SAE International™	**SURFACE VEHICLE INFORMATION REPORT**	**J2719 APR2008** Issued 2005-11 Revised 2008-04 Superseding J2719 NOV2005

Information Report on the Development of a Hydrogen Quality Guideline for Fuel Cell Vehicles

RATIONALE

This document is being revised to encompass changes indicative of industry progress in the determination of acceptable levels of contaminants and advances in the methodologies used to verify those levels.

Since the initial publication of this TIR, proposals have been introduced to the Interface Working Group (IWG) by members of the energy and specialty gas industries seeking to modify the values of contaminants initially contained in Table 1. These proposals were intended to bring the TIR into conformance with presently established norms for hydrogen production and delivery. These proposals have been discussed at length within the IWG and, by consensus, have been accepted. Acceptance of these proposals also dictated that the values of the Hydrogen Fuel Index and the Total allowable non-hydrogen, non-particulate constituents contained in Table 1 be updated.

This revision also contains clarifications of current works in progress pursuant to the enhanced test methodologies being developed by the ASTM D03 (Gaseous Fuels) Committee.

Additionally, there are numerous editorial corrections to the wording of the document to provide a) clarifications meant to enhance the understanding of the allowable levels of contaminant components (Table 1, Note e), b) correction of inaccurate statements (wording of the definition of inert gases), c) correction of spelling errors, and d) basic information (contained in Appendix B) that provides a more generally accurate picture of the commonly agreed upon impact of hydrogen fuel contaminants to the PEM fuel cell stack, Balance of Plant of the fuel cell system, and hydrogen storage systems in use today.

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1. SCOPE

This Information Report provides interim background information and an interim specification of hydrogen fuel quality for commercial proton exchange membrane (PEM) fuel cell vehicles. This Report also provides background information on how this interim specification was developed by the Hydrogen Quality Task Force (HQTF) of the Interface Working Group (IWG) of the SAE Fuel Cell Standards Committee.

The constituents and thresholds listed in Table 1 are based on a survey of the industry, the published literature and reflects current and draft analytical test methods. Some of the allowable constituent levels are higher than desired because a published detection method is not available for the desired threshold. Some of the allowable constituent levels may be lower than desired due to incomplete evaluations and/or an attempt to minimize testing costs (such as including methane in total hydrocarbons).

Additional testing of the effects of impurities on fuel cells, fuel systems, and storage media is required. Furthermore, development is required on suitable, cost effective test methods, sampling methodologies and equipment for laboratory, in-line and field evaluation. The American Society of Testing and Materials (ASTM) D03 (Gaseous Fuels) Committee has been charged to address some of these issues.

1.1 Purpose

The purpose of this hydrogen fuel quality specification guideline is to provide a common hydrogen fuel quality specification for all US commercial hydrogen refueling stations for fuel cell vehicles (FCVs) and hydrogen internal combustion engine vehicles (ICEVs). Hydrogen quality is defined as being measured at the dispenser nozzle using a suitable adapter and methodology developed by ASTM D03 (Gaseous Fuels) Committee.

1.2 Field of Applicability

The hydrogen quality guideline presented in this Information Report is applicable to PEM FCVs at the point of interface between the fueling station and the vehicle. The specification of hydrogen quality is intended to meet the requirements of FCVs for near term demonstration vehicles, and to meet the requirements of ICEVs to the extent that they have currently been determined. Information considered in the specification of the fuel quality includes:

- Applicable standard chemical analysis test methods to quantify the presence of identified H_2 impurities
- Infrastructure sources of impurities and cost related to production, distribution, storage and handling of H_2
- Fuel cell systems, specifically, levels of impurities that adversely impact performance and/or durability
- On-board H_2 storage and delivery systems

1.3 Relationship of SAE Standard to ISO and ASTM Standards

The guidelines and information presented in this SAE J2719 Information Report was brought to SAE for use in Table 1 and is coordinated with ISO TC197/WG12 (H_2 Fuel – Product Specification Working Group) as well as the ASTM D03 (Gaseous Fuels) Committee and is consistent with ISO 14687 Part2.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, 610-832-9585, www.astm.org.

ASTM D 5454-99 Standard Test Method for Water Vapor Content of Gaseous Fuels Using Electronic Moisture Analyzers

ASTM D 5504-9 Standard Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Chemiluminescence

ASTM D 6348-03 Standard Test Method for Determination of Gaseous Compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy

ASTM D 6968-03 Standard Test Method for Simultaneous Measurement of Sulfur Compounds and Minor Hydrocarbons in Natural Gas and Gaseous Fuels by Gas Chromatography and Atomic Emission Detection

2.1.2 EPA Publications

Available from EPA/NSCEP, P.O. Box 42419, Cincinnati, OH 45249-0419, Tel. 800-490-9198, www.epa.gov/ncepihom/ordering.

