Hydrogen and the Built Environment

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INSTRUCTOR

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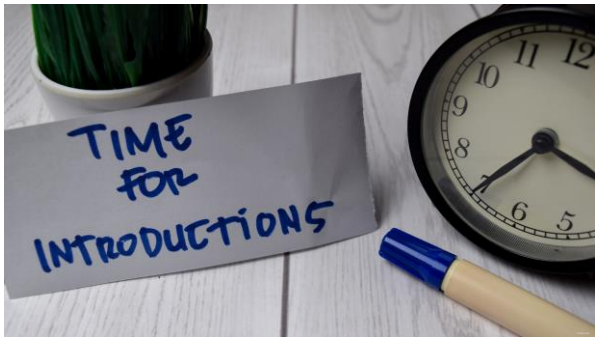

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GOAL & OBJECTIVES

Goal: Develop an understanding of hydrogen's role in global efforts of decarbonization, the US federal investments in regional clean hydrogen hubs, and the role of codes and standards in the built environment.

1) Understanding contributors for the recent advancement and investment in hydrogen use.
2) Create awareness on the future of hydrogen use and its introduction in the built environment.
3) Review actions taken by the International Code Council to address the expanding hydrogen industry and its role in decarbonization.
4) Reviewing Codes and Standards for Gaseous Hydrogen Implementation in the Built Environment.

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Course Elements

1. US Federal actions taken to meet Paris Agreement commitments.
2. Facts about Hydrogen
3. ICC's role in the safe use of hydrogen.
4. Regulatory requirement overview of Codes and Standards

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What are the first thoughts you have when you hear the word hydrogen?

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Why Hydrogen?
Why Now?

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Credit
UNFCCC

The Paris Agreement | UNFCCC

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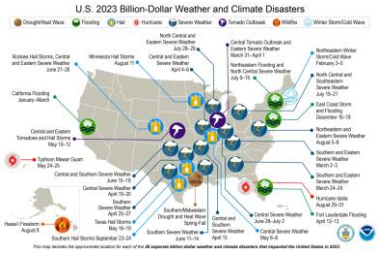
Image Credit: NOAA/NCEI



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US Bipartisan Infrastructure Law's 9.5 Billion for Clean Hydrogen Initiatives

The Bipartisan Infrastructure Law includes $8 billion for Regional Clean Hydrogen Hubs expecting to create jobs to expand use of clean hydrogen in the industrial sector and beyond.

$1 billion for a Clean Hydrogen Electrolysis Program to reduce costs of hydrogen produced from clean electricity.

$500 million for Clean Hydrogen Manufacturing and Recycling Initiatives to support equipment manufacturing and strong domestic supply chains.

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U.S. National Clean Hydrogen Strategy and Roadmap

- The U.S. National Clean Hydrogen Strategy and Roadmap is a national framework for facilitating large-scale production, processing, delivery, storage, and use of clean hydrogen to help meet decarbonization goals across virtually all sectors of the economy.
- Mandatory update at least every 3 years.

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Decarbonization Targets

- The hydrogen technology investments from the Bipartisan Infrastructure Law plan to decarbonize multiple industries:
  - The industrial sector, which accounts for a third of domestic carbon emissions.
  - Steel manufacturing
  - Industrial Heat
  - Bio/synthetic fuels using hydrogen
  - Medium and Heavy-duty transportation
  - Rail
  - Maritime
  - Aviation
  - Offroad equipment (mining, construction, agriculture)
  - Natural Gas/Hydrogen Blending
  - Building or district heating for hard to electrify areas.
- Today, the U.S. produces about 10 million metric tons of hydrogen annually, most of which is produced from natural gas through steam methane reforming, compared to approximately 90 million tons produced per year globally.

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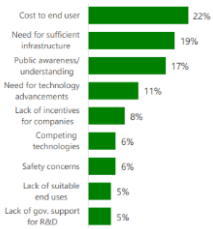
Challenges for Hydrogen



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Source: Office of Clean Energy Demonstrations.

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Mid-Atlantic Regional Hydrogen Hub

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Mid-Atlantic Regional Hydrogen Hub

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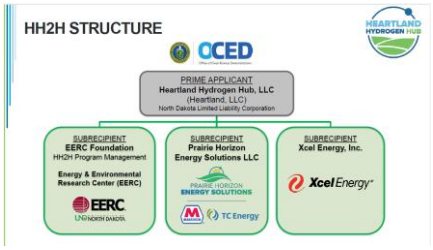
Heartland Regional Hydrogen Hub



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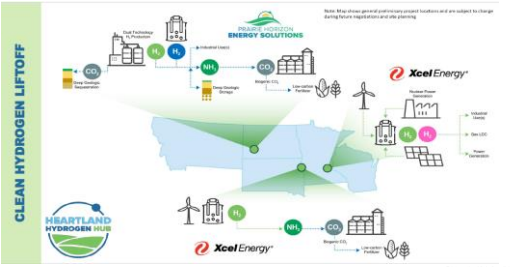
Heartland Regional Hydrogen Hub



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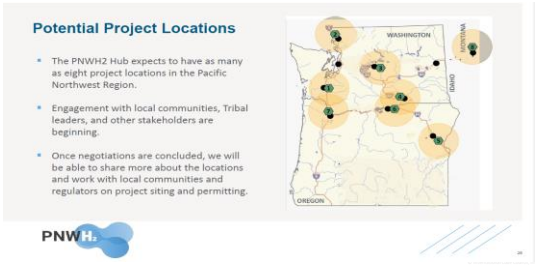
Pacific Northwest Regional Hydrogen Hub



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Pacific Northwest Regional Hydrogen Hub

Projected Environmental Outcomes

End Use Application	GHG Expected Reductions (MT/yr)
Long Duration Energy Storage	465,375
Refineries	419,750
HD trucking – GH2	189,425
HD trucking – LH2	120,085
HD trucking – mining	5,110
MD transportation (transit buses)	58,400
Regional aviation	3,285
Ferries and maritime	10,220
Light industrial	72,635
Fertilizer production	404,785
Total	1,649 MMT/yr

