U.S. National Work Group Meeting for the Development of Commercial Hydrogen Measurement Standards

June 19, 2008

Fuel Specifications Subcommittee

Appendix E
The Starting Point: A Discussion Paper Describing a Proposed Method of Sale and Quality Specification for Hydrogen Vehicle Fuel

I. Prologue

This discussion paper presents initial proposals relating to the development of a uniform method of sale and quality specifications on hydrogen vehicle fuel for consideration by the Fuel Specifications Subcommittee (FSS) of the U.S. National Work Group for the Development of Commercial Hydrogen Measurement Standards (USNWG). The purpose of this document is to organize, focus, and record the work of the FSS. Participation in the work of the subcommittee is open to anyone with an interest in the subject and who wants to make a contribution to the process. The goal of this effort is to develop proposals for inclusion in NIST Handbook 130 "Uniform Laws and Regulations in the areas of Legal Metrology and Engine Fuel Quality"[1] a source for model laws that the States use in developing their legal requirements and standards.

The subcommittee held its first meeting on March 6, 2008 in West Sacramento, California. Participants included hydrogen producers, dispenser and component manufacturers, weights and measures, air resource, and fuel quality officials and other interested parties. Absent from the discussion were automotive and fuel cell manufacturers, marketers, and other experts who certainly will have questions, concerns, and suggestions for improving on the initial work of the FSS. One purpose of this document is to give interested parties the opportunity to participate in this effort to commercialize hydrogen as a vehicle fuel.

Method of Sale and Fuel Quality Standard

Participants at the FSS meeting considered a draft proposal for a Method of Sale for Hydrogen Fuel that was prepared by the National Institute of Standards and Technology (NIST) and that is discussed in Section II below. Also discussed was the need for a quality standard and the basis for that discussion was the proposed Hydrogen Fuel Standard developed by the California Department of Food and Agriculture, Division of Measurement Standards (CDFA/DMS) contained in a March 3, 2008, regulatory notice.[2] While recognizing and commending the State of California for sharing its knowledge and experience in helping provide a starting point for a national standard for hydrogen fuel nothing in this document should be interpreted as either an endorsement or criticism of the CDFA/DMS proposal by either the FSS or NIST unless otherwise stated below. See Section III for the discussion of the fuel quality item.

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[1] See NIST HB 130 at http://www.nist.gov/owm.

[2] Available at http://www.cdfa.ca.gov/dms/hydrogenfuel/hydrogenfuel.html.

The states are historically the leaders in establishing and enforcing the laws and regulations for legal metrology and fuel quality in the United States. The proposals described in this document are being developed for possible inclusion in NIST Handbook 130 "Uniform Laws and Regulations in the Areas of Legal Metrology and Engine Fuel Quality," which contains the model laws and regulations that States refer to when they consider adopting new requirements. Some states adopt the regulations in that handbook by reference or citation in law, and this approach has provided national uniformity in regulation of a number of significant issues including packaging and labeling, net quantity of contents, and fuel quality.

The members of the FSS recognize that when small groups develop standards for emerging technologies it is impossible to know all they should know about a subject which is, by its nature, changing even as a meeting takes place or a report of its progress is being typed. With this frame of reference in mind please review this document and contribute your knowledge, understanding, and ideas to this effort.

Section II. A Uniform Method of Sale for Hydrogen Vehicle Fuel

Defining a legal requirement for a uniform method of sale for commodities is one of the most practical and efficient ways that weights and measures uses to ensure that consumers can make value comparisons between competing sellers of the same commodity, so that their purchasing decisions enable them to obtain the greatest value. A uniform method of sale also ensures that sellers advertise and deliver a commodity using a single unit of measurement so comparisons can be quick and simple. Typically commodities (e.g., gasoline, diesel fuel, food, milk, wine, sand and gravel, and others) are sold by weight, measure (volume or dimensions, including area), or count.

Establishing a method of sale for any product is a critical first step in the development of a fair and competitive marketplace for any commodity especially one that is just emerging and for which there is not a traditional method of sale for the commodity on which to build. History has shown that when products are introduced into the marketplace without the existence of a legally defined standard, confusion and unfair competitive practices can quickly evolve and potentially harm the consumer's perception of the product and business reputation of the seller. The 2005 "Hydrogen Delivery Technology Roadmap"[3] also called on retailers and appropriate government agencies for the establishment of a legal unit of measurement for hydrogen.

