 Equipment disconnection. Where the piping system is connected to appliances, equipment or components designed for operating pressures of less than the test pressure, such appliances, equipment and components shall be isolated from the piping system by disconnecting them and capping the outlet(s).

705.3.7.3 Equipment isolation. Where the piping system is connected to appliances, equipment or components designed for operating pressures equal to or greater than the test pressure, such appliances, equipment and components shall be isolated from the piping system by closing the individual appliance, equipment or component shutoff valve(s).

705.4 Detection of leaks and defects. The piping system shall withstand the test pressure specified for the test duration specified without showing any evidence of leakage or other defects. Any reduction of test pressures as indicated by pressure gauges shall indicate a leak within the system. Piping systems shall not be approved except where this reduction in pressure is attributed to some other cause.

705.4.1 Corrections. Where leakage or other defects are identified, the affected portions of the piping system shall be repaired and retested.

705.5 Purging of gaseous hydrogen piping systems. Purging shall comply with Sections 705.5.1 through 705.5.4.

705.5.1 Removal from service. Where piping is to be opened for servicing, addition or modification, the section to be worked on shall be isolated from the supply at the nearest convenient point and the line pressure vented to the outdoors. The remaining gas in this section of pipe shall be displaced with an inert gas.

705.5.2 Placing in operation. Prior to placing the system into operation, the air in the piping system shall be displaced with inert gas. The inert gas flow shall be continued without interruption until the vented gas is free of air. The inert gas shall then be displaced with hydrogen until the vented gas is free of inert gas. The point of discharge shall not be left unattended during purging. After purging, the vent opening shall be closed.

705.5.3 Discharge of purged gases. The open end of piping systems being purged shall not discharge into confined spaces or areas where there are sources of ignition except where precautions are taken to perform this operation in a safe manner by ventilation of the space, control of purging rate and elimination of all hazardous conditions.

705.5.3.1 Vent pipe outlets for purging. Vent pipe outlets for purging shall be located such that the inert gas and fuel gas is released outdoors and not less than 8 feet (2438 mm) above the adjacent ground level. Gases shall be discharged upward or horizontally away from adjacent walls to assist in dispersion. Vent outlets shall be located such that the gas will not be trapped by eaves or other obstructions and shall be at least 5 feet (1524 mm) from building openings and lot lines of properties that can be built upon.

705.5.4 Placing equipment in operation. After the piping has been placed in operation, all equipment shall be purged in accordance with Section 707.2 and then placed in operation, as necessary.

SECTION 706 (IFGC) LOCATION OF GASEOUS HYDROGEN SYSTEMS

[F] 706.1 General. The location and installation of gaseous hydrogen systems shall be in accordance with Sections 706.2 and 706.3.

Exception: Stationary fuel-cell power plants in accordance with Section 633.

[F] 706.2 Indoor gaseous hydrogen systems. Gaseous hydrogen systems shall be located in indoor rooms or areas in accordance with one of the following:

1. Inside a building in a hydrogen cutoff room designed and constructed in accordance with Section 420 of the *International Building Code*;
2. Inside a building not in a hydrogen cutoff room where the gaseous hydrogen system is listed and labeled for indoor installation and installed in accordance with the manufacturer's installation instructions; and
3. Inside a building in a dedicated hydrogen fuel dispensing area having an aggregate hydrogen delivery capacity not

greater than 12 SCFM and designed and constructed in accordance with Section 703.1.

[F] 706.3 Outdoor gaseous hydrogen systems. Gaseous hydrogen systems shall be located outdoors in accordance with Section 2209.3.2 of the *International Fire Code*.

**SECTION 707 (IFGC)
OPERATION AND MAINTENANCE OF
GASEOUS HYDROGEN SYSTEMS**

[F] 707.1 Maintenance. Gaseous hydrogen systems and detection devices shall be maintained in accordance with the *International Fire Code* and the manufacturer's installation instructions.

[F] 707.2 Purging. Purging of gaseous hydrogen systems, other than piping systems purged in accordance with Section 705.5, shall be in accordance with Section 2211.8 of the *International Fire Code* or in accordance with the system manufacturer's instructions.

**SECTION 708 (IFGC)
DESIGN OF LIQUEFIED HYDROGEN SYSTEMS
ASSOCIATED WITH HYDROGEN
VAPORIZATION OPERATIONS**

[F] 708.1 General. The design of liquefied hydrogen systems shall comply with Chapter 32 of the *International Fire Code*.