PNWH2

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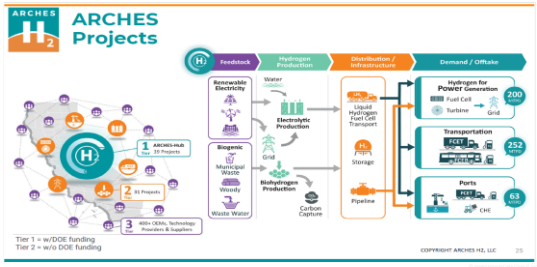
California Regional Hydrogen Hub



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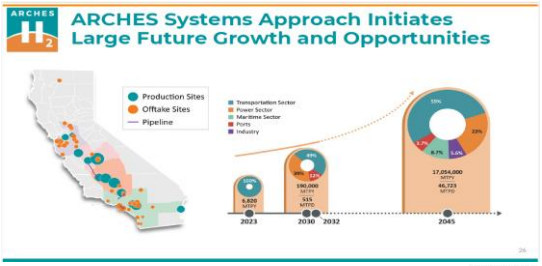
California Regional Hydrogen Hub



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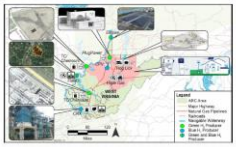
Appalachian Hydrogen Hub

ARCH2 Project Summaries

- **CNX/ TransGas:** Low-CI ammonia production
- **TC Energy/ Chemours**: Electrolysis-based H2 production in two chemical facilities
- **Fidelis / Mountaineer GigaSystem**: NG + biomass to produce Low CI H2 for datacenters, other off-takers.
- **HLA:** H2 off-taker: H2 use as fuel for off-site aggregate delivery trucks and on-site haul trucks/equipment.
- **Hope Gas/ WATT Fuel Cell Corp / EQT**: Produce clean H2 from NG for blending in Hope local distribution system and residential fuel cells.
- **Empire Diversified Energy**: Anaerobically digested food waste based H2 production for industrial and transportation fuel.
- **Plug Power/ Amazon:** Green H2 production facility in northern WV.



Note: Proposed project locations based on preliminary siting are subject to change during the detailed planning phase (phase 1).

Re-energizing Appalachia
Economically • Socially • Environmentally

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Appalachian Hydrogen Hub

ARCH2 Project Summaries

- **MPLX:** H$_2$ storage facility development with connective infrastructure to support ARCH2 producers, storage, and end-users
- **Dominion Energy Ohio:** H2 production with CO$_2$ capture to supply H$_2$ to regional transit (e.g., SARTA)
- **Plug Power/ Amazon:** One distribution center with H$_2$ fueling MHE; fueling station FCEV delivery trucks.
- **First Mode:** H$_2$ end-user: Manufacturing facility for retrofitting mining trucks with H$_2$ fuel cell power system.
- **Independence Hydrogen:** H2 production facility using industrial off-gas as feedstock in Ashtabula, Ohio to provide clean hydrogen for material handling equipment at distribution centers.

Note: Proposed project locations based on preliminary siting are subject to change during the detailed planning phase (phase 1).

Re-energizing Appalachia
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Appalachian Hydrogen Hub

ARCH2 Project Summaries

- **EQT-GTL:** Low-carbon NG and renewable natural gas (RNG) (as required) to produce low-carbon aviation fuel.
- **Air Liquide** - Liquified H2 facility in southwest PA to serve as an offtake for EQT's excess hydrogen to be used in the mobility sector.
- **KeyState:** H$_2$ production plus other products (NH3, urea/diesel exhaust fluid (DEF))

Note: Proposed project locations based on preliminary siting are subject to change during the detailed planning phase (phase 1).

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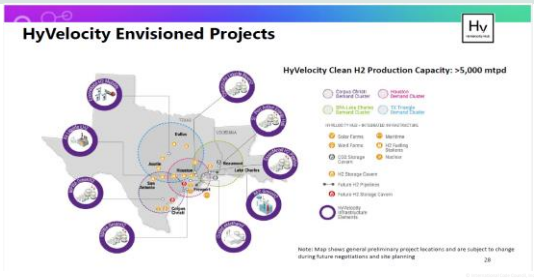
Gulf Coast Hydrogen Hub



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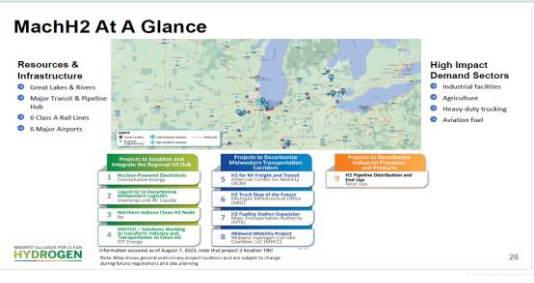
Midwest Regional Hydrogen Hub



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KEY POINTS

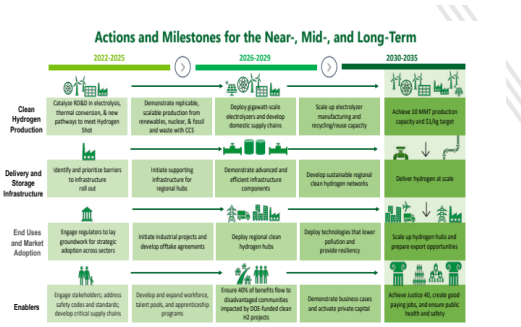

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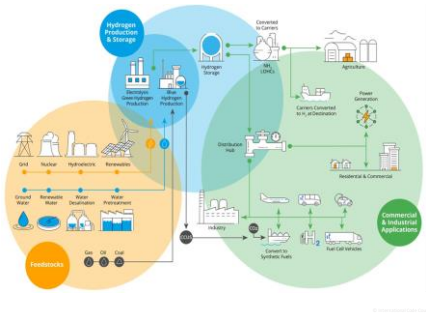
Image courtesy of Black & Veatch



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What is Carbon Capture?