Establishing a uniform method of sale ensures marketplace integrity and increases consumer confidence while ensuring fair trade practice in a competitive marketplace. In past experience, the lack of a legal standard of sale has resulted in sellers establishing different methods of sale for the same product. This resulted in investments in weighing and measuring equipment and spending on packaging and marketing programs only to find that the units of measurement used were not appropriate for the commodity. Once a new standard was established existing measuring equipment, labeling, and sales literature had to be retrofitted or discarded. Establishing a method of sale early in the process informs the designers of weighing and measuring devices about how they are to design the device and the user interface. It also enables

[3] Available at http://www1.eere.energy.gov/vehiclesandfuels on the Internet.

marketers to create sales and promotional programs for the product using a consistent unit of measurement throughout the system.

Past experience with conflicting methods of sale has taught weights and measures and sellers many valuable lessons over the years. One of the most important lessons is that consumers are intelligent and willing to learn new methods of sale and readily accept products and services, if the information they receive from different sellers is informative, uniform, and accurate.

Establishing a uniform method of sale will also inform automobile and fuel cell manufacturers about how they will need to educate consumers in sales literature and owners' manuals about the fuel and how it will be measured for dispensing into the vehicles and other refueling applications. Decisions are needed so that as marketing and promotional ideas are being considered and developed the uniqueness of the fuel and dispensers can be addressed using a single unit of measurement.

Sales Based on the Kilogram

The FSS discussed a draft of a NIST Handbook 130 Method of Sale for hydrogen vehicle fuel. The industry's pre-market practice has been to dispense hydrogen into fuel cell vehicles using the kilogram as the unit of measurement. The use of mass was strongly favored by the FSS participants who agreed to propose that as the basis for retail commercial transactions. By requiring use of the kilogram as the unit of measurement for all retail dispensers consumers can make value comparisons between competing retailers. Dispensing hydrogen by mass using the kilogram is specified in Section 2.4.2. of OIML R 139 "Compressed Gaseous Fuel Measuring Systems for Vehicles" (Edition 2007) and is the method of sale used in other countries. By using the kilogram, the U.S. approach will be consistent with the global hydrogen marketplace in terms of the method of sale. As this fuel becomes fully commercialized, consumers considering the lease or purchase of a hydrogen vehicle will need to learn the fueling process for their hydrogen vehicle and be educated that their fuel purchases will be made on the basis of mass using the kilogram.

One question raised at the FSS meeting was whether the marketing of hydrogen vehicles against those that use fuels sold on the basis of a gallon would benefit from the establishment of a Gasoline Gallon Equivalent (GGE). GGEs are based on energy content of fuels. GGE for hydrogen is mentioned in the media and government literature as 1 kg = 119,823 kilojoules (kJ) (113,571 BTU (LHV).[4] GGE is used to compare the fuel in terms of price per gallon and to introduce hydrogen as a commercial vehicle fuel. This approach facilitates those comparisons as long as it is also understood that the energy content in a gallon of fuel varies widely with the fuel. When the GGE for Compressed Natural Gas (CNG) was developed as a legally defined value in 1990's, one reason for its adoption was to allow consumers to compare the cost of competing fuels on street signs and on dispensers in a unit of measurement that was comparable among fuels such as gasoline. Thus, consumers could determine the potential savings of

[4] See 11. Appendix: Conversion Factors "Hydrogen Delivery Technologies Roadmap" Nov 2005. The National Hydrogen Association provides the value of 120,951.6 kJ (114,640 BTU) per kg at www.hydrogentassociation.org under FAQ. (Viewed 3/28/08)

choosing a vehicle capable of using one type of fuel over another. In 1994 the GGE was set at 2.567 kg of CNG by the National Conference on Weights and Measures (NCWM) using the lower heating value of gasoline which was then given at 120,401.7 kJ (114,118.8 BTU).[5 & 6] It should be noted that the adoption of the GGE for CNG was somewhat contentious. A proposal to add a Diesel Gallon Equivalent (DGE) for CNG is expected to be on the NCWM's agenda in 2009.

