DRAFT OF PROPOSED CHANGES TO THE IRC – 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)

RM1-02
1307.3

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 definition as follows:

SECTION R202
DEFINITIONS

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.

2. Revise IRC as follows:

SECTION M1307
APPLIANCE INSTALLATION

1307.3 Location ~~Elevation~~ of ignition source. 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 garages where flammable liquids or flammable gases heavier than air are present. 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 garage.

1307.4 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 garages where gaseous hydrogen is present. 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:

1. Where rooms or areas that contain hydrogen generating or refueling systems are ventilated in accordance with Section 1307.4.1
2. 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 present 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.

3. Where rooms or areas that contain hydrogen generating or refueling systems are ventilated in accordance with Section 1307.4.2

1307.4.1 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 1307.4 or shall communicate with the outdoors in accordance with Sections 1307.4.1.1 through 1307.4.1.2. 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.

1307.4.1.1 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.

1307.4.1.2 Louvers and grilles. In calculating free area required by Section 1307.4.1, 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.

1307.4.2 Specially engineered installations. As an alternative to the provisions of Sections 304.4.1, the necessary supply of air for, ventilation and dilution of flammable gases shall be provided by an approved engineered system.

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.

IRC Section 1307.4. 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 ft^2/1000 ft^3 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 are 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 ½ $ft.^2$ 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.

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	