Carbon capture image courtesy of US Dept. of Energy

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Carbon Capture Methods

- **Storage/sequestration (CCS)** currently most common discussed process.
- **Carbon capture and utilization (CCU)** utilized for various purposes such as fuel or fertilizer production without being stored.
- **Carbon capture, utilization, and storage/sequestration (CCUS)** combines both approaches.

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Exxon mobile carbon capture and storage hub rendition:
lowcarbon.exxonmobile.com

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REALITY CHECK

Why Does This Matter?

- How familiar are you with the use of hydrogen?
- What information would you ask for to issue a building permit for a hydrogen project?
- As companies commit to decarbonization, small scale projects will become more commonplace.
- Do you know of any hydrogen projects upcoming or underway in your areas?

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Examples of Hydrogen Projects in the US

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Facts About Hydrogen

Abundance	Atomic Weight	Characteristics	BTU Value Comparison
Hydrogen is the most abundant element in the universe, three times more abundant than helium (the second most widely occurring element).	1.008 Due to its atomic weight, hydrogen is 14 times lighter than air.	Hydrogen is colorless, odorless, tasteless and nontoxic. Hydrogen molecules are also much smaller than traditional fossil fuels making material selection critical for its safe use.	Hydrogen Lower Heating Value (LVH) @77˚ F (BTU/ft3) 266 Natural Gas Lower Heating Value (LVH) @77˚ F (BTU/ft3) 881

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Hydrogen Transportation

- Gaseous hydrogen is liquefied by cooling it below -423˚F (-253˚C). Once hydrogen is liquified it can be stored in insulated tanks.
- Currently, for shorter distances, hydrogen is typically transported in the gaseous state by tube trailers, for longer distances, hydrogen is transported as a liquid in super-insulated, cryogenic tanker trucks.
- After liquefaction, the liquid hydrogen is dispensed to delivery trucks and transported to distribution sites where it is vaporized to a high-pressure gaseous form for dispensing.
- US regional hydrogen hubs will incorporate transmission lines from production facilities creating the infrastructure needed to reduce transportation costs which will allow for expansion of the use of hydrogen across many sectors.

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Content Review

- What are the driving forces triggering the expansion of the hydrogen industry?
- What is the name of the guiding document developed for deployment of hydrogen hubs across the US?
- How many extreme weather events were recorded in 2023 which broke the previous record occurring in 2020?
- What is the term referred to for carbon capture storage?
- What are some of the characteristics of hydrogen identified?

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The I-Codes play an important role in the safe installation of gaseous hydrogen systems.

- IFC, IBC, IRC, IFGC, and IMC all contain provisions on gaseous hydrogen.
- Key standards: NFPA 2, NFPA 55, ASME B31.3, ASME B31.12, ANSI A13.1, and CGA S-1.1, S-1.2, S-1.3.
- ICC's participation in the development of hydrogen standards for appliances, equipment, and piping systems extends globally.
- ICC's efforts to support the international harmonization of standards are currently underway.

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International Code Council Hydrogen Activities

ICC participation in development of Canadian and US National Hydrogen Code and Standards Strategy and Roadmaps.

ICC's membership to the Center for Hydrogen Safety

ICC participates in the development of CSA, NFPA, and ASTM standards for hydrogen and hydrogen admixtures with natural gas requirements.

ICC PMG Code Action Committee formation of Hydrogen Working Group tasked with developing requirements to address hydrogen admixtures with natural gas for use in the built environment.

Early stages of development for hydrogen tools including best practices, permitting, and inspection guidance.

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ICC PMG CAC H2 Working Group 2027 IFGC/IFC code proposal review

Proposed revisions to the 2027 IFGC:

101.2.2.1 Systems where hydrogen admixtures greater than 5-percent are supplied..

Fuel gas, where hydrogen admixtures are delivered, shall meet the requirements of Chapters 3, 4, 5, and 6 for the supplier-defined hydrogen admixture limits, expressed in volume concentration of gaseous hydrogen for service up to the defined hydrogen admixture limits.

107.1.1 Fuel gases..

Where hydrogen admixtures are supplied, the code official shall be provided with compositional description of the fuel gas.

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Item 2 IFGC Part I Update Hydrogen Blending Provisions

- **Revise as follows:**

FUEL GAS. A natural gas, manufactured gas, liquefied petroleum gas or mixtures of these gases including up to 5-percent hydrogen gas by volume.

- **Add new definition as follows:**

HYDROGEN ADMIXTURE. Fuel gas to which hydrogen is blended or mixed by the fuel supplier or at the point of delivery greater than 5% and less than 95%.

301.3.1 Appliances and equipment listed and labeled for use with hydrogen admixture..
Appliances and equipment operating on hydrogen admixtures shall be listed and labeled for operation on the hydrogen admixture limits defined under Section 101.2.1.1.

301.3.2 Piping systems listed and labeled for use with hydrogen admixture..
Piping systems and fuel gas system components shall be listed and labeled for the applicable hydrogen admixture limits.

301.5 Label information. A permanent factory-applied nameplate(s) shall be affixed to appliances on which shall appear in legible lettering, the manufacturer's name or trademark, the model number, serial number and, for listed appliances, the seal or mark of the testing agency. A label shall include the hourly rating in British thermal units per hour (Btu/h) (W); the type of fuel(ses) approved for use with the appliance; and the minimum clearance requirements.

634.1 Installation.
The installation of gaseous hydrogen systems shall be in accordance with ~~the applicable requirements~~ Chapter 7 of this code, the International Fire Code, ~~and~~ the International Building Code, and NFPA 2.

701.1 Scope.
The installation of gaseous hydrogen systems shall comply with this chapter, and Chapters 53 and 58 of the International Fire Code and NFPA 2. Compressed gases shall also comply with Chapter 50 of the International Fire Code for general requirements.

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~~ NFPA 2 and then placed in operation, as necessary.