It is difficult to make accurate comparisons between fuels because energy content varies by fuel, by region, and season for gasoline. Currently the *Transportation Energy Data Book*[7] lists the net energy of a gallon of gasoline at 121,753.4 kJ (115,400 BTU) and diesel as 135,785.7 kJ (128,700 BTU). Variations in energy content increase when gasoline is blended with Ethanol (E10 or E20), and E85 (15 % gasoline + 85 % ethanol) contains only 89,679.76 kJ (85,000 BTUs) according to the National Ethanol Vehicle Coalition.[8] Hydrogen fuel, which is expected to come into the marketplace as a commercial fuel within the next ten years, will be competing for customers who have a far more fuel choices than are currently available. If a GGE is considered for hydrogen the question that should be asked is "Would a GGE based on today's net energy content for gasoline for Hydrogen be a valid tool 10 years from now to compare it against gasoline, CNG, E85, diesel, and other fuels and the new electric cars expected from GM and other manufacturers?"

Because of constant changes in energy policies and environmental concerns new fuels and blends will continue to emerge in the marketplace. This constant state of change impacts the validity of GGEs. One question that must be raised if a GGE for hydrogen is proposed is if these artificial comparison tools should be periodically reviewed to ensure they provide an equitable means of ensuring reasonable and reliable comparisons between fuels.

There was no indication among the participants at the FSS's first meeting that there was any interest in pursuing the development of a legally defined GGE for hydrogen vehicle fuel. The proposal presented below recommends the kilogram as the unit of measurement to be used in commercial sales and on street signs when a unit price is displayed (see Figure 1 on page 6 which provides an example of how the unit of measurement might appear on the dispenser). The unit can be shown using the term "kilogram" or by use of its accepted abbreviation "kg," which is its prescribed symbol in NIST Special Publication 330 – "The International System of Units (SI)."[9]

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[5] See Item 337-2 "S.1.2.6, Units of Measure for Natural Gas Sold as and Engine Fuel" (p 322 to 326) in the NIST Special Publication 854 "Report of the 78th National Conference on Weights and Measures – 1993" for a complete discussion of the information and research behind the values used.

[6] Claims of energy content of the GGE vary widely. For example the Natural Gas Vehicle Coalition (see http://www.ngvc.org/mktplace/fact.html (viewed 3/27/08)) says that the GGE for CNG has the energy content of 131,670 kJ (124,800 BTUs).

[7] See http://cta.ornl.gov/data/tedb26/Spreadsheets/TableB_04.xls. (viewed 3/27/08)

[8] http://www.e85fuel.com/legislation/documents/nevc_state_road_tax_april06.doc. (viewed 3/27/08)

[9] See NIST Special Publication 330 – 2008 "The International System of Units (SI)." Ambler Thompson, Editor.

Nothing in the proposal should be interpreted as prohibiting the use of a Hydrogen GGE for information purposes to facilitate general comparisons with other fuels in advertisements and other literature. Consumers who are considering the lease or purchase of a hydrogen vehicle should be informed that they will be purchasing fuel by the kilogram and that they can make reliable value comparisons using that method of sale.

Dispenser Labeling and Advertisement Requirements

Currently some dispensers are marked with service pressures in units of bar[10] (e.g., 350 bar and 700 bar) which are the pressures available to service hydrogen vehicles. Knowing the service pressure of the dispenser is a critical factor for consumers as the hydrogen storage tanks on their vehicle is designed to be filled at one of those pressures. In addition to needing this information for safety and vehicle filling purposes participants at the FSS indicated that retailers may charge different prices for hydrogen depending on the delivery pressure at which it is dispensed. The FSS agreed that the service pressure at which the hydrogen is dispensed should be posted on the user's interface of all dispensers. While the bar is acceptable for use with the International System of Units (SI), the metric system, the primary SI unit for pressure is the Pascal (international symbol - Pa). Some dispenser manufacturers use mega Pascal (MPa) in trade publications and in declaring dispenser delivery pressures. The service pressures for hydrogen dispensers in Pascal units are 35 MPa (350 bar – 5,000 psi) and 70 MPa (700 bar – 10,000 psi). One of the questions that the FSS must decide is which unit of measurement would be most appropriate to use for declaring service pressures on both dispensers, street signs and advertisements, if it is determined that information is critical for consumers.