EPA Method T012 Listing Background Document for the Chlorinated Aliphatics Listing Determination (Final Rule)

EPA Method T015 Hazardous Air Pollutant Emissions for Miscellaneous Coating Manufacturing

EPA Method 200.7 Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emissions Spectrometry

EPA Method 11 Determination of Hydrogen Sulfide Content of Fuel Gas Streams in Petroleum Refineries

EPA 625/R-96/010A Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air—Second Edition

EPA Method 5i Determination of Low Level Particulate Matter Emissions

2.1.3 JIS Publications

Available from Japanese Standards Association, 4-1-24 Akasaka Minato-ku, Tokyo 107-8440, Japan, Tel: +81-3-3583-8005, www.jsa.or.jp.

JIS K0101:1998 Testing Methods for Industrial Water

JIS K0114:2000 General Rules for Gas Chromatographic Analysis

JIS K0123:1995 General Rules for Analytical Methods in Gas Chromatography Mass Spectrometry

JIS K0124:2002 General Rules for High Performance Liquid Chromatography

JIS K0127:2001 General Rules for Ion Chromatographic Analysis

JIS K0225:2002 Testing Methods for Determination of Trace Components in Diluent Gas and Zero Gas

JIS K0804:1998 Gas Detector Tube Measurement System (Length-of-Stain Type)

2.1.4 NIOSH Publication

Available from National Institute for Occupational Safety and Health, Tel: 800-356-4674, www.cdc.gov/niosh.

NIOSH 2541:1994 Formaldehyde by GC

2.1.5 SCAQMD Publication

Available from South Coast Air Quality Management District, 21865 Copley Drive, Diamond Bar, CA 91765, Tel: 909-396-2000, www.aqmd.gov.

SCAQMD Method 301-91 Identification of Particles by Microscopy

3. DEFINITIONS

Hydrogen fuel consists of pure hydrogen gas and impurities embedded in the fuel stream. The impurities consist of inerts and reactive contaminants. Inerts, as a general rule, do not permanently affect the performance of a fuel cell. Inerts may temporarily affect the performance of the fuel cell system including H_2 storage tanks, regulators etc. Reactive contaminants can be reversible, partially reversible or irreversible and have a lasting affect the performance and/or life of the fuel cell.

3.1 Constituent

A component (or compound) found within a hydrogen fuel mixture

3.2 Contaminant

An impurity that adversely affects the components within the fuel cell system or the hydrogen storage system by reacting with its components. An adverse effect can be reversible or irreversible.

3.3 Diluent

An impurity which reduces the concentration of hydrogen, and may be a contaminant or non-reactive in nature.

3.4 Fuel Cell System

A power system producing electrical energy which typically includes the fuel cell stack, equipment for air processing, fuel processing, thermal management, water management, and the automatic control system

3.5 Hydrogen Fuel Index

The fraction or percentage of a fuel mixture that is hydrogen. It is a value established by the subtraction of the total non hydrogen constituents listed in Table 1, specifically detected, from 100 percent hydrogen. Note that the total (300 ppm) of all non hydrogen, non-particulate constituents is less than the sum of the maximum allowable limits of all non hydrogen constituents shown in Table 1.

3.6 Inert Gas

Non-reactive gases in the noble gas family including argon, helium, krypton, neon, radon, and xenon.

3.7 Impurity

A non-hydrogen constituent in hydrogen fuel.

3.8 Impurity Limit

The concentration threshold level of each specific impurity analyzed in a hydrogen fuel. Impurity limits are designated in micromoles per mole of fuel (μmol/mol) with the exception of particulates, which are designated by size (in micrometres) and mass concentrations (micrograms per liter of hydrogen fuel at 0 °C, 1 atm pressure: μg/L @NTP).

3.9 Odorant

A chemical or combination of chemicals added to a gaseous fuel to impart a characteristic and distinctive (usually disagreeable) warning odor so leaks can be detected. Currently used odorants are presently unacceptable in hydrogen fuel cell vehicles and some hydrogen storage systems.

3.10 Particulate

A solid or aerosol particle that may be entrained somewhere in the delivery, storage, or use of the hydrogen fuel. Particulates are specified by size (aerodynamic diameter in micrometres) and mass concentration (micrograms per liter of fuel at 0 °C and 1 atm pressure).