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PMG/FC CAC Item 2 IFGC Part II Update Hydrogen Blending Provisions

Revise as follows:

[F] 633.1 General. Stationary fuel-cell power systems having a power output not exceeding 10 MW shall be tested listed in accordance with ANSI/CSA FC 1 and shall be installed in accordance with the manufacturer's instructions, NFPA 853, the International Building Code and the International Fire Code . Hydrogen fuel cell power systems shall also comply with Chapter 7 of this code and NFPA 2.

[F] 703.4 Venting.
Relief device vents shall be terminated in an approved location in accordance with ~~Section 2309 of the International Fire Code~~ NFPA 2.

[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] 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 and NFPA 2.

[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 Sections 2309.6 and 2309.6.1 of the International Fire Code or in accordance~~ with the system manufacturer's instructions and NFPA 2.

[F] 708.1 General.
The design of liquefied hydrogen systems shall comply with Chapters 55 and 58 of the International Fire Code and NFPA 2.

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2024 IFGC Chapter 1 Scope and Administration

[A] 101.2.2 Gaseous hydrogen systems.
Gaseous hydrogen systems shall be regulated by Chapter 7.

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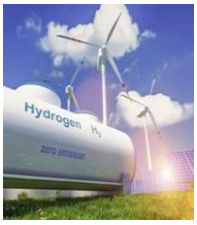
[A] 101.2.5 Systems, appliances and equipment outside the scope.



5. **Industrial gas applications** using gases such as acetylene and acetylenic compounds, hydrogen, ammonia, carbon monoxide, oxygen and nitrogen.

10. *Fuel gas piping* in **power and atomic energy plants.**

15. **Installation of** hydrogen gas, *LP-gas* and compressed natural gas (CNG) **systems on vehicles.**

19. Portable fuel cell *appliances* **that are neither connected** to a fixed *piping* system nor interconnected to a power grid.

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IFGC Chapter 7 Gaseous Hydrogen Section 701 General

701.1 Scope.
The installation of gaseous hydrogen systems shall comply with this chapter and Chapters 53 and 58 of the *International Fire Code*. Compressed gases shall also comply with Chapter 50 of the *International Fire Code* for general requirements.

701.2 Permits.
Permits shall be required as set forth in Section 105 and as required by the *International Fire Code*.

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Section 702 General Definitions

[F] 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.

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IFGC Chapter 7 Definitions

- **[F] HYDROGEN FUEL-GAS ROOM.** A room or space that 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.

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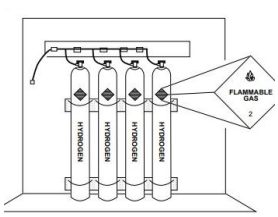
Section 703 General Requirements



703.1 Hydrogen-generating and refueling operations. Hydrogen-generating and refueling *appliances* shall be installed and located in accordance with their listing and the manufacturer's instructions. Exhaust ventilation shall be required in public garages, private garages, repair garages, automotive motor fuel-dispensing facilities and parking garages that contain hydrogen-generating appliances or refueling systems in accordance with NFPA 2. 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.

[F] 703.2 Containers, cylinders and tanks. Compressed gas containers, cylinders and tanks shall comply with Chapters 53 and 58 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 Chapter 50 of the International Fire Code, ASME Boiler and Pressure Vessel Code (Section VIII) or DOTn 49 CFR, Parts 100-180.

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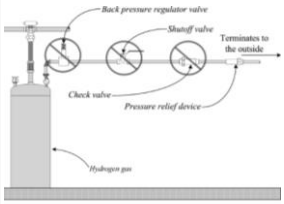
Pressure relief devices.



Valves prohibited between a relief valve and container

[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.

[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.

Exception: A locked-open shutoff valve on containers equipped with multiple pressure relief device installations where the arrangement of the valves provides the full required flow through the minimum number of required relief devices at all times.

[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.

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Section 704 Piping, Use and Handling

- **Key Requirements**
  - Piping, tubing, valves and fittings shall be sized in accordance with approved engineering methods.
  - Hydrogen Piping systems shall be marked in accordance with ANSI A13.1.
    - Markings shall consist of the name of the contents and shall include a direction-of-flow arrow.
    - Markings shall be provided at each valve, wall, floor and ceiling penetration, change of direction, and at intervals not exceeding 20'.
  - Piping and tubing materials shall be 300 series stainless steel, or materials *listed* or *approved* for hydrogen service and intended for operating conditions to which they will be subjected. Piping shall not be installed in or though a circulating air duct; chimney or gas vent; ventilating duct; dumbwaiter; or elevator shaft.
  - Piping shall not be concealed or covered by the surface of any wall, floor or ceiling.
  - Piping shall not penetrate the outer foundation or basement wall of any building.

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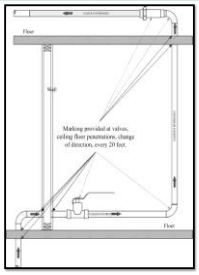
ANSI A13.1 Scheme for the identification of Piping Systems.



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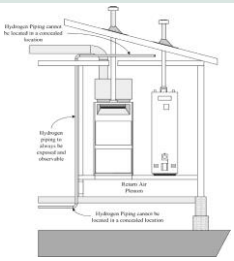
Section 704 Piping, Use and Handling

- Except for through penetrations, *piping* located inside of buildings shall be installed in exposed locations and provided with ready *access* for visual inspection.
  - Piping installed indoors shall not be concealed.
- Underground *piping* shall not penetrate the outer foundation or basement wall of a building.



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Section 704 Piping, Use and Handling

- 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 B31.12. Threaded and flanged connections shall not be used in areas other than hydrogen cutoff rooms and outdoors.
  - Brazing alloys shall have a melting point greater than 1,000°F (538°C).
  - Mechanical joints shall maintain electrical continuity through the joint or a bonding jumper shall be installed around the joint.

All joining methods for piping and tubing must be listed as complying with the referenced standards, including welded, brazed, flared, socket, slip or compression fittings.