The FSS also agreed that the conditions for sale, such as operation pressure, should be stated with the unit price in whole cents per kilogram in street signage to inform drivers of hydrogen vehicles of the service pressures available at the retailer's facility. The proposed regulation <u>does not</u> mandate street signs, but when street signs are available they must display the unit price and service pressure of the hydrogen dispensers. The requirement is only applicable when retailers voluntarily post or present the price of hydrogen fuel in advertisements and on street signs.

The FSS agreed the petroleum industry's trade practice of using decimal fractions of a cent in unit pricing in advertisements, the unit price, or in the calculation of total price should not be extended to sales of hydrogen fuel. Under the proposed method of sale that practice is prohibited (e.g., "$3.499 per kg" would not be permitted but "$3.49" per kg would be permitted).

[10] A bar is an atmospheric pressure defined as 100 kilopascals. See NIST Special Publication 330 – 2008 "The International System of Units (SI)." Ambler Thompson, Editor.

Figure 1 provides examples of the way service pressure (in MPa or bar) may be displayed on the user interface of a dispenser.

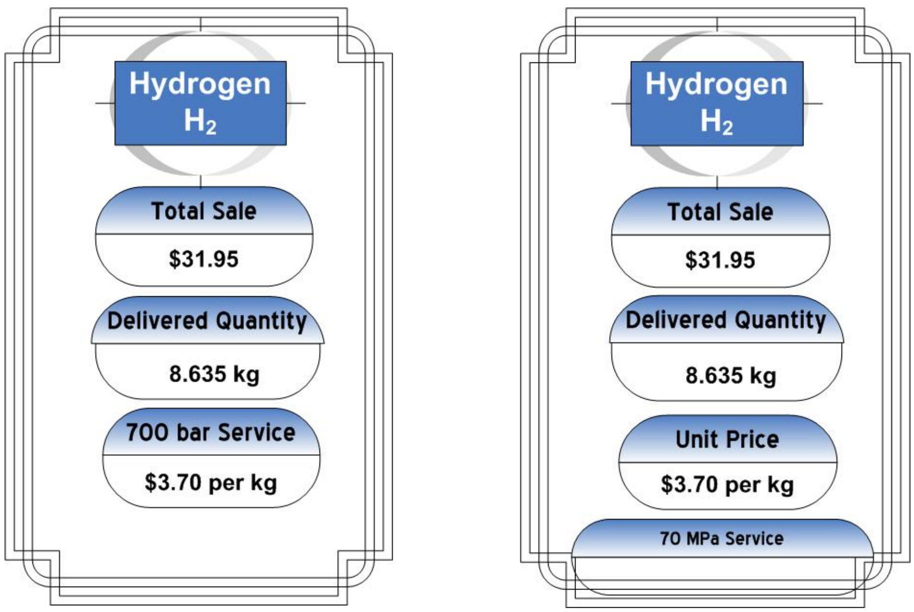

Figure 1. Examples of the Display Unit of Measurement and Service Pressure in MPa and bar on the user's interface of a H_2 Dispenser

The illustrations in Figures 2 & 3 depict a compressed picture of how a hydrogen fueling station in the marketplace might display required information. Due to the current cost of these installations, the limited user base, the development of home based fueling systems, and limited availability of portable fueling units we are not likely to see competitors offering hydrogen fuels across the street from one another for some time. However, the purpose of the graphics is to illustrate that a uniform method of sale in a single unit of measurement and other requirements for posting of service delivery information will facilitate value comparison in a competitive hydrogen marketplace and provide users with critical information. The graphics of the signage shows how posting the unit of measurement and service pressure provides drivers with information to permit them to make product and service pressure value comparisons between retailers.

