

**DRAFT OF PROPOSED CHANGES TO THE IFGC – 2002 Code Development Cycle
TO ADD PROVISIONS FOR THE USE OF GASEOUS HYDROGEN AS A FUEL**

Final DRAFT—December 18th, 2001

(Includes modifications approved by the AHC in Houston, TX, Editorial revisions by Staff of 11/13/01, and AHC Conference Call Comments of 12/14/01 to 'DRAFT' dated October 19th, 2001)

FG1-02

101

Proponent: Guy Tomberlin, Chair, ICC Ad Hoc Committee for Hydrogen Gas

Add new text as follows and re-designate remaining section numbers:

1. Revise IFGC as follows:

CHAPTER 1 ADMINISTRATION

SECTION 101 (IFGC) GENERAL

101.2 Scope.

This code shall apply to the installation of fuel gas piping systems, fuel gas utilization equipment, and related accessories as follows:

1. Coverage of piping systems shall extend from the point of delivery to the connections with gas utilization equipment. (See “point of delivery”.)
2. Systems, other than hydrogen systems, with an operating pressure of 125 psig (862 kPa gauge) or less.

Piping systems for gas-air mixtures within the flammable range with an operating pressure of 10 psig (69 kPa gauge)

LP-Gas piping systems with an operating pressure of 20 psig (140 kPa gauge) or less.

3. Piping systems requirements shall include design, materials, components, fabrication, assembly, installation, testing, inspection, operation, and maintenance.
4. Requirements for gas utilization equipment and related accessories shall include installation, combustion and ventilation air and venting.
5. Gaseous hydrogen systems.

This Code shall not apply to the following:

1. Portable LP-Gas equipment of all types that are not connected to a fixed fuel piping system.
2. Installation of farm equipment such as brooders, dehydrators, dryers, and irrigation equipment.
3. Raw material (feedstock) applications except for piping to special atmosphere generators.

4. Oxygen-fuel gas cutting and welding systems.
5. Industrial gas applications using gases such as acetylene and acetylenic compounds, hydrogen, ammonia, carbon monoxide, oxygen, and nitrogen.
6. Petroleum refineries, pipeline compressor or pumping stations, loading terminals, compounding plants, refinery tank farms, and natural gas processing plants.
7. Integrated chemical plants or portions of such plants where flammable or combustible liquids or gases are produced by chemical reactions or used in chemical reactions.
8. LP-Gas installations at utility gas plants.
9. Liquefied natural gas (LNG) installations.
10. Fuel gas piping in power and atomic energy plants.
11. Proprietary items of equipment, apparatus, or instruments such as gas generating sets, compressors, and calorimeters.
12. LP-Gas equipment for vaporization, gas mixing, and gas manufacturing.
13. Temporary LP-Gas piping for buildings under construction or renovation that is not to become part of the permanent piping system.
14. Installation of LP-Gas systems for railroad switch heating.
15. Installation of hydrogen gas, LP-Gas and compressed natural gas (CNG) systems on vehicles.
16. Except as provided in Section 401.1.1, gas piping, meters, gas pressure regulators, and other appurtenances used by the serving gas supplier in the distribution of gas, other than undiluted LP-Gas.
17. Building design and construction, except as specified herein.
18. Portable fuel cell appliances that are not connected to a fixed piping system and are not interconnected to a power grid.

CHAPTER 2 DEFINITIONS

SECTION 202 (IFGC) GENERAL DEFINITIONS

FUEL GAS. A natural, manufactured, liquefied petroleum or a mixture of these Fuel gases include: natural gas, manufactured gas, liquefied petroleum gas, hydrogen gas or a mixture of these gases.

GASEOUS HYDROGEN SYSTEM. An assembly of equipment designed to generate, contain, distribute or transport hydrogen in the gaseous form and hydrogen-containing mixtures having a minimum of 5% hydrogen gas by volume. Such systems can consist of a compressed gas container or containers, reactors and appurtenances, including pressure regulators, pressure relief devices, manifolds, pumps, compressors and interconnecting piping and tubing and controls between such assemblies of equipment.

PORTABLE FUEL CELL APPLIANCE. A fuel cell generator of electricity, which is not fixed in place. A portable fuel cell appliance utilizes a cord and plug connection to a grid-isolated load and has an integral fuel supply.

Reason:

Introduction. Hydrogen energy safety is based on three primary elements: regulatory requirements, capability of safety technology and the systemic application of equipment and procedures to minimize risks. Groups involved in the industrial scale production of hydrogen (producers) currently implement many successful proprietary methodologies for safely generating and handling large amounts of hydrogen. Hydrogen users (e.g., NASA) depend on cryo-hydrogen as a fuel and have effectively proven the safety of large scale ground and vehicle systems which support the Space Shuttle Program.

The efforts of the International Code Council Ad Hoc Committee for Hydrogen Gas (AHC) intend to address how future building codes can safely cover hydrogen applications in fuel cell vehicles and hydrogen gas motor-vehicle fuel dispensing and generation stations. The AHC consists of a balanced membership of user, producer and regulatory interests working together with a diverse group of technical and advisory interests to propose changes as necessary to the ICC International Codes. This, and other, related proposals is a summation of their work.

Proposed Revisions to IFGC Section 101.2—Scope. The commercial products industry is moving toward the use of hydrogen in vehicles, generators and equipment to replace petroleum-based fuels in order to reduce atmospheric emissions and facilitate a shift to the use of renewable energy supplies. Furthermore, the commercialization of fuel cells, and the goal of sustainable development has propelled hydrogen supply technology to the forefront of clean energy applications for transportation and distributed and regenerative electric power.

In many cases the hydrogen fuel is utilized, with air, within a fuel cell to produce electricity and in some cases co-generate heat. Typically, building officials will be faced with two classes of equipment – those that generate hydrogen (for use by other devices) and those that utilize hydrogen as their energy input such as a stationary fuel cell (as covered in the IFGC-§633, IMC-§924 and IRC-§M1903.1) or portable fuel cell appliances (as addressed in the IMC-§106.2 and IRC-§R105.2).

With regard to proposed Exception 18, the AHC feels that the reason to support this proposed change and related changes to the IMC (M1-01 Item 1, Approved as Submitted 11-0) and the IRC-Plumbing/Mechanical (M1-01 Item 2, Approved as Submitted 8-0) approved during last year's cycle remains valid. Two specific stationary fuel cell power plant designs are commercially available now. An ANSI Z21.83 Standard exists for these stationary power plants and has been adopted by reference in the 2000 IMC and the 2001 Supplement to the 2000 IFGC. Regardless of the adoption and implementation of these standards and codes, the vast majority of building regulatory authorities in the U.S. has yet to see a stationary fuel cell or consider approving an installation.

In many cases, hydrogen will be utilized in a manner similar to the current use of natural gas. However, there are two important differences that cause the requirement to amend the ICC codes. First, both hydrogen and natural gas are lighter than air, but hydrogen is lighter than natural gas and is both more diffusive and more buoyant than natural gas. This means that in well-ventilated situations (e.g. outdoors) hydrogen will dissipate more quickly than natural gas, and much more quickly than either propane or gasoline, both of which have fumes that are heavier than air and will linger at an accident site. However, hydrogen and natural gas can both accumulate in unventilated pockets at the top of indoor structures and could represent a risk in such situations. Similarly, propane and gasoline fumes can accumulate at the floor level in unventilated spaces, posing a different risk. Thus ignition sources must be averted at the top of any unventilated spaces for hydrogen and natural gas, while ignitions sources must be precluded near the floor for gasoline or propane vehicles indoors. Second, hydrogen is odorless, colorless and burns with a flame that is not visible to the human eye. This means that it is unlikely that people will be able to detect unsafe conditions (without appropriate instrumentation) if they develop (similar to CO accumulation in a structure).