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Electrical Continuity

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.

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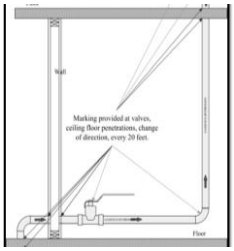
Valves and Piping Components

- **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 with-stand 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.*



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Testing and Inspections

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Section 705 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.

705.3 Pressure tests.
A hydrostatic or pneumatic leak test shall be performed.

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Testing Continued

- **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.

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Testing Continued

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 $^1/_2$ hour. The test duration shall be not less than $^1/_2$ 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*.

62

Section 706 Location of Gaseous Hydrogen Systems

- **[F] 706.2 Indoor gaseous hydrogen systems.**
Gaseous hydrogen systems shall be located in indoor rooms or areas constructed in accordance with this code, the *International Building Code*, the *International Mechanical Code* or NFPA 2.

- **[F] 706.3 Outdoor gaseous hydrogen systems.**
Gaseous hydrogen systems shall be located outdoors in accordance with Section 2309.3.1.1 of the *International Fire Code*.

63

Section 707 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 Sections 2309.6 and 2309.6.1 of the *International Fire Code* or in accordance with the system manufacturer's instructions.

64

Section 708 Design of Liquified Hydrogen Systems Associated with Hydrogen Vaporization Operations.

- **[F] 708.1 General.**
The design of liquefied hydrogen systems shall comply with Chapter 55 of the *International Fire Code*.

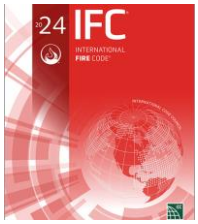
65

Let's Review

- How many of the I-Codes have hydrogen provisions?
- What percent of hydrogen admixtures with natural gas to the hydrogen PMG Code Action Committee proposals intent to regulate?
- What standard is referenced for hydrogen piping marking requirements?
- How many cubic feet of hydrogen stored indoors at normal temperature and pressure (NTP), are allowed to be stored in accordance with the IRC?
- Hydrostatic test pressure on hydrogen piping systems shall be how many times greater than the maximum working pressure, and not less than how many psig?

66

International Fire Code Permit Requirements



105.5.9 Compressed gases.
An operational permit is required for the storage, use or handling at *normal temperature and pressure* (NTP) of *compressed gases* in excess of the amounts listed in Table 105.5.9.

TABLE 105.5.9
PERMIT AMOUNTS FOR COMPRESSED GASES

Type of Gas	Amount (cubic feet at NTP)
Flammable	200

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IFC Definitions

COMPRESSED GAS.
A material, or mixture of materials that:
1. Is a gas at 68°F (20°C) or less at 14.7 psia (101 kPa) of pressure; and
2. Has a *boiling point* of 68°F (20°C) or less at 14.7 psia (101 kPa) which is either liquefied, nonliquefied or in solution, except those gases which have no other health- or physical-hazard properties are not considered to be compressed until the pressure in the packaging exceeds 41 psia (282 kPa) at 68°F (20°C).

CONTROL AREA. Spaces within a building where quantities of hazardous materials not exceeding the *maximum allowable quantities per control area* are stored, dispensed, used or handled. See also the definition of "*Outdoor control area*."

MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA. The maximum amount of a hazardous material allowed to be stored or used within a *control area* inside a building or an *outdoor control area*. The maximum allowable quantity per *control area* is based on the material state (solid, liquid or gas) and the material storage or use conditions.

OUTDOOR CONTROL AREA. An outdoor area that contains hazardous materials in amounts not exceeding the maximum allowable quantities of Table 5003.1.1(3) or Table 5003.1.1(4).

68

Section 5003

- **5003.1 Scope.**

The storage, use and handling of all hazardous materials shall be in accordance with this section.

- **5003.1.1 Maximum allowable quantity per control area.**

The *maximum allowable quantity per control area* shall be as specified in Tables 5003.1.1(1) through 5003.1.1(4).

For retail and wholesale storage and display in Group M occupancies and Group S storage, see Section 5003.11.


TABLE 5003.1.1(1)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD[a, b, c, h, i, j]

MATERIAL	CLASS	GROUP WHEN THE MAXIMUM ALLOWABLE QUANTITY IS EXCEEDED	STORAGE[d]			USE-CLOSED SYSTEMS[e]			USE-OPEN
			Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet
Flammable gas	Gaseous	H-2	NA	NA	1,000[f, g]	NA	NA	1,000[f, g]	NA
	Liquefied			(150)[f, g]	NA		(150)[f, g]	NA	

a. The aggregate quantity in use and storage shall not exceed the quantity listed for storage.
d. Maximum allowable quantities shall be increased 100 percent in buildings equipped throughout with an approved automatic sprinkler system in accordance with Section 903.3.1.1. Where Note e applies, the increase for both notes shall be applied accumulatively.
e. Maximum allowable quantities shall be increased 100 percent where stored in approved storage cabinets, day boxes, gas cabinets, gas rooms, exhausted enclosures or in listed safety cans in accordance with Section 307.1.1.2. Where Note d applies, the increase for both notes shall be applied accumulatively.

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IBC Occupancy Classification H-2

203.6.4 High-hazard Group H-2.

Buildings and structures containing materials that pose a deflagration hazard or a hazard from accelerated burning shall be classified as Group H-2. Such materials shall include, but not be limited to, the following:

- Class I, II or IIIA flammable or combustible liquids that are used or stored in normally open containers or systems, or in closed containers or systems pressurized at more than 15 pounds per square inch gauge (103.4 kPa)
- Combustible dusts where manufactured, generated or used in such a manner that the concentration and conditions create a fire or explosion hazard based on information prepared in accordance with Section 414.1.3 of the International Building Code
- Cryogenic fluids, flammable
- Category 1A flammable gases
- Category 1B flammable gases having a burning velocity greater than 3.9 inches per second (99 mm/s)
- Organic peroxides, Class I
- Oxidizers, Class 3, that are used or stored in normally open containers or systems, or in closed containers or systems pressurized at more than 15 pounds per square inch gauge (103 kPa)
- Pyrophoric liquids, solids and gases, nondetonable
- Unstable (reactive) materials, Class 3, nondetonable
- Water-reactive materials, Class 3

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Maximum Allowable Quantities Outdoors

CONTROL AREA. Spaces within a building where quantities of hazardous materials not exceeding the *maximum allowable quantities per control area* are stored, dispensed, used or handled. See also the definition of "*Outdoor control area*."