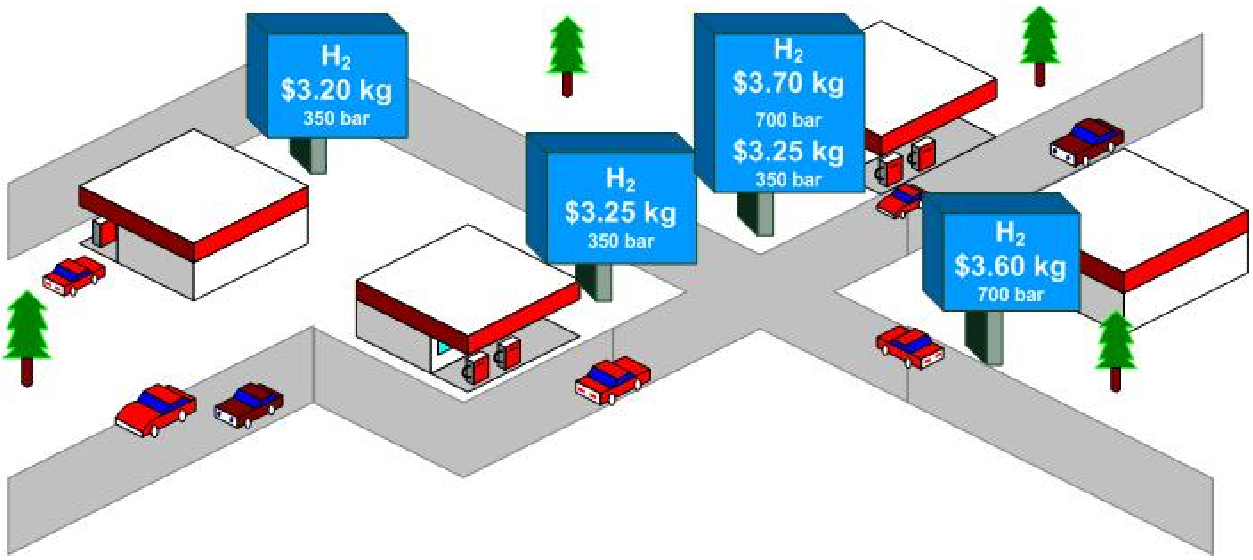

Figure 2. Showing the Use of the Uniform Unit of Measurement and Posting of Service Pressure in bar to Enable Value Comparison

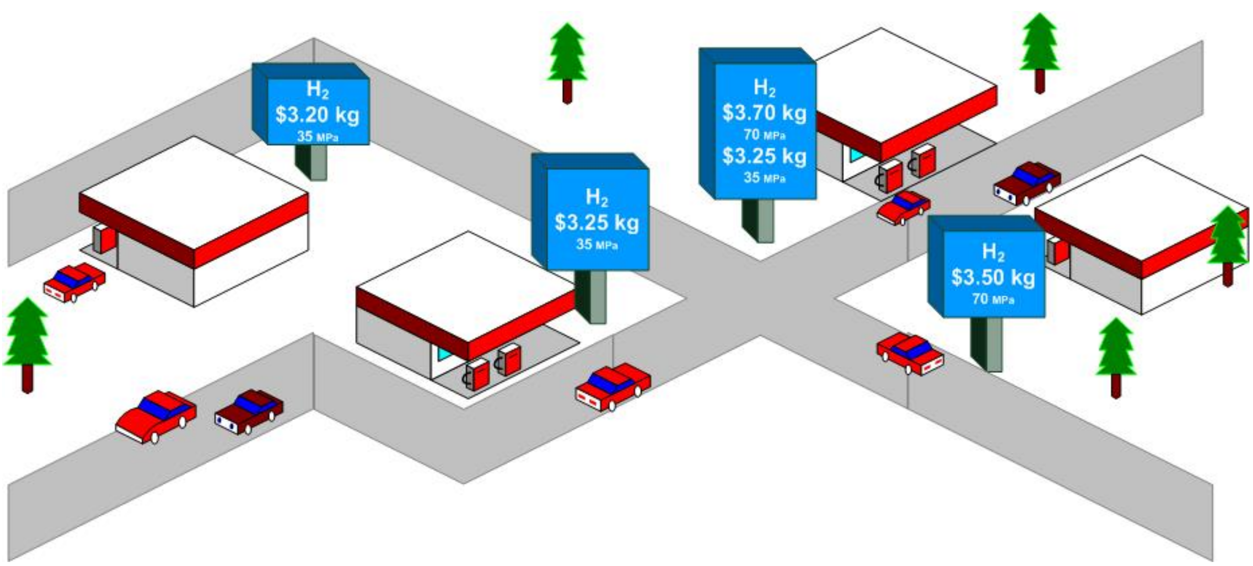

Figure 3. Showing the Use of the Uniform Unit of Measurement and Posting of Service Pressure in MPa to Enable Value Comparison

One alternative to the posting of service pressures (perhaps even unit prices) may be found in the growing prevalence of vehicle navigation systems and satellite information services. If drivers of hydrogen vehicles have access to real-time price and service pressure information through those systems and use them to make their purchasing decisions the current approach of using street sign pricing may not be continued in a hydrogen marketplace.