It is important that the ICC provide building officials with the necessary tools so that they can continue to ensure public safety as the public sector begins to adopt sources of hydrogen within the energy infrastructure. Therefore, the AHC has detailed a foundation for code requirements which will allow the safe handling and use of hydrogen as a fuel. Throughout their work, the AHC has sought consistency with existing codes and standards wherever possible. Where hydrogen standards in place today, do not cover the full scope of use or range of available or anticipated technologies, the AHC actively worked with a diverse group of technical and advisory parties from industry to establish criteria in the model codes to cover the installation and integration of these technologies with the building or facilities with which they are associated.

It is important to note that a given volume of natural gas has more than three times the energy of the same volume of hydrogen. Therefore, a given volume of pipe containing natural gas will contain the same energy (potential hazard) as a three times larger volume of hydrogen (see "Comparison of Motor Fuels" attached).

The revisions proposed to Section 101.2 along with the more specific requirements detailed in this proposal clearly define gaseous hydrogen within the scope of the International Fuel Gas Code (IFGC), and allow gaseous hydrogen to be stored and generated indoors not unlike natural gas, provided specific safeguards are implemented. All portions of the system are designed to be fail safe to provide adequate safety under "worst case" conditions.

Proposed Definitions to IFGC Section 202, FUEL GAS. The AHC believes the current definition in the IFGC for FUEL GAS to be a potential source of nonuniform interpretation and nonuniform enforcement if this code were to cover gaseous hydrogen as a fuel gas. The current form of the definition reads as follows: *FUEL GAS. A natural, manufactured, liquefied petroleum or as a mixture of these.* The proposed definition adds clarity and is consistent with NFPA 54/ANSI Z223.1 National Fuel Gas Code (a.k.a., IFDS)

which defines gases as follows: *GASES -- Include natural gas, manufactured gas, liquefied petroleum (LP) gas in the vapor phase only, liquefied petroleum gas-air mixtures, and mixtures of these gases, plus gas-air mixtures within the flammable range, with the fuel gas or the flammable component of a mixture being a commercially distributed product.* Through reasonable interpretation of the code text, the term "manufactured" as it pertains to gas, could be construed as applying to hydrogen. Alternatively, the word "hydrogen" or the phraseology "gas-air mixtures within the flammable range," could secure the same intent in the current form of the code.

GASEOUS HYDROGEN SYSTEM. Section 202 currently does not define GASEOUS HYDROGEN SYSTEM. In as much as the IFGC by interpretation applies to Hydrogen and would explicitly apply with the clarification provided in the prior definition proposed for FUEL GAS, it is imperative that the proposed definition be added to the IFGC. This definition is derived from the IFC Compressed Gases and NFPA 50A. It is the International Code Council Ad Hoc Hydrogen (H2) Committee's intent that appurtenant systems apply to natural gas piping, hydrogen de-sulfurizers, etc., necessary to support operation of the gaseous H₂ system.

PORTABLE FUEL CELL APPLIANCE. Portable fuel cell appliances are quickly reaching their deployment potential and will be commercially available from neighborhood hardware and appliance stores shortly. To the extent that these devices become permanent, a reference to the exception and definition in the code specific to portable fuel cell appliances will provide the code official the necessary information to discern whether these appliances and their associated equipment are "stationary," as subject to the provisions of the IFGC or "portable," and therefore exempt.

In their reason for disapproval the 2001 IFGC Code Development Committee cited an inherent understanding on behalf of all code users that the IFGC does not intend to address "portable" appliances. The presumption that all code users hold this view as self evident, especially as it pertains to emerging fuel cell technologies, does nothing to assist building regulatory officials who enforce the IFGC to assess fuel cell installations proposed in their jurisdictions. Furthermore, if this view is indeed self evident, is there a need for existing Exceptions 1), 2), 4), and 15) to IFGC Section 101.2 as they pertain to "portable" LP-Gas equipment, farm equipment, welding systems, and vehicles, respectively?

In Summary. The AHC has developed these changes through the consultation of a diverse group of technical and advisory parties from various parties in the hydrogen community, inclusive of industry, professional associations, testing laboratories, agencies of government, academic and research institutions and believes it important to provide a template for thorough coverage in the International Codes of equipment, appliances and vehicles that will utilize hydrogen as a fuel such that regulators have a sound technical basis on which to verify installation and to uphold the standard of health and safety for the citizens of their jurisdictions.

Industry is ready to commercialize hydrogen energy systems. The AHC urges your APPROVAL of this proposal "as submitted".

Public Hearing: Committee: AS AM D
Assembly: ASF DF

FG2-02

305.2

Proponent: Guy Tomberlin, Chair, ICC Ad Hoc Committee for Hydrogen Gas

Add new text as follows and re-designate remaining section numbers:

1. Revise IFGC as follows:

CHAPTER 3 GENERAL REGULATIONS

SECTION 305 (IFGC) INSTALLATION

305.2 Location ~~Elevation~~ of ignition source. Equipment and appliances having an ignition source shall be elevated such that the source of ignition is not less than 18 inches (457 mm) above the floor in hazardous locations and public garages, private garages, repair garages, automotive service stations and parking garages where flammable liquids or flammable gases heavier than air are present. Such equipment and appliances shall not be installed in Group H occupancies or control areas where open-use, handling or dispensing of combustible, flammable or explosive materials occurs. 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.

305.3 Hydrogen Generating and Refueling Operations . In rooms or areas that contain hydrogen generating or refueling systems, equipment and appliances having an ignition source shall be located such that the source of ignition is not less than 24 inches (457 mm) below the ceiling in hazardous locations and public garages, private garages, repair garages, automotive service stations and parking garages where gaseous hydrogen is present. Such equipment and appliances shall not be installed in Group H occupancies or control areas where open-use, handling or dispensing of combustible, flammable or explosive materials occurs. 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.

Exception: Where rooms or areas that contain hydrogen generating or refueling systems are ventilated in accordance with Section 502.15 of the *International Mechanical Code* and the following:

1. The ventilation system shall be designed to maintain the maximum concentration of flammable gas below 25 percent of the lower flammability limit of the substance for the expected room temperature; or
2. Continuous ventilation shall be provided at a rate not less than 1 cubic foot per minute per square foot (1 ft³/min/ft²) [(0.0051m³/(s x m²)] of floor area of the room.

305.3.1 Natural Ventilation. Rooms or spaces located underneath or adjacent to habitable space and intended for hydrogen generating or refueling operations shall be provided with mechanical ventilation as required by exception to Section 305.3 or shall communicate with the outdoors in accordance with Section 305.3.1.1 through 305.3.1.2. The minimum dimension of air openings shall be not less than 3 in. (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.

305.3.1.1 Two openings. Two permanent openings, one commencing within 12 inches (305 mm) of the ceiling of the garage, and one commencing within 12 inches (305 mm) of the floor of the garage, shall be provided. The openings shall communicate directly, or by ducts, with the

outdoors. Each opening shall directly communicate with the outdoors horizontally, and have a minimum free area of ½ square foot per 1,000 cubic feet of garage volume.

305.3.1.2 Louvers and grilles. In calculating free area required by Section 305.3.1, 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.

305.3.2 Specially engineered installations. As an alternative to the provisions of Sections 305.2.2, the necessary supply of air for, ventilation and dilution of flammable gases shall be provided by an approved engineered system.