OUTDOOR CONTROL AREA. An outdoor area that contains hazardous materials in amounts not exceeding the maximum allowable quantities of Table 5003.1.1(3) or Table 5003.1.1(4).

MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA. The maximum amount of a hazardous material allowed to be stored or used within a *control area* inside a building or an *outdoor control area*. The maximum allowable quantity per *control area* is based on the material state (solid, liquid or gas) and the material storage or use conditions.

TABLE 5003.1.1(3)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD IN AN OUTDOOR CONTROL AREA[a, b, c, d, e]

MATERIAL	CLASS	STORAGE[f]			USE-CLOSED SYSTEMS[f]			USE-OPEN SYSTEMS[f]	
		Solid pounds (cubic feet)	Liquid gallons (pounds)[g]	Gas cubic feet at NTP	Solid pounds (cubic feet)	Liquid gallons (pounds)[g]	Gas cubic feet at NTP	Solid pounds (cubic feet)	Liquid gallons (pounds)[g]
Flammable gas	Gaseous								
	1A and 1B (High BV)[i]	Not Applicable	Not Applicable	3,000	Not Applicable	Not Applicable	1,500	Not Applicable	Not Applicable
	1B (Low BV)[i]			100,000			67,500		
	Liquefied								
	1A and 1B (High BV)[i]		(300)	Not Applicable		(150)	Not Applicable		
	1B (Low BV)[i]		(20,000)			(13,500)			

For SI: 1 pound = 0.454 kg, 1 gallon = 3.785 L, 1 cubic foot = 0.0283 m³.

a. For gallons of liquids, divide the amount in pounds by 10 in accordance with Section 5003.1.2.

b. The aggregate quantities in storage and use shall not exceed the maximum allowable quantity for storage, including applicable increases.

c. The aggregate quantity of nonflammable solid and nonflammable or noncombustible liquid hazardous materials allowed in outdoor storage per single property under the same ownership or control used for retail or wholesale sales is allowed to exceed the maximum allowable quantity per control area where such storage is in accordance with Section 5003.11.

d. Quantities in parentheses include quantity units in parentheses at the head of each column.

e. "High BV" Category 1B flammable gas has a burning velocity greater than 3.9 inq (10 cmq). "Low BV" Category 1B flammable gas has a burning velocity of 3.9 inq (10 cmq) or less.

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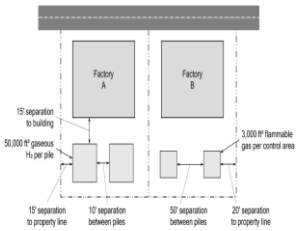
Example: NFPA 2 compared to IFC Chapter 50 Outdoor Location Requirements

- ***Outdoor control areas.*** *Outdoor control areas for hazardous materials shall be in accordance with the following general requirements…*
- (See IFC Section 5003.12 for requirements.)
- ***Outdoor storage location.*** *Outdoor storage areas for hazardous materials shall be located as required by Section 5003.12 except where material-specific requirements, including requirements in referenced standards, are provided in other chapters of this code.*
- ***Outdoor location.*** *Outdoor handling areas for hazardous materials shall be located as required by Section 5003.12 except where material-specific requirements, including requirements in referenced standards, are provided in other chapters of this code.*



For SI: 1 foot = 304.8 mm, 1 cubic foot = 0.0283 m³.

Factory A has complied with the requirements in NFPA 2 for hydrogen gas and Factory B has complied with the requirements in Chapter 50 for flammable gas in an outdoor control area.

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Hazardous Materials

5004.5 Automatic sprinkler systems.
Indoor storage areas and storage buildings shall be equipped throughout with an *approved automatic sprinkler system* in accordance with Section 903.3.1.1. The design of the sprinkler system shall be not less than that required for Ordinary Hazard Group 2 with a minimum design area of 3,000 square feet (279 m^2). Where the materials or storage arrangement are required by other regulations to be provided with a higher level of sprinkler system protection, the higher level of sprinkler system protection shall be provided.

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Ventilation

- **5004.7 Standby or emergency power.**
- Where mechanical ventilation, treatment systems, temperature control, alarm, detection or other electrically operated systems are required, such systems shall be provided with an emergency or standby power in accordance with Section 1203.

74

Flammable Gases and Flammable Cryogenic Fluids

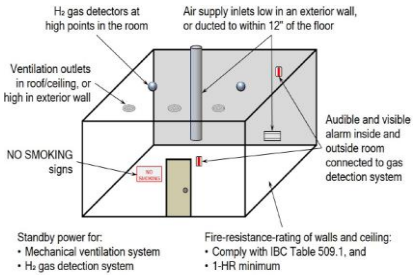
5801.1 Scope.
The storage and use of flammable gases and flammable cryogenic fluids shall be in accordance with this chapter, NFPA 2 and NFPA 55. Compressed gases shall also comply with Chapter 53 and cryogenic fluids shall also comply with Chapter 55. Flammable cryogenic fluids shall comply with Section 5806. Hydrogen motor fuel-dispensing stations and repair garages and their associated above-ground hydrogen storage systems shall also be designed, constructed and maintained in accordance with Chapter 23.

Exceptions:

1. Gases used as refrigerants in refrigeration systems (see Section 608).
2. Liquefied petroleum gases and natural gases regulated by Chapter 61.
3. Fuel-gas systems and appliances regulated under the International Fuel Gas Code other than gaseous hydrogen systems and appliances.
4. Pyrophoric gases in accordance with Chapter 64.