3.11 Sublimate

An impurity that may undergo a phase-change from solid to gaseous state in the delivery, storage or use, of the hydrogen fuel.

3.12 Tracer

An easily detected inert substance introduced into a fuel stream.

4. CURRENT STATUS OF H_2 QUALITY SPECIFICATIONS

At the present time there is no US or international standard that specifies a grade of hydrogen fuel that is acceptable for PEM fuel cell vehicles and hydrogen ICEVs. As a result, a recommended list of constituents, which includes the stipulated chemical compounds as well as their maximum concentration levels in the hydrogen fuel, is not available. Nevertheless, fuel cell developers working with government-sponsored groups (e.g., California Fuel Cell Partnership (CaFCP), New Energy and Industrial Technology Development Organization (NEDO)/Japan Automobile Research Institute (JARI), and US DOE national laboratories) and universities are exploring the impact of impurities on PEM fuel cell performance

Several groups have brought experimental data and analyses to the SAE Working Group for consideration. Specifically, JARI addressed hydrogen fuel quality for FCVs based on the results of experiments that measured the impact of selected impurities on a fuel cell. Short-term exposures (10 hr) were used to evaluate the impact of assorted concentrations of each impurity on a single cell. The concentration that caused a voltage drop of 2% or more was characterized to be unacceptable for fuel cells. Fuel cell developers from General Motors, Ballard and UTC have brought information on specific contaminants, such as CO, sulfur and halogenates into consideration. Additionally, the guideline used at the two stations of the California Fuel Cell Partnership was available to the Working Group for consideration.

5. TIMELINE OF ACTIVITIES TO DEVELOP A HYDROGEN FUEL QUALITY STANDARD FOR VEHICLES

In order to address hydrogen fuel quality for hydrogen powered vehicles in a systematic and comprehensive way, the IWG developed a plan and timeline of activities that will act as a guideline to establish a H_2 quality standard. The IWG recognized that hydrogen fuel quality should be quantified at the interface between the vehicle and the refueling station and all potential impurities that may affect the fuel cell and fuel storage systems onboard the vehicle should be considered. Figure 1 provides a schematic of this approach. Figure 2 presents the timeline and associated activities envisioned by SAE for completion of this specification.