Reason:

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IFGC Section 305.2. Ventilation, whether natural or mechanical, cannot remove all risk from combustible gas leaking into a garage. Based on ongoing research into the dispersion characteristics of gaseous hydrogen, and conducted at the University of Miami, Coral Gables, ½ square foot of opening area per 1,000 cubic feet of garage volume greatly reduces risk, assuming upper and lower openings of approximately equal areas are used. In addition, relying entirely on natural (i.e., passive) ventilation, the ventilation exchange rate increases with increasing hydrogen concentration due to the buoyancy of hydrogen. This is in contrast to mechanical (i.e., active) ventilation, which remains at a constant rate despite any change in hydrogen concentration.

The following is a comparison of a ventilated garage with an unventilated garage, for three leakage rates. The leakage rates were 1.0, 4.0 and 13.0 SCFM. It should be stated clearly that the findings of the University of Miami are based on leakage at the refueling interface and not the vehicle fuel tank. The AHC feels this is a reasonable assumption given the very real potential for the future installation of remote home gaseous hydrogen refueling appliances.

The comparisons of hydrogen accumulation in the garage show the reduction in risk with garage ventilation. The comparisons were made after 20 minutes of leakage. If a garage has openings, the hydrogen accumulation has reached relative equilibrium after 20 minutes and does not continue to increase appreciably with time. If a garage is not ventilated the hydrogen will continue to accumulate with time and eventually produce a hazardous environment.

The two garages, in Figures C1 through C6, are identical with the exception that the first garage did not have an upper opening. Both garages have lower openings, which spanned the bottom of the garage door. The openings were sized at ½ ft²/1000 ft³ of garage volume. The leak was assumed to occur at the vehicle-filling interface, as this type of leakage is difficult to detect. The filling interface was located on the rear passenger side fender. The garage was 9 feet 2.5 inches high by 12 feet 2 inches wide by 21 feet long.

Figures C1 and C2 show the results of hydrogen leaking at 1 SCFM for 20 minutes. The garage without an upper opening is shown in figure C1. The red lines are a surface of constant 4.1% concentration. 4.1% concentration is the lean limit of combustion for hydrogen. It can be seen that a layer of burnable gases approximately 9 inches thick were trapped against the garage ceiling. The blue lines represent a surface of constant 0.82% hydrogen (20% of the lean limit of combustion). They exist down to a level approximately 28 inches below the ceiling. The result of using both lower and upper openings can be seen in figure C2. No appreciable burnable (4.1% hydrogen concentration) gases exist in the garage and the gases, which are richer than 20% of the lean limit of combustion, are only 21 inches thick. As the leak continues the upper garage will continue to fill with greater amounts of hydrogen while lower garage will stay at a relatively constant concentration.

As seen in figure C3 and C4, a 4.0 SCFM leak of hydrogen produces a burnable mixture in both garages. The layer of burnable gases in the lower garage (figure C4 with upper and lower openings) was about 11.0 inches thick, as opposed to 34 inches thick, and contained less than 1/10 the energy of the upper garage (figure C3). The severity of an accident would be substantially reduced by the lower energy content of the burnable gases in figure C4. The buoyancy of hydrogen created an 83 SCFM ventilation rate in the garage in figure C4.

As seen in figure C5, a 20-minute 13.0 SCFM leak of hydrogen almost completely filled the garage with a burnable mixture if no upper opening was provided. The ventilated garage (figure C6) contained a burnable layer approximately 22 inches thick. This was noticeably less than in the unventilated garage with a 4 SCFM leak (figure C4) and contained less than half the energy. The buoyancy of hydrogen created a 123 SCFM ventilation rate in the garage in figure C6.

The SAE Fuel Cell Vehicle (FCV) Standards Committee has been monitoring and contributing to the work of the AHC and is aware of the AHC's decision to require additional natural or mechanical ventilation ONLY in rooms or spaces intended for hydrogen generating or refueling operations. To be explicitly clear it is NOT the intent of the AHC to require additional natural or mechanical ventilation in areas solely dedicated to the parking/storage of hydrogen-fueled vehicles (i.e., where no hydrogen generating or refueling operation is present).

Therefore, to inform the U.S. Building Regulatory Community of measures the SAE Fuel Cell Vehicle (FCV) Standards Committee plans to take to ensure safety, the Safety Working Group of the SAE FCV Standards Committee is currently preparing two "recommended practices". The following recommendations have been incorporated into drafts of these standards to address hydrogen safety for the situation cited above:

1. Fuel systems will be designed and built to appropriate standards and leak tested to demonstrate integrity.
2. Performance-based requirements related to parking an FCV in a single-bay residential garage have been established. The standard requires validation testing in a garage with very low natural ventilation (of only 0.2 air exchanges per hour) to ensure that the vehicle is normally capable of being safely stored in a residential garage.
3. The vehicle manufacturer (VM) is required to perform a Failure Mode and Effects Analysis (FMEA) for the vehicle. If a single failure could lead to hazardous event, the vehicle manufacturer is required to either modify the system to preclude the failure mode, add failsafe or redundant design measures to prevent the failure, or improve the integrity of components and systems such that risks of these failures are acceptably minimal.
4. If the vehicle manufacturer (VM) is unable to meet any of the above requirements, then the VM shall caution the owner/operator of the vehicle of any operating or parking restrictions.

SAE trusts that the U.S. Building Regulatory Community will find these measures suitable for product introduction. As operating experience is accrued with these new types of vehicles, both SAE and the ICC may need to reassess the situation and provide additional measures for FCV safety as necessary.

Thus, in crafting the proposed language specific to ventilation, the AHC has reviewed the findings of the University of Miami and takes the position that existing provisions for mechanical ventilation of residential garages are not enforced. In concert with these findings and our confidence in the SAE Safety Working Group's investigations into failure mode analyses for hydrogen-fueled vehicle design, the AHC has recommended both natural and mechanical ventilation alternatives for private garages located underneath living space and intended for hydrogen generating or refueling operations. For the natural ventilation alternative, the proposed $\frac{1}{2}$ ft.² of net free area per 1,000 cubic feet of garage floor area represents a minimum. This level of ventilation provides more than a 100 SCFM mechanical system would provide when the hydrogen leak is greater than 8 SCFM. Protection against higher leakage rates than those represented in the University of Miami study could be obtained by larger opening areas. In fact, the opening size and location criteria are not unlike those required to meet combustion air requirements.

In Summary. The AHC has developed these changes through the consultation of a diverse group of technical and advisory parties from various parties in the hydrogen community, inclusive of industry, professional associations, testing laboratories, agencies of government, academic and research institutions and believes it important to provide a template for thorough coverage in the International Codes of equipment, appliances and vehicles that will utilize hydrogen as a fuel such that regulators have a sound technical basis on which to verify installation and to uphold the standard of health and safety for the citizens of their jurisdictions.

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Public Hearing: Committee: AS AM D
Assembly: ASF DF

FG3-02

CHAPTER 7 (NEW)

Proponent: Guy Tomberlin, Chair, ICC Ad Hoc Committee for Hydrogen Gas

Add new text as follows and re-designate remaining section numbers:

1. Add new text to IFGC as follows:

CHAPTER 2

DEFINITIONS

SECTION 202 (IFGC)

GENERAL DEFINITIONS

HYDROGEN CUT-OFF 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.

CHAPTER 4

GAS PIPING INSTALLATIONS

SECTION 416 (IFGC) (NEW)

GASEOUS HYDROGEN SYSTEMS

416.1 General.

The installation of gaseous hydrogen systems shall be in accordance with Chapter 7 and the International Fire Code.

CHAPTER 7 (NEW: Underlining removed for clarity)

DESIGN OF 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. Containers provided with pyrophoric material shall also comply with Chapter 41 of the *International Fire Code*. Containers having residual gaseous hydrogen shall be considered as full for the purposes of the controls required.