75

Section 5808.1 Safety features in a hydrogen fuel gas room.



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IFC Section 5808 Hydrogen Fuel Gas Rooms

5808.2 Location	5808.3 Design and Construction	5808.3.1 Pressure Control	5808.4 Exhaust Ventilation
Hydrogen fuel gas rooms shall not be located below grade.	Hydrogen fuel gas rooms not exceeding the *maximum allowable quantity per control area* in Table 5003.1.1(1) shall be separated from other areas of the building in accordance with Section 509.1 of the *International Building Code*.	Hydrogen fuel gas rooms shall be provided with a ventilation system designed to maintain the room at a negative pressure in relation to surrounding rooms and spaces.	Hydrogen fuel gas rooms shall be provided with mechanical exhaust ventilation in accordance with the applicable provisions of Section 2311.8.2.

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Hydrogen Fuel Gas Rooms Continued

- **5808.5 Gas detection system.**

  Hydrogen fuel gas rooms shall be provided with a gas detection system that complies with Sections 916, 5808.5.1 and 5808.5.2.

- **5808.5.2 Failure of the gas detection system.**

  - Failure of the gas detection system shall automatically activate the mechanical exhaust ventilation system, stop hydrogen generation and cause a trouble signal to sound at an *approved* location.

- **5808.5.1 System activation.**

  Activation of a gas detection system alarm shall result in both of the following:

  1. Initiation of distinct audible and visible alarm signals both inside and outside of the hydrogen fuel gas room.
  2. Automatic activation of the mechanical exhaust ventilation system.

- **5808.6 Explosion control.**

  Explosion control shall be provided where required by Section 911.

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IFC 5808.6 Explosion control.
Explosion control shall be provided where required by Section 911.

911.1 General.
Explosion control shall be provided in the following locations:

1. Where a structure, room or space is occupied for purposes involving explosion hazards as identified in Table 911.1.

2. Where quantities of hazardous materials specified in Table 911.1 exceed the maximum allowable quantities in Table 5003.1.1(1).

Such areas shall be provided with explosion (*deflagration*) venting, explosion (*deflagration*) prevention systems or *barricades* in accordance with this section and NFPA 68, NFPA 69 or NFPA 495 as applicable.

Deflagration venting shall not be utilized as a means to protect buildings from *detonation* hazards.

TABLE 911.1 EXPLOSION CONTROL REQUIREMENTS[f]

MATERIAL	CLASS	EXPLOSION CONTROL METHODS	
		Barricade construction	Explosion (deflagration) venting or explosion (deflagration) prevention systems
Hazard Category			
Flammable gas	Gaseous	Not required	Required
	Liquefied	Not required	Required

f. Explosion venting is not required for Group H-5 Fabrication Areas complying with Chapter 27 and the International Building Code.

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Section 5808
Hydrogen Fuel
Gas Rooms

5808.7 Standby power.
Mechanical ventilation and *gas detection systems* shall be connected to a standby power system in accordance with Section 1203.

Summary of Key Requirements:

1. Stationary Standby Power Generators shall be listed in accordance with UL 2200.
2. Fuel lines supplying a generator set inside of high-rise building shall be separated from areas of the building other than the room the generator is located in accordance with 1203.1.2.
3. Standby power systems must be installed in accordance with IBC, NFPA 70, NFPA 110, and NFPA 111.
4. Standby power must be provided within 60 second of primary power failure in accordance with NFPA 70.
5. Must provide power for a minimum of 2 hours without refueling or recharging.

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International Building Code Table 509.1

TABLE 509.1
INCIDENTAL USES

ROOM OR AREA	SEPARATION AND/OR PROTECTION
Furnace room where any piece of equipment is over 400,000 Btu per hour input	1 hour or provide automatic sprinkler system
Rooms with boilers where the largest piece of equipment is over 15 psi and 10 horsepower	1 hour or provide automatic sprinkler system
Refrigerant machinery room	1 hour or provide automatic sprinkler system
Hydrogen fuel gas rooms, not classified as Group H	1 hour in Group B, F, M, S and U occupancies; 2 hours in Group A, E, I and R occupancies.
Incinerator rooms	2 hours and provide automatic sprinkler system
Paint shops, not classified as Group H, located in occupancies other than Group F	2 hours; or 1 hour and provide automatic sprinkler system
In Group E occupancies, laboratories and vocational shops not classified as Group H	1 hour or provide automatic sprinkler system
In Group I-2 occupancies, laboratories not classified as Group H	1 hour and provide automatic sprinkler system
In ambulatory care facilities, laboratories not classified as Group H	1 hour or provide automatic sprinkler system
Laundry rooms over 100 square feet	1 hour or provide automatic sprinkler system
In Group I-2, laundry rooms over 100 square feet	1 hour
Group I-3 cells and Group I-2 patient rooms equipped with padded surfaces	1 hour
In Group I-2, physical plant maintenance shops	1 hour
In ambulatory care facilities or Group I-2 occupancies, waste and linen collection rooms with containers that have an aggregate volume of 10 cubic feet or greater	1 hour
In other than ambulatory care facilities and Group I-2 occupancies, waste and linen collection rooms over 100 square feet	1 hour or provide automatic sprinkler system
In ambulatory care facilities or Group I-2 occupancies, storage rooms greater than 100 square feet	1 hour
Electrical installations and transformers	See [IBC] Sections 110.26 through 110.34 and Sections 450.8 through 450.48 of NFPA 70 for protection and separation requirements.

For SI: 1 square foot = 0.0929 m^2, 1 pound per square inch (psi) = 6.9 kPa, 1 British thermal unit (Btu) per hour = 0.293 watts, 1 horsepower = 746 watts, 1 gallon = 3.785 L, 1 cubic foot = 0.0283 m^3.