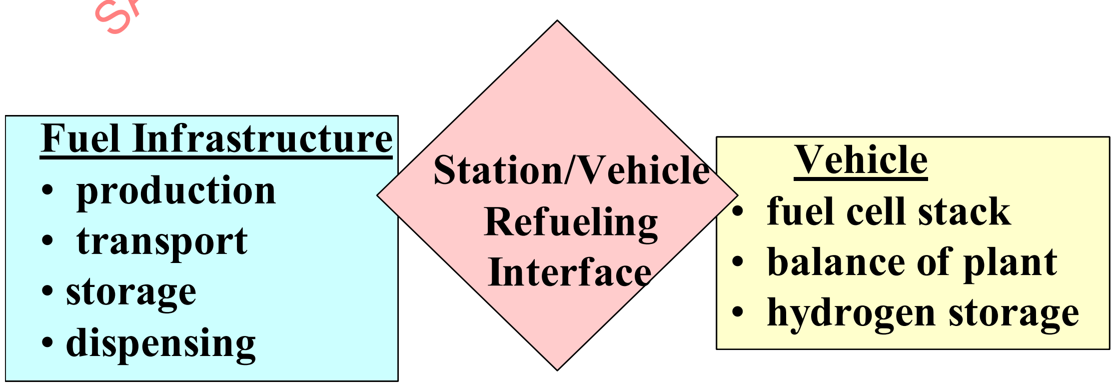

FIGURE 1 - FUEL-VEHICLE INTERFACE CONSIDERATION IN SPECIFYING H_2 QUALITY REQUIREMENTS FOR TRANSPORTATION

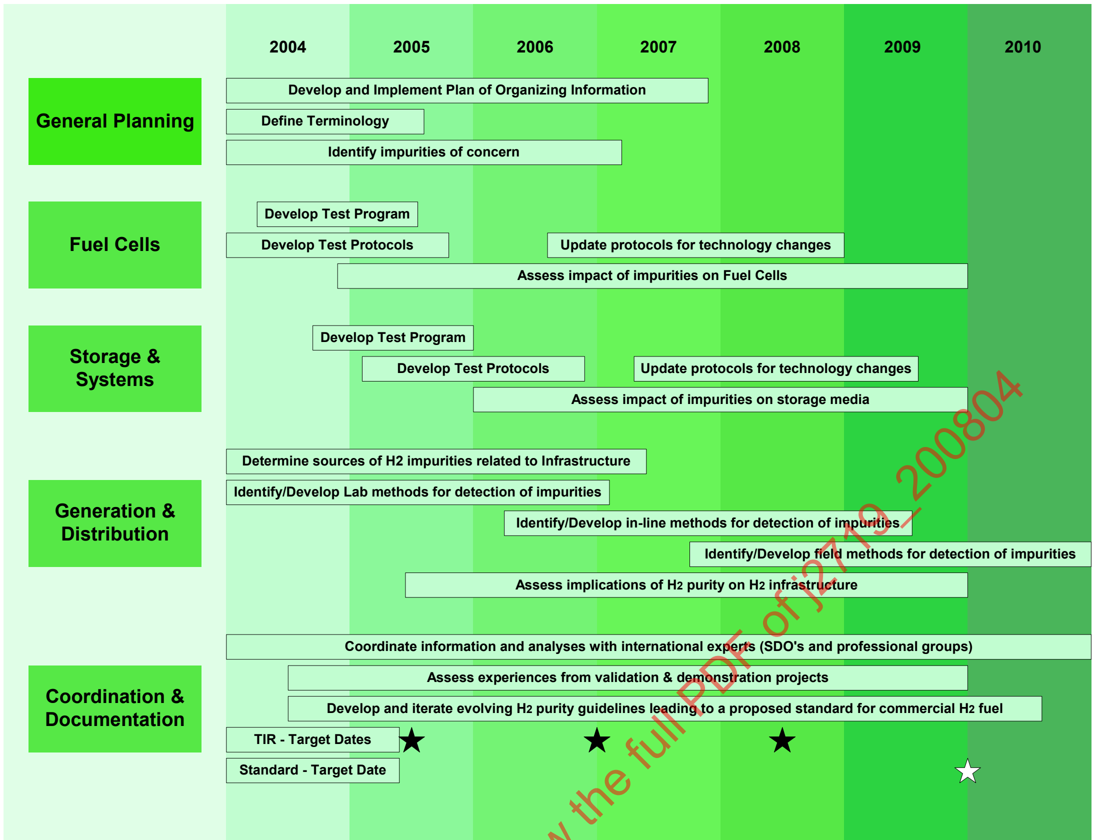

FIGURE 2 - TIMELINE OF ACTIVITIES TO DEVELOP A H_2 FUEL QUALITY STANDARD FOR PEM FUEL CELL VEHICLES

According to the SAE plan, this Technical Information Report (TIR) is one of several evolutions of this document. These reports will document the development and use of information used to specify revisions to a recommended hydrogen fuel quality guideline in order to facilitate moving towards the development of a standard.

6. H_2 QUALITY SPECIFICATION GUIDELINE

Technical presentations given to the IWG by industry, universities and other organizations, such as NEDO/JARI, DOE national laboratories, CaFCP, U.S. Fuel Cell Council (USFCC) and the American Society of Testing and Materials (ASTM), were considered in the development of this technical information report. The hydrogen quality guideline developed is shown in Table 1, Hydrogen Quality Guideline.

The thresholds in Table 1 were derived by consensus considering data supplied to the Working Group. The analytical methods and detection limits were identified by ASTM, CaFCP, and JARI. The species are listed in terms of family of compounds associated with the total accepted threshold value per family, as well as example species in the particular family. The list is not intended to be totally inclusive. Although there may be more (or less) speciation per each family, the data presented here reflect the current knowledge of species of concern. Subsequent evolutions of this TIR are expected to provide an updated version of species as more data become available. In addition, the constituent list addresses a wide range of species, not all of which are expected to be present in every source of hydrogen. Particulate matter should be kept ≤ 10 micrometres via filtering at the station side.

The suggested analytical methods of detection are based on currently available ASTM methods. Although in the majority of species the analytical techniques currently available may satisfy the requirements for testing hydrogen fuel for demonstration purposes, in the future better detection methods will be required. As indicated in Table 1 the suggested thresholds for some constituents are the same as the detection limits. As a result these species need better resolution (i.e. detection limits one or more orders of magnitude below the suggested threshold).

Total hydrocarbons on a C1 basis is an analytic technique where total carbon is calculated and all of the hydrocarbons are assumed to have only a single carbon atom. Therefore, if the total carbon on a C1 basis calculates out to 1 µmole hydrocarbon/mole of hydrogen and the hydrocarbon was methane (CH4), there would be 1 µmole of methane/mole of hydrogen. However, if the hydrocarbon were benzene (C6H6), 1 µmole hydrocarbon/mole of hydrogen calculates out to 0.17 µmole benzene/mole of hydrogen.

This guideline should be considered a reflection of current knowledge. Thresholds will be revised as additional information on long-term impacts and mechanisms of fuel cell impact are explored and understood. Test methodology will be updated as it becomes available from ASTM. See Note (e) of Table 1.

TABLE 1 - HYDROGEN FUEL QUALITY SPECIFICATION GUIDELINE

- Units are µmol/mol unless otherwise specified
- All limits are subject to revision after additional testing under realistic operational conditions and improved standardized analytical procedures
- Limits are upper limits except for hydrogen fuel index where it is a lower limit.

Constituent	Chemical Formula	Limits	Laboratory Test Methods to Consider and Under Development[e]	Current Detection Limit
Hydrogen fuel index	H_2	> 99.97%		
Total allowable non-hydrogen, non-particulate constituents listed below		300		
Acceptable limit of each individual constituent				
Water[a]	H_20	5	No standardized test method available ASTM test methods for trace water in hydrogen under development (Work Item 10196) and ASTM D 1946 under revision (Work Item 4548)	0.5
Total hydrocarbons[b] (C_1 basis)		2	No standardized test method available ASTM D 1946 under revision (Work Item 4548)	0.1
Oxygen	O_2	5	No standardized test method available ASTM D 1946 under revision for low level O_2, N_2, Ar, CO_2, and CO (Work Item 4548)	1
Helium		300	No standardized test method available ASTM D 1946 under revision for low level O_2, N_2, Ar, CO_2, and CO (Work Item 4548)	10
Nitrogen, Argon	N_2, Ar	100	No standardized test method available ASTM D 1946 under revision for low level O_2, N_2, Ar, CO_2, and CO (Work Item 4548)	60
Carbon dioxide	CO_2	2	No standardized test method available ASTM D 1946 under revision for low level O_2, N_2, Ar, CO_2, and CO (Work Item 4548) ASTM developing new standard (WK10196)	0.1
Carbon monoxide	CO	0.2	No standardized test method available ASTM D 1946 under revision for low level O_2, N_2, Ar, CO_2, and CO (Work Item 4548) ASTM developing new standard (WK10196)	0.2

TABLE 1 - HYDROGEN FUEL QUALITY SPECIFICATION GUIDELINE (CONTINUED)

- Units are µmol/mol unless otherwise specified
- All limits are subject to revision after additional testing under realistic operational conditions and improved standardized analytical procedures
- Limits are upper limits except for hydrogen fuel index where it is a lower limit.

Constituent	Chemical Formula	Limits	Laboratory Test Methods to Consider and Under Development[e]	Current Detection Limit
Total sulfur[c]		0.004	No standardized test method available ASTM developing a new standard (Work Item 4548) ASTM acquiring data on D5504 demonstrating ultra-low sensitivity to sulfur gases	0.004
Formaldehyde	HCHO	0.01	No standardized test method available ASTM developing new standards (Work Items 4548 and 6624)	0.01
Formic acid	HCOOH	0.2	No standardized test method available ASTM developing new standards (Work Items 4548 and 9211)	0.2
Ammonia	NH_3	0.1	No standardized test method available ASTM developing new standards (Work Items 4548, 6527, 10196)	0.1
Total halogenates[d]		0.05	No standardized test method available ASTM developing new standard (Work Item 4548)	0.01
Max. Particulate Size		< 10 µm	No standardized test method available ASTM developing new standard (Work Item 9688)	1 µm
Particulate Concentration		1 µg/l	No standardized test method available ASTM developing new standard (Work Item 9688)	1 µg/l

[a] Due to water threshold level, the following constituents should not be found, however should be tested if there is a question on water content:
Sodium (Na+) @ < 0.05 µmole/mole H_2 or < 0.05 µg/liter
Potassium (K+) @ < 0.05 µmole/mole H_2 or < 0.08 µg/liter
or Potassium hydroxide (KOH) @ < 0.05 µmole/mole H_2 or < 0.12 µg/liter

[b] Includes, for example, ethylene, propylene, acetylene, benzene, phenol (paraffins, olefins, aromatic compounds, alcohols, aldehyds). THC may exceed 2 micromoles per mole due only to the presence of methane, in which case the summation of methane, nitrogen and argon is not to exceed 100 ppm.

[c] Includes, for