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 REQUIREMENTS

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

702.1.1 Limitations for indoor storage and use. Flammable gas cylinders in occupancies regulated by the *International Residential Code* shall not exceed 250 cubic feet at Normal Temperature and Pressure (NTP).

702.1.2 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 DOT 49 CFR, Parts 100-180.

702.2 Pressure relief devices. Pressure relief devices shall be provided in accordance with Sections 702.2.1 through 702.2.7. Pressure relief devices shall be sized and selected in accordance with CGA S-1.1, CGA S-1.2 and CGA S-1.3.

702.2.1 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.

702.2.2 Installation. Valves and other mechanical restrictions shall not be located between the pressure relief device and the point of release to the atmosphere

702.2.3 Containers. Containers shall be provided with pressure relief devices in accordance with ASME *Boiler and Pressure Vessel Code, Section VIII*, DOTn and Section 702.2.7.

702.2.4 Vessels or equipment other than containers. Vessels or equipment other than containers shall be protected with pressure relief devices in accordance with ASME *Boiler and Pressure Vessel Code, Section VIII*, or DOTn.

702.2.5 Sizing. Pressure relief devices shall be sized in accordance with the specifications to which the container was fabricated. The relief device shall also be sized to prevent the maximum design pressure of the container or system from being exceeded.

702.2.6 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 and other debris accumulating inside the vent or obstructing the vent.

702.2.7 Accessibility. Pressure relief devices shall be located such that they are provided with ready access for inspection and repair.

702.2.8 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 or entrainment in enclosed spaces. The discharge shall not terminate, under eaves or canopies.

Exception: DOTn-specified containers with an internal volume of 2 cubic feet (0.057 m³) or less.

702.3 Venting . Gas vents shall be terminated to an approved location in accordance with Section 2209 of the *International Fire Code*.

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

702.5 Electrical wiring and equipment. Electrical wiring and equipment shall comply with the ICC Electrical Code.

SECTION 703 (IFGC) USE AND HANDLING

703.1 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.

703.1.1 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.

703.1.2 Piping systems. Piping, tubing, valves and fittings conveying gaseous hydrogen shall be designed and installed in accordance with ASME B31.3, the material-specific provisions of Sections 703.1.2.1 through 703.1.2.5 and Chapter 27 of the *International Fire Code*. Cast-iron pipe, valves and fittings shall not be used.

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

703.1.2.2 Design and construction. Piping systems shall be suitable for hydrogen service and the use intended through the full range of pressure and temperature to which they will be subjected. Piping systems shall be designed and constructed to provide allowance for expansion, contraction, vibration, settlement and fire exposure.

703.1.2.2.1 Prohibited locations. Piping shall not be installed in or through a circulating air duct, clothes chute, chimney or gas vent, ventilating duct, dumbwaiter, or elevator shaft.

703.1.2.2.2 Piping in solid partitions and walls. Concealed piping shall not be located in solid partitions and solid walls, unless installed in a ventilated chase or casing.

703.1.2.2.3 Piping in concealed locations. Portions of a piping system installed in concealed locations shall not have unions, tubing fittings, right or left couplings, bushings, compression couplings and swing joints made by combinations of fittings.

Exceptions:

1. Tubing joined by brazing.
2. Fittings listed for use in concealed locations.

703.1.2.2.4 Piping through foundation wall. Underground piping, where installed below grade, shall not penetrate the outer foundation or basement wall of a building.

703.1.2.2.5 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 inch (25.4 mm) from the nearest edge of the member, the pipe shall be protected by shield plates. Shield plates shall be a minimum of 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. Piping passing through interior concrete or masonry walls shall be protected against differential settlement.

703.1.2.2.6 Piping in solid floors. Piping in solid floors shall be laid in channels in the floor and covered in a manner that will allow access to the piping with a minimum amount of damage to the building. Where such piping is subject to exposure to excessive moisture or corrosive substances, the piping shall be protected in an approved manner. As an alternative to installation in channels, the piping shall be installed in a casing of schedule 40 steel, wrought iron, PVC or ABS pipe with tightly sealed ends and joints and ventilated to the outdoors. Both ends of such casing shall extend not less than 2 inches (51 mm) beyond the point where the pipe emerges from the floor.

703.1.2.2.7 Piping outdoors. Piping installed aboveground 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.

703.1.2.3 Joints. Joints on piping and tubing shall be listed for hydrogen service, inclusive of welded, brazed, flared, socket, slip or compression fittings. Gaskets and sealants shall be listed for hydrogen service. Threaded or flanged connections shall not be used in areas other than hydrogen cut-off rooms or outdoors..

703.1.2.4 Valves and piping components . Valves, regulators and piping components shall be listed for hydrogen service , shall be accessible, and shall be designed and constructed to withstand the maximum pressure to which they will be subjected.

703.1.2.4.1 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 readily accessible.

703.1.2.5 Testing. Testing for physical integrity shall be performed at not less than 150 percent of the maximum allowable working pressure, or in accordance with the requirements of ASME B31.3.

703.3 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 (0.80 rad) from the vertical.

703.4 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*.

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

SECTION 704 (IFGC)

LOCATION OF GASEOUS HYDROGEN SYSTEMS

704.1 General. This section shall govern the design, location, construction and installation of gaseous hydrogen systems.

Exceptions:

1. Dispensing equipment need not be separated from canopies that are constructed in accordance with the *International Building Code*, in a manner that prevents the accumulation of hydrogen gas.
2. Gaseous hydrogen systems located in a separate building designed and constructed in accordance with the *International Building Code* and NFPA 50A.
3. Gaseous hydrogen systems located inside buildings in a hydrogen cut-off room. Hydrogen cut-off rooms shall be designed and constructed in accordance with this Chapter and the *International Building Code*.
4. Gaseous hydrogen systems located inside buildings not in a hydrogen cut-off room. The gaseous hydrogen system shall be listed and labeled for indoor installation and installed in accordance with the manufacturer's installation instructions.
5. Gaseous hydrogen systems installed in vaults constructed in accordance with the applicable requirements of Chapter 34 of the *International Fire Code*. Such locations shall be provided with mechanical ventilation in accordance with the applicable provisions for repair garages in Chapter 5 of the *International Mechanical Code*.
6. Stationary fuel cell power plants in accordance with Section 623.0.

704.2 Location on property. Gaseous hydrogen systems shall be located in accordance with Chapter 22 of the *International Fire Code*.

704.3 Hydrogen cut-off rooms. Hydrogen cut-off rooms shall be designed and constructed in accordance with Sections 704.3.1 through 704.3.8 and the *International Building Code*.

704.3.1 Design and construction. Interior building openings shall be equipped with self-closing devices. Interior openings shall be electronically interlocked with the gaseous hydrogen system to prevent operation of the system when ajar or otherwise provided with a mechanical exhaust ventilation system designed with a capture velocity at the opening of at least 60 fpm. Operable windows are prohibited in interior walls.

704.3.2 Ventilation. Cut-off rooms shall be provided with mechanical ventilation in accordance with the applicable provisions for repair garages in Chapter 5 of the *International Mechanical Code*.

EXCEPTION: Ventilation systems which meet the requirements of Section 704.3.1.

704.3.3 Gas detection system. Hydrogen cut-off rooms shall be provided with an approved flammable gas detection system in accordance with Sections 704.3.3.1 through 704.3.3.3.

704.3.3.1 System design. The flammable gas detection system shall be listed for use with hydrogen and any other flammable gases used in the room. The gas detection system shall be designed to activate when the level of flammable gas exceeds 25 percent of the lower flammability limit (LFL) for the gas or mixtures present at anticipated temperature and pressure.