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International Building Code Occupancy Separation Requirements

TABLE 508.4
REQUIRED SEPARATION OF OCCUPANCIES (HOURS)[f]

OCCUPANCY	A, E	I-1[e], I-3, I-4	I-2	R[a]	F-2, S-2[b], U	B[f], F-1, M, S-1	H-1	H-2	H-3, H-4	H-5
	S NS	S NS	S NS	S NS	S NS	S NS	S NS	S NS	S NS	S NS
A, E	N N	1 2	2 2	NP 1	2 N	1 1	2 NP	3 4	2 3	2 NP
I-1[e], I-3, I-4	1 2	N N	2 NP	1 NP	1 2	1 2	NP NP	3 NP	2 NP	2 NP
I-2	2 NP	2 NP	N N	2 NP	2 NP	2 NP	NP NP	3 NP	2 NP	2 NP
R[a]	1 2	1 NP	2 NP	N N	1[c] 2[c]	1 2	NP NP	3 NP	2 NP	2 NP
F-2, S-2[b], U	N 1	1 2	2 NP	1[c] 2[c]	N N	1 2	NP NP	3 4	2 3	2 NP
B[f], F-1, M, S-1	1 2	1 2	2 NP	1 2	1 2	N N	NP NP	2 3	1 2	1 NP
H-1	NP NP	NP NP	NP NP	NP NP	NP NP	NP NP	N N	NP NP	NP NP	NP NP
H-2	3 4	3 NP	3 NP	3 NP	3 4	2 3	NP NP	N NP	1 NP	1 NP
H-3, H-4	2 3	2 NP	2 NP	2 NP	2 3	1 2	NP NP	1 NP	1[d] NP	1 NP
H-5	2 NP	2 NP	2 NP	2 NP	2 NP	1 NP	NP NP	1 NP	1 NP	N NP

S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
NS = Buildings not equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
N = No separation requirement.
NP = Not Permitted.
a. See Section 420.
b. The required separation from areas used only for private or pleasure vehicles shall be reduced by 1 hour but not to less than 1 hour.
c. See Sections 406.3.2 and 406.6.4.
d. Separation is not required between occupancies of the same classification.
e. See Section 422.2 for *ambulatory care facilities*.
f. Occupancy separations that serve to define fire area limits established in Chapter 9 for requiring fire protection systems shall also comply with Section 707.3.10 and Table 707.3.10 in accordance with Section 901.7.

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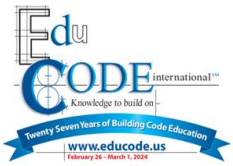
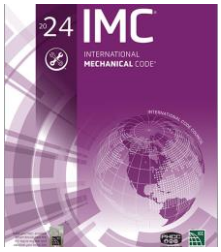
Hydrogen Ventilation Requirements





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IMC Ventilation Requirements

Hydrogen-generating and refueling operations

Hydrogen-generating and refueling appliances must be installed per manufacturer instructions and listings.

Ventilation is mandatory in specified locations such as public garages, private garages, repair garages, and automotive fuel-dispensing facilities containing such appliances or systems.

Rooms connected to private garages are considered part of the garage.

Natural Ventilation

Indoor areas designated for hydrogen-generating or refueling activities must adhere to specific regulations. These areas are limited to a maximum floor space of 850 square feet (79 m2) and must have adequate ventilation connecting them to the outdoors as per Sections 304.5.1.1 and 304.5.1.2.

Additionally, hydrogen-generating appliances in these spaces must not exceed a maximum rated output of 4 standard cubic feet per minute (0.00189 m3/s) of hydrogen for every 250 square feet (23 m2) of floor area. Air openings must have a minimum cross-sectional dimension of 3 inches (76 mm), and any ducts used must match the cross-sectional area of the openings. Furthermore, equipment and appliances with ignition sources must be positioned at least 12 inches (305 mm) away from the ceiling in these locations.

Section 304.5.1.1 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.

Section 304.5.1.2 Louvers and grilles

In calculating free area required by Section 304.5.1, 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.

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Hydrogen-generating and refueling operations.

- **[FG] 304.5.2 Mechanical ventilation.**
- Indoor locations intended for hydrogen-generating or refueling operations shall be ventilated in accordance with Section 502.16. 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).

- **[FG] 304.5.3 Specially engineered installations.**
- As an alternative to the provisions of Sections 304.5.1 and 304.5.2, the necessary supply of air for ventilation and dilution of flammable gases shall be provided by an approved engineered system.

85

Let's Review

- In accordance with Chapter 1 of the IFC, an operational permit is required for storage, use or handling of NTP compressed flammable gases when in excess of many cubic feet?
- What is the maximum allowable quantity per control area of flammable gases of a use-closed system in accordance with Table 5003.1.1(1)?
- What code should be used for compliance with outdoor storage requirements for hydrogen gas?
- Where are audio and visual alarms required for gas detection systems of hydrogen gas rooms?
- Why type of back up power is required for mechanical ventilation and gas detection systems for hydrogen?

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KEY POINTS

1) The expansion of use for hydrogen as a low carbon or carbon free fuel are occurring at a rapid pace.
2) The construction of seven US clean hydrogen hubs will expand hydrogen infrastructure and end uses.
3) Understanding the regulatory requirements for hydrogen production, storage, and end use are critical for safety.
4) Natural Gas and hydrogen admixtures are seen to be a desired approach to decarbonization of heating sectors.
5) Code proposals addressing NG/H2 admixtures have been submitted for consideration for 2027 I-Codes.
6) ICC is committed to the development of additional resources for our members to assist with the expansion of the hydrogen industry.

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References

- The Paris Agreement | UNFCCC
- National Centers for Environmental Information (NCEI)
- U.S. National Clean Hydrogen Strategy and Roadmap | Hydrogen Program (energy.gov)
- DOE Industrial Decarbonization Roadmap | Department of Energy
- Office of Clean Energy Demonstrations | Department of Energy
- Exxon Mobile's rendition of potential Carbon Capture and Storage locations.
- Black & Veatch hydrogen feedstock image

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EVALUATON & SIGN OUT

Thanks for Allowing Us to Serve You!

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