Recommendation: The Fuel Specification Subcommittee presents the following recommendation for review and comment by all interested parties. This recommendation will be used as the basis of discussion at the June 2008 FSS's meeting.

1. Retail Sales - Hydrogen Fuel.

1.1. Definition – Hydrogen Fuel

A fuel composed of the chemical hydrogen intended for consumption in an internal combustion engine or fuel cell.

1.2. Method of Sale

All hydrogen vehicle fuel kept, offered, or exposed for sale and sold at the retail level must be in terms of the kilogram.

1.3. Retail Dispenser Labeling

- **a. A computing dispenser must display the unit price in whole cents on the basis of price per kilogram.**
- **b. The service pressure(s) of the dispenser must be conspicuously shown on the user interface in bar or MPa.**

1.4. Street Signs and Advertisements.

When a unit price for hydrogen fuel is shown on street signs or in advertisements:

- **a. The unit price must be in terms of price per kilogram in whole cents (e.g., "$3.49 per kg" not $3.499 per kg).**
- **b. The sign or advertisement must include the service pressure(s) at which the dispenser(s) delivers hydrogen fuel.**

Section III. Hydrogen Vehicle Fuel Quality Specification

The USNWG FSS will develop a model regulation to specify the quality requirements for hydrogen vehicle fuel for addition to the Uniform Fuels and Lubricants Regulation (UFLR) in NIST Handbook 130. The UFLR cites ASTM International and SAE International standards for gasoline, diesel and other fuels. At least 11 states use that model regulation as a basis for their rules on fuel quality. As with other fuels the regulations in Handbook 130 will reference standards from appropriate standards organization and utilize the test methods authorized and referenced by those standards. The proposed regulation for hydrogen will most likely include standards developed by ASTM International, SAE International, and the International Organization for Standardization (ISO) or from another American National Standards Institute (ANSI) accredited organization.

Currently the State of California is at the forefront in establishing a Hydrogen fuel quality standard as a result of a legislative mandate.[11] At its first meeting in March 2008, the FSS participants reviewed the March 3, 2008 draft developed by the California Department of Food and Agriculture's/Division of Measurement Standards (CDFA/DMS) so that it could be used as a starting point in the development process for a national standard. This approach was taken by the NIST Technical Advisor to take advantage of California's expertise and because it has been published for comment as part of that state's rulemaking process which means that it has received public review. The CDFA/DMS proposal was developed to provide an interim standard for hydrogen fuel. Once an American National Standards Institute (ANSI) accredited standards organization has adopted a hydrogen fuel standard the CDFA/DMS is required by law to adopt that standard by reference. Since test procedures have not yet been finalized to measure the properties specified in the CDFA/DMS interim standard the agency will adopt sampling and test procedures in regulation as they are developed. The agency will begin enforcement of its regulations and require compliance once sample and test procedures have been adopted by an accredited organization and its regulation are finalized. Several participants at the meeting reminded the group that the higher the quality of the fuel the higher its cost may be so the approach taken in the United States must be practical if the commercialization of hydrogen vehicle fuel is to be successful.

Proposed Specification for Hydrogen Fuel

The FSS identified several quality criteria where there was tentative agreement with their associated values (see items 6, 7, 8, 9, 12, 14, and 16 which are highlighted in green) in the proposed Table 1. Hydrogen Fuel Quality Specification. When a quality property and numerical value (defining a maximum or minimum limit) is added to the specification appropriate test methods must then be identified. As test methods are identified and adopted by the FSS they will be added to Column 5 in Table 1.