704.3.3.2 Operation. Activation of the gas detection system shall result in all of the following:

1. Initiation of distinct audible and visual alarm signals both inside and outside the cut-off room.
2. Activation of the mechanical ventilation system.

704.3.3.3 Failure of the gas detection system. Failure of the gas detection system shall result in, activation of the mechanical ventilation system, cessation of hydrogen generation, and a trouble signal to sound in an approved location.

704.3.4 Ignition source control. Open flames, flame-producing devices and other sources of ignition shall be controlled in accordance with Chapter 35 of the *International Fire Code*.

704.3.5 Explosion control. Explosion control shall be provided in accordance with Chapter 9 of the *International Fire Code*.

704.3.6 Standby power. Mechanical ventilation and gas detection systems shall be connected to a secondary source of power to automatically supply electrical power in the event of loss of power from the primary source in accordance with Chapter 27 of the *International Fire Code*.

704.3.7 Smoking. Smoking shall be prohibited in hydrogen cut-off rooms. "No Smoking" signs shall be provided at all entrances to hydrogen cut-off rooms.

704.3.8 Housekeeping. The hydrogen cut-off room shall be kept free from combustible debris at all times.

SECTION 705 (IFGC) OPERATION AND MAINTENANCE OF GASEOUS HYDROGEN SYSTEMS

705.1 Maintenance. Gaseous hydrogen systems and detection devices shall be maintained in accordance with the *International Fire Code* and the manufacturers installation instructions.

705.2 Purging. Purging of gaseous hydrogen systems shall be in accordance with Section 2210.8 of the *International Fire Code*.

2. Revise IFC as follows:

CHAPTER 35 FLAMMABLE GASES

SECTION 3501 GENERAL

3501.1 Scope. The storage and use of flammable gases shall be in accordance with this chapter. Compressed gases shall also comply with Chapter 30. ~~Gaseous hydrogen systems at consumer sites shall also comply with NFPA 50A.~~

Exceptions:

1. Gases used as refrigerants in refrigeration systems (see Section 606).
2. Liquefied petroleum gases and natural gases regulated by Chapter 38.
3. Fuel gas systems and appliances regulated under the *International Fuel Gas Code*.

SECTION 3503 GENERAL REQUIREMENTS

3503.1.1 Limitations for indoor storage and use. Flammable gases shall not be stored or used in Group A, B, E, F, I, M, R or S occupancies.

Exceptions:

1. Cylinders not exceeding a capacity of 250 cubic feet (7.08 m³) each at NTP used for maintenance purposes, patient care or refueling and operation of equipment.
2. Food service operations in accordance with Section 3803.2.1.7.
3. Hydrogen gas refueling stations designed and constructed in accordance with Chapter 22.

3. Revise IBC as follows:

Table 302.1.1

INCIDENTAL USE AREAS

ROOM OR AREA	SEPARATION
Hydrogen cut-off rooms	<u>1-hour fire barriers and floor-ceiling assemblies in Group B, F, H, M, S and U occupancies. 2-hour fire barriers and floor ceiling assemblies in Group A, E, I and R occupancies.</u>

Reason:

Introduction. Hydrogen energy safety is based on three primary elements: regulatory requirements, capability of safety technology and the systemic application of equipment and procedures to minimize risks. Groups involved in the industrial scale production of hydrogen (producers) currently implement many successful proprietary methodologies for safely generating and handling large amounts of hydrogen. Hydrogen users (e.g., NASA) depend on cryo-hydrogen as a fuel and have effectively proven the safety of large scale ground and vehicle systems which support the Space Shuttle Program.

The efforts of the International Code Council Ad Hoc Committee for Hydrogen Gas (AHC) intend to address how future building codes can safely cover hydrogen applications in fuel cell vehicles and hydrogen gas motor-vehicle fuel dispensing and generation stations. The AHC consists of a balanced membership of user, producer and regulatory interests working together with a diverse group of technical and advisory interests to propose changes as necessary to the ICC International Codes. This, and other, related proposals is a summation of their work.

Related Revisions to IFGC Section 101.2—Scope. The commercial products industry is moving toward the use of hydrogen in vehicles, generators and equipment to replace petroleum-based fuels in order to reduce atmospheric emissions and facilitate a shift to the use of renewable energy supplies. Furthermore, the commercialization of fuel cells, and the goal of sustainable development has propelled hydrogen supply technology to the forefront of clean energy applications for transportation and distributed and regenerative electric power.

In many cases the hydrogen fuel is utilized, with air, within a fuel cell to produce electricity and in some cases co-generate heat. Typically, building officials will be faced with two classes of equipment – those that generate hydrogen (for use by other devices) and those that utilize hydrogen as their energy input.

In many cases, hydrogen will be utilized in a manner similar to the current use of natural gas. However, there are two important differences that cause the requirement to amend the ICC codes. First, both hydrogen and natural gas are lighter than air, but hydrogen is lighter than natural gas and is both more diffusive and more buoyant than natural gas. This means that in well-ventilated situations (e.g. outdoors) hydrogen will dissipate more quickly than natural gas, and much more quickly than either propane or gasoline, both of which have fumes that are heavier than air and will linger at an accident site. However, hydrogen and natural gas can both accumulate in unventilated pockets at the top of indoor structures and could represent a risk in such situations. Similarly, propane and gasoline fumes can accumulate at the floor level in unventilated spaces, posing a different risk. Thus ignition sources must be averted at the top of any unventilated spaces for hydrogen and natural gas, while ignitions sources must be precluded near the floor for gasoline or propane vehicles indoors. Second, hydrogen is odorless, colorless and burns with a flame that is not visible to the human eye. This means that it is unlikely that people will be able to detect unsafe conditions (without appropriate instrumentation) if they develop (similar to CO accumulation in a structure).

It is important that the ICC provide building officials with the necessary tools so that they can continue to ensure public safety as the public sector begins to adopt sources of hydrogen within the energy infrastructure. Therefore, the AHC has detailed a foundation for code requirements which will allow the safe handling and use of hydrogen as a fuel. Throughout their work, the AHC has sought consistency with existing codes and standards wherever possible. Where hydrogen standards in place today, do not cover the full scope of use or range of available or anticipated technologies, the AHC actively worked with a diverse group of technical and advisory parties from industry to establish criteria in the model codes to cover the installation and integration of these technologies with the building or facilities with which they are associated.

It is important to note that a given volume of natural gas has more than three times the energy of the same volume of hydrogen. Therefore, a given volume of pipe containing natural gas will contain the same energy (potential hazard) as a three times larger volume of hydrogen.

The revisions proposed in a related proposal to Section 101.2 along with the more specific requirements detailed in this proposal clearly define gaseous hydrogen within the scope of the International Fuel Gas Code (IFGC), and allow gaseous hydrogen to be stored and generated indoors not unlike natural gas, provided specific safeguards are implemented. All portions of the system are designed to be fail safe to provide adequate safety under "worst case" conditions.

Proposed Definitions to IFGC Section 202, HYDROGEN CUT-OFF ROOM. Section 202 currently does not define HYDROGEN CUT-OFF ROOM. The efforts of the International Code Council Ad Hoc Hydrogen (H2) Committee intend to address how future building codes can safely cover hydrogen applications in fuel cell vehicles and hydrogen gas motor-vehicle fuel dispensing and generation stations. Accordingly, the H2 committee finds it necessary to prescribe requirements for hydrogen gas fuel dispensing and generation stations that are similar in format to existing International Fire Code provisions specific to "lighter-than air" fuels. The proposed language is needed to support the work of the H2 committee as it pertains to the hydrogen infrastructure (i.e., service stations, parking garages, loading areas, on-site generation and refueling applications and similar uses). This definition is derived from the IMC and NFPA 50A definition for SPECIAL ROOM, see §3-2.2.

HYDROGEN GENERATING APPLIANCE. Section 202 currently does not define HYDROGEN GENERATING APPLIANCE. The efforts of the International Code Council Ad Hoc Hydrogen (H2) Committee intend to address how future building codes can safely cover hydrogen applications. Most of the hydrogen now produced in the United States is on an industrial scale by the process of steam reforming, or as a byproduct of petroleum refining and chemicals production. However, there is growing interest in two different types of hydrogen generating appliances to produce hydrogen on-site at the customer's refueling facility or even at a private residence from either electricity or from natural gas, propane or other fuels. Hydrogen Generating Appliances based on electrolyzers separate the elements of water – hydrogen and oxygen- by charging water with an electrical current. Adding an electrolyte such as salt improves the conductivity of the water and increases the efficiency of the process. The electrical charge breaks the chemical bond between the hydrogen and oxygen and splits apart the atomic components. Hydrogen Generating Appliances based on chemical reformers separate out the hydrogen from fossil fuels such as natural gas, propane, gasoline, etc. This is the same high temperature chemical process used at large oil refineries to produce hydrogen. By generating the hydrogen on-site at the fueling station or customer's facility, these Hydrogen Generating Appliances avoid the high cost of either liquefying hydrogen and delivering it by cryogenic tanker truck, or installing a national hydrogen pipeline system that could cost many tens of billions of dollars. In effect, these on-site Hydrogen Generating Appliances take advantage of one of two existing energy infrastructures: either the natural gas distribution system or the electrical grid.

IFGC Section 416. Wherever possible, requirements for hydrogen gas fuel dispensing and generation stations that were similar to existing IFC content for "lighter-than air" fuels were intentionally correlated or reproduced in context. The newly proposed language is necessary to support the work of the H2 committee as it pertains to the hydrogen infrastructure (i.e., service stations, parking garages, loading areas, self-sustaining on-site generation and refueling applications and similar uses), for vehicle applications.

IFGC Section 701.1. Chapters 30 and 35 of the IFC address the hazards of compressed hydrogen gas systems including stored hydrogen gas in pressure vessels. These referenced code provisions are intended to reduce the risk posed by the inadvertent rupture of a pressure vessel and its hydrogen gas component or the leakage of the flammable gas associated with a piping rupture. The AHC felt that a reference to the commensurate IFC provisions appropriately serve to limit the quantities of compressed hydrogen gas present on both commercial and residential sites, and considers indoor and outdoor use aspects adequately. Reference to Chapter 41 covering pyrophoric materials is intended to address emerging technology (now being contemplated by the automotive industry) that allows for storage of higher densities of compressed hydrogen gas in containers with relatively lower applied pressures.

The AHC feels it appropriate to work under the assumption that liquid hydrogen issues related to gaseous hydrogen production are to be covered by a new Chapter 8. Thus, the correlation with a proposed new Chapter 7 for gaseous hydrogen is intentional. Furthermore, since NFPA50A and NFPA50B do not scope all of the issues specific to self-sustained commercial or remote refueling operations, the AHC proposes a new Chapter 7 as a tool for addressing the installation and approval of systems and equipment utilizing gaseous hydrogen as a fuel. For example, there are no system size limitations in the AHC's proposal. NFPA 50A does not cover single systems with a total hydrogen content less than 400 ft³. Moreover, 50A does not apply to manufacturing plants or establishments other than "consumer premises." That is, plants and bulk distribution sites operated by a hydrogen supplier or the supplier's agent for the purpose of storing hydrogen and refilling portable containers, trailers, mobile supply trucks, tank cars or motor vehicles are beyond the scope of NFPA 50A. See also, the *Source-Book For Hydrogen Applications* (Hydrogen Research Institute and National Renewable Energy Laboratory, 1998), pages 67-69 for detailed explanation.

IFGC Section 702.1. It is not the intent of the AHC to directly or indirectly limit container, cylinder, tank size to no more than 250 scf per tank outside of residential occupancies. The purpose of the reference to Chapter 35 of the IFC is solely for container, cylinder, tank construction criteria and to ensure that bulk cylinders are not stored in residential occupancies. (See proposed revisions to IFC Section 3503.1.1)

IFGC Section 702.1.1. Addition of this language avoids elimination of Section 3501.1, Exception 3 of the IFC. The AHC feels this is a cleaner way to address bulk cylinder size in garages and detached structure associated with occupancies regulated by the IRC and their accessory structures. The IFC does not apply to occupancies regulated by the IRC and their accessory structures. None-the-less, elimination of the exception could be misinterpreted by subjecting occupancies regulated by the IRC to a number of requirements in the IFC that the committee does not necessarily feel are appropriate

IFGC Section 702.1.2. Consistent with NFPA 50A. For the design and construction of compressed hydrogen gas containers, a single reference to current IFC Section 2703.2.1 could be entertained here, but provides only general guidance (i.e., "in accordance with approved standards"). The structure of the proposed language is derived from IFC Section 3203.1.1. The AHC is not aware of

any hydrogen containers meeting less than ASME VIII criteria. Provisions for alternative approval would address any nonstandard containers encountered.

The structure of proposed **IFGC Section 702.2** and subsections was derived from current IFC Section 3203.2. Standard CGA S-1.1 does not yet cover relief devices on metal hydride containers. At this point the issue is gaseous hydrogen and the circumstances surrounding container failure. While preliminary, CGA is currently addressing issues of container performance at failure (as similar to a Boiling Liquid, Expanding Vapor Explosion, BLEVE), and the particulate matter that may potentially foul the pressure relief device. However, from the standpoint of the AHC a metal hydride container is considered a gaseous hydrogen source. It is the AHC's intent that metal hydride containers be evaluated under provisions for alternative approval.

IFGC Section 702.2.1. The AHC's intent here is to require a pressure relief device (PRD) providing protection from over-pressure without obstruction. The presumption is that the PRD is sized correctly.

IFGC Section 702.2.3. This section is consistent with NFPA 50A as it requires PRD's only as dictated by the specifications to which the container was fabricated (i.e., ASME or DOTn).

IFGC Section 702.2.7. Regarding accessibility, the AHC did not intend to prohibit PRD's integral to the container or vessel. It is implicit, however, that the container or vessel standard will address the issue of "integral" PRD's]]

IFGC Section 702.3. In developing provisions for the venting of hydrogen systems the AHC consulted with hydrogen producers, and their corresponding gas and equipment group—engineering safety departments. In general, four general hydrogen design considerations are included in the design of all hydrogen process vent piping: 1) Vent to a safe area, 2) Ignition likely, 3) Design for thermal radiation from flame, and 4) Design to prevent (un-ignited) flammable mixtures from reaching personnel areas and ignition sources. While these considerations are general in nature and intended for use by designers, fabricators, installer, users and maintainers of hydrogen piping systems, the AHC also sought consistency with existing codes and standards wherever possible and in the best interest to safety personnel, fire departments, code officials and other emergency personnel. This included a review of the Compressed Gas Association's "Standard for Hydrogen Piping Systems at Consumer Locations," CGA G-5.4. CGA G-5.4 specifies that piping systems should be designed in accordance with ASME B31.3, "Chemical Plant and Petroleum Refinery Piping."

Also a consideration in the AHC's work, is the most modern view of many members of the CGA S-1.1 Committee (CGA S-1.1, Pressure Relief Device Standards—Part 1—Cylinders for Compressed Gases) which will most likely be reflected in the next edition of CGS A-1.1.; and that is: "The 'engulfing fire case' shall not be included in the approach to hydrogen safety." Therefore, the AHC has adopted the intent that it is far more effective to mitigate the risk of an engulfing fire by diking, rather than address the concept of the maximum hypothetical accident directly. Typically the normal sizing of PRD's for other demands (e.g., a runaway hydrogen compressor) is much smaller than the engulfing fire case, hence the height and distances criteria for the vent stack are easier to accommodate without truly sacrificing safety.

Regarding ventilation, proposed **IFGC Section 702.4** requires mechanical exhaust consistent with the applicable provisions for repair garages in Chapter 5 of the *International Mechanical Code*. The exhaust flow rates specified therein must be provided at all times and interlocked to respond to fan failure or hydrogen detection. The goal of these provisions is to never permit the maximum concentration of flammable contaminants in air to exceed more than 25% of the LFL for hydrogen during the period that the credible leak exists. It should be made perfectly clear that the room or space shall be depressurized by means of exhaust rather than pressurized or otherwise diluted to achieve these levels.

The exception is specific to interior spaces harboring "Gaseous hydrogen systems." That is, Section 704.2 does not apply to your typical hydrogen-fueled vehicle parked in a garage, with or without a vehicle fueling appliance located in the garage. Note however, that the same concepts derived from the University of Miami research were utilized as the basis for this natural alternative. (See reason to IFGC Section 305.2)

Regarding the security arrangements required by proposed **IFGC Section 702.5**: The structure of this language was derived from current IFC Section 3003.3. The intent is to require "nesting" or locking of cylinders or cylinder groups. Site-perimeter security could be viewed as an approved alternative.

IFGC Section 703.1.2. The ASME Boiler and Pressure Vessel Code (Section II) discusses issues related to hydrogen service but does not make specific material recommendations. The *Source Book* and the *Safety Standard for Hydrogen and Hydrogen Systems* (NASA, 1997) provide more specific guidelines. The following information is a reasonably conservative summary of these guidelines.

For metallic materials: Aluminum and its alloys, austenitic stainless steels with greater than 7% nickel (such as 304, 304L, 308, 316, 321, 347), copper and its alloys (such as brass, bronze, and copper nickel), and titanium and its alloys are generally satisfactory for hydrogen service. Care must be taken to not over-stress components in systems as some of these materials may lose ductility if stressed beyond yield.

Nickel and nickel steels are generally not recommended. Ordinary carbon steels may be used in gaseous hydrogen service at ambient temperature. Carbon steels, low alloy steels, chromium, molybdenum, niobium, and zinc are not acceptable for cryogenic temperatures. Grey, ductile or cast iron should not be used in hydrogen service (NFPA 50A).

For welds: Welding requirements are given in the ASME Boiler and Pressure Vessel Codes and ANSI/ASME B31.3. Care must be taken as welds of some of the acceptable materials (listed above) are susceptible to hydrogen embrittlement and/or cracking if not properly executed.

For non-metallic materials: Use of elastomers and plastics should be limited in gasketing, packing or other sealing elements where failure as a result of fire could cause hydrogen leakage. Valve seat materials should be the materials of standard industrial practice for gaseous hydrogen near room temperature. Teflon™ or Kel-F™ can be used in cold gaseous hydrogen or liquid hydrogen systems for valve seats (although Fluorogreem™ preferred), coatings on metallic O-rings, gaskets for tongue and groove flanges, or gland packing or seals (only if maintained near ambient temperature). Kel-F™ is preferred rather than Teflon™ for liquid hydrogen service as it has a higher tensile strength and is less brittle. All Teflon™ gaskets must be totally contained to prevent cold flow and subsequent leakage. Valves for liquid service over 2.1 MPa (300 psia) should use metal-to-metal seats.

IFGC Section 703.1.2.5. Pressure testing in the ASME Boiler and Pressure Vessel Code may be either hydro or pneumatic. Hydro-tests are 150% of the maximum allowable working pressure (MAWP) times a temperature correction factor. In some situations, particularly when the hydrogen system contains catalysts or other materials which could be damaged by water, a pneumatic test is preferable to a hydro-test. This flexibility is therefore, intentional. A pneumatic test is typically conducted at 125% rather than 150% of the MAWP.

IFGC Section 704.1 defers to NFPA 50A for installation issues only, and in the absence of any exception. NFPA 50A does not outline requirements for establishments operated by a hydrogen supplier or the supplier's agent for the purpose of storing hydrogen and refilling portable containers, trailers, vehicles, supply trucks or tank cars (i.e., These examples are not considered "Consumer Sites" as referenced by the Standard). However, while both NFPA 50A and the criteria proposed herein for the International Codes are both based on the hazards associated with specific quantities and types of materials at consumer sites, the circumstances addressed here by exception, ensure coverage for the full range of available or anticipated technologies. Moreover, the circumstances addressed by exception are inclusive of the forecasted use of gaseous hydrogen as a fuel, and the quantities stored such that the materials will not represent an undue risk to personnel in the area or to the building or facilities with which they are associated.

IFGC Section 704.2 defers to Chapter 22 of the International Fire Code (IFC) specifically for locating hydrogen systems on property (See AHC's proposal and reason to Chapter 22 of the IFC). The IFC requirements are based on the hazards associated with the specific materials, e.g. compressed, flammable gas. These requirements are framed such that the location on the property is appropriate for use with this class of material, and will not represent an undue risk to personnel in the area or to the building or facilities with which they are associated.

IFGC Section 704.3. In the best interest of consistency, the AHC proposes to defer to the *International Building Code* for building construction requirements. The IBC requirements are based on the hazards associated with material-specific properties. For hydrogen, a flammable gas, there are specific requirements to ensure that the building is appropriate for use with this class of material. Sections 704.3.1 through 704.3.8 deal with fire safety provisions for use with hydrogen. Since the chapter associated with flammable gases in the International Fire Code exempts hydrogen systems which are regulated under the International Fuel Gas Code, these code sections are necessary in the IFGC to ensure the implementation of fire safety systems.

IFGC Section 704.3.1 intends to detail the design and construction criteria for the cut-off room. These requirements are loosely based on NFPA 50A requirements (Gaseous Hydrogen Systems at Consumer Sites) for "Special Rooms." To allow for broader applications (such as emergency generators using fuel cell technology), interior wall openings are allowed for easy access to the systems. The hydrogen generation shall be terminated if an interior door is opened through the use of interlocks to prevent the migration of flammable gas to an area which is not properly ventilated. In applications where it is not appropriate for interlocks to be installed (i.e., emergency generators), significant ventilation is required to ensure that a flammable mixture is not attained within the room.

IFGC Section 704.3.2 intends to prevent a dangerous accumulation of flammable gas in the room through the use of an exhaust ventilation system. The Source-Book for Hydrogen Applications recommends ventilation at the rate of 1 CFM per square foot of floor area, which is relative to the requirements in Chapter 5 of the IMC. The exception in 704.3.2 is provided to allow exhaust systems which are designed with a capture velocity of 60 fpm at the door opening. This capture velocity exceeds the requirements found in Chapter 5 of the IMC. Since hydrogen is non-toxic, if a release can be kept below its flammable limit, there is minimal hazard. The ventilation requirements are designed to perform that function.

There are no requirements for gas detection in NFPA 50A. The AHC believes gas detection appropriate and integral to life safety. Therefore, **IFGC Section 704.3.3** was derived from current IFC Section 2210.7.2, and intends to address the fact that early detection of the presence of a flammable gas will allow adequate safeguards to be taken. Hydrogen fires are not normally extinguished until the supply of hydrogen has been shut off because of the danger of re-ignition or explosion. A gas detection system in the room or space harboring a gaseous hydrogen system provides for early notification of a leak that is occurring before the escaping gas reaches hazardous exposure concentration levels. The required local alarm is intended to alert the occupants to an emerging hazardous condition in the vicinity. The monitor control equipment must also initiate operation of the mechanical ventilation system in the event of a leak or rupture in the gaseous hydrogen system to prevent an accumulation of flammable gas. Systems shall be designed to be "fail-safe" such that all safety systems shall be activated to alert any occupants that a problem exists and to prevent more hydrogen from being generated by any appliances in the room.

IFGC Section 704.3.4 is intended to prevent any flammable gas releases from finding ignition sources. These requirements are identified in the IFC in locations where flammable gases are stored or used. The requirements are consistent with NFPA 50A and the Sourcebook for Hydrogen Applications. The energy required for ignition of hydrogen-air mixtures is extremely small, and every effort must be made to control ignition sources until the area can be properly ventilated, thus removing the hazard.

IFGC Section 704.3.5 is intended to prevent a catastrophic failure of the cut-off room. It is the final safeguard in case other prevention methods fail (ventilation, alarms). An ignited hydrogen mixture produces large quantities of heat causing a rapid expansion of the surrounding air. This can cause a pressure increase in a confined space and a catastrophic failure. Explosion control methods are identified in the IFC to prevent such a catastrophic failure. The explosion control requirements for hydrogen are consistent with the requirements in NFPA 50A, the IFC, and the Sourcebook for Hydrogen Applications.

IFGC Section 704.3.6 intends to ensure that safety systems remain active in the event of a power failure of the primary power supply. Hydrogen is a colorless, odorless gas and a release may go undetected if detection systems are not functioning. The accumulation of hydrogen in an unventilated area can lead to mixtures in the flammable range if safety systems mechanical ventilation systems are not in operation. Chapter 27 of the IFC addresses emergency and standby power requirements for emergency systems. It also allows an exception to the requirement for systems which are fail safe (see IFC Section 2704.7 Exception 4). This exception may be utilized in cut-off rooms where hydrogen is generated, but not stored. Any storage of hydrogen within the cut-off room would not qualify for the exception, because in the event of a power failure, there will be no way to detect or ventilate a release from a storage vessel.

IFGC Section 704.3.7 intends to augment the requirement in Section 704.3.4. The intent is the same as is in the ignition source control section.

IFGC Section 704.3.8 intends to protect the cut-off room from the storage of other materials which may ignite and cause an exposure fire in the room. Preclusion of combustible materials eliminates this hazard and protects the equipment and storage containers.

IFGC Section 705.1. This section refers to the IFC for maintenance of hydrogen systems. More specifically, Section 2703.2.6 of the IFC details required maintenance activities for hazardous materials storage and use. This includes maintenance of alarms, cylinders, ventilation systems and other devices needed to ensure safety of the gaseous hydrogen system. Failure to properly maintain any of these systems increases the likelihood of a hydrogen release and compromises the safety of the operation. This section is also consistent with the general maintenance provision of the IFC identified in Section 107.1.

IFC Section 3503.1.1. Exception 3 to Section 3503.1.1 is necessary to enable commercial refueling stations designed for that purpose, but also to address remote storage and refueling operations affiliated with buildings designed and constructed in accordance with the IRC (i.e., One- and Two-Family Dwellings and Townhomes). The development of hydrogen fueled vehicles and equipment is a rapidly developing area. Making gaseous hydrogen available as motor vehicle fuel will likely require storage of that fuel gas in quantities beyond what is currently allowed by this section. In order to safely facilitate the continued technological developments a safe means of handling and storage, the fuel must be manufactured some how. To address this, a new section of code is concurrently proposed to Chapter 22 of the IFC which addresses hydrogen gas refueling stations. It has specific details as to requirements for the safe storage, use and handling of the flammable gas. These details include vehicle protection, exposure setbacks, electrical area classifications and other pertinent requirements. Since specific code language has been written to address the hazards associated with the refueling stations, the AHC feels the more general language of Chapter 35 need not apply.

In Summary. The AHC has developed these changes through the consultation of a diverse group of technical and advisory parties from various parties in the hydrogen community, inclusive of industry, professional associations, testing laboratories, agencies of government, academic and research institutions and believes it important to provide a template for thorough coverage in the International Codes of equipment, appliances and vehicles that will utilize hydrogen as a fuel such that regulators have a sound technical basis on which to verify installation and to uphold the standard of health and safety for the citizens of their jurisdictions.

Industry is ready to commercialize hydrogen energy systems. The AHC urges your APPROVAL of this proposal "as submitted".

Public Hearing: Committee: AS AM D
Assembly: ASF DF

FG4-02

CHAPTER 8 (NEW)

Proponent: Guy Tomberlin, Chair, ICC Ad Hoc Committee for Hydrogen Gas

Add new text as follows and re-designate remaining section numbers:

1. Add new text to IFGC as follows:

CHAPTER 8 (IFGC) (NEW)

DESIGN OF LIQUIFIED HYDROGEN SYSTEMS ASSOCIATED WITH HYDROGEN VAPORIZATION OPERATIONS

801.1 General. The design of liquefied hydrogen systems shall comply with Chapter 32 of the *International Fire Code*.

Reason:

Introduction. Hydrogen energy safety is based on three primary elements: regulatory requirements, capability of safety technology and the systemic application of equipment and procedures to minimize risks. Groups involved in the industrial scale production of hydrogen (producers) currently implement many successful proprietary methodologies for safely generating and handling large amounts of hydrogen. Hydrogen users (e.g., NASA) depend on cryo-hydrogen as a fuel and have effectively proven the safety of large scale ground and vehicle systems which support the Space Shuttle Program.

The efforts of the International Code Council Ad Hoc Committee for Hydrogen Gas (AHC) intend to address how future building codes can safely cover hydrogen applications in fuel cell vehicles and hydrogen gas motor-vehicle fuel dispensing and generation stations. The AHC consists of a balanced membership of user, producer and regulatory interests working together with a diverse group of technical and advisory interests to propose changes as necessary to the ICC International Codes. This, and other, related proposals is a summation of their work.

IFGC Section 801.1. It is anticipated that large consumers of hydrogen as a fuel gas will ultimately utilize liquid hydrogen storage as the supply. While the storage, handling and vaporization of liquid hydrogen is no more technically sophisticated than the storage, handling and vaporization of liquefied petroleum gas (LPG) which the IFGC allows now, the design requirements for liquid storage, handling, and vaporizers are different from what is addressed in the AHC's related proposal to Chapter 7. Therefore, the AHC believes that until the technology for bulk-commercial liquefied hydrogen refueling systems matures, the current edition of NFPA-50B will prove an effective resource for design guidance. It is envisioned that when such equipment is eventually provided for commercial or residential occupancies, it will be in the form of listed packages similar to LPG.

In Summary. The AHC has developed these changes through the consultation of a diverse group of technical and advisory parties from various parties in the hydrogen community, inclusive of industry, professional associations, testing laboratories, agencies of government, academic and research institutions and believes it important to provide a template for thorough coverage in the International Codes of equipment, appliances and vehicles that will utilize hydrogen as a fuel such that regulators have a sound technical basis on which to verify installation and to uphold the standard of health and safety for the citizens of their jurisdictions.

Industry is ready to commercialize hydrogen energy systems. The AHC urges your APPROVAL of this proposal "as submitted".

Public Hearing: Committee: AS AM D
Assembly: ASF DF