The FSS did not agree on all of the properties contained in the DMS proposal because there was either not enough research data or test methods available to support a decision (see items 1, 2, 3,

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[11] See http://www.cdfa.ca.gov/dms/hydrogenfuel/hydrogenfuel.html for more information on the California Division of Measurement Standards Hydrogen Fuel Program. (Viewed 4/11/08)

4, 5, 10, 11, 13, and 15 which are highlighted in yellow) in Table 1 below. These and perhaps other properties will receive further consideration by the FSS and may be added to the quality standard in the future when such action is supported by research.

1. Specification for Hydrogen Fuel for Internal Combustion Engines and Fuel Cells

2. Definitions

(a) **Fuel Cell.** - an electrochemical device used to convert hydrogen and oxygen into electrical energy to power a motor vehicle.

(b) **Internal Combustion Engine.** - a device used to ignite hydrogen in a confined space to create mechanical energy to power a motor vehicle.

(c) **Hydrogen Fuel.**- a fuel composed of the chemical hydrogen intended for consumption in an internal combustion engine or fuel cell.

2. **Specification.** Hydrogen fuel shall conform to the requirements in Table 1.

Table 1. Hydrogen Fuel Quality Specification

Property		Value	Unit	Limit	Test Method(s)
1	Ammonia	0.1	ppm v/v	Maximum	to be specified
2	Carbon Dioxide	2	ppm v/v	Maximum	to be specified
3	Carbon Monoxide	0.2	ppm v/v	Maximum	to be specified
4	Formaldehyde	0.01	ppm v/v	Maximum	to be specified
5	Formic Acid	0.2	ppm v/v	Maximum	to be specified
6	Helium	300	ppm v/v	Maximum	to be specified
7	Hydrogen Fuel Index	99.97	% (a)	Minimum	to be specified
8	Nitrogen and Argon	100	ppm v/v	Maximum	to be specified
9	Oxygen	5	ppm v/v	Maximum	to be specified
10	Particulate Concentration	1	µg/L@NTP (b)	Maximum	to be specified
11	Particulates Size	10	µm	Maximum	to be specified
12	Total Gases	300	ppm v/v (c)	Maximum	to be specified
13	Total Halogenated Compounds	0.05	ppm v/v	Maximum	to be specified
14	Total Hydrocarbons	2	ppm v/v (d)	Maximum	to be specified
15	Total Sulfur Compounds	0.004	ppm v/v	Maximum	to be specified
16	Water	5	ppm v/v	Maximum	to be specified

Footnotes to Table 1 - a. Hydrogen fuel index is the value obtained with the value of total gases (%) subtracted from 100%. b. Particulate Concentration is stated as µg/L@NTP = micrograms per liter of hydrogen fuel at 0 °C and at 1 atmosphere pressure (1 bar). c. Total Gases = Sum of all impurities listed on the table except particulates. d. Total Hydrocarbons may exceed 2 ppm v/v only due to the presence of methane, provided that the total gases do

not exceed 300 ppm v/v.

The FSS will monitor national and international standard activities, research, and other programs to avoid duplication of effort and ensure that its work provides a fuel specification for hydrogen vehicle fuel that serves the needs of the this emerging marketplace. Quality standards are currently under development in SAE International (e.g., SAE J2719 "Hydrogen Specification Guideline for Fuel Cell Vehicles") and in ASTM International (e.g., see www.astm.org for a list of the work underway in its Committee D03.14 on Hydrogen and Fuel Cells and that organizations other committees).

Quality standards are under consideration around the world including the European Union, Japan and other countries. Also of interest are the efforts of Working Group 12 of ISO's Technical Committee 197 on Hydrogen which is very active in this area.[12] ISO's website indicates that its fuel quality standard will be finalized within a few years.

Future work of the FSS may include the development of recommendations for field sampling equipment and handling procedures, along with suggestions about what type of test equipment is appropriate for establishing a hydrogen vehicle fuel quality laboratory.

For Further Information or to Comment Contact:

Please send comments and suggestions concerning the proposals presented in this document to Ken Butcher, Technical Advisor to the Fuel Specifications Subcommittee at kbutcher@nist.gov or at 301-975-4859. Faxes may be sent to 301-975-8091.

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12 http://www.iso.org/iso/standards_development/technical_committees/list_of_iso_technical_committees/iso_technical_committee.htm?commid=54560. (Viewed 4/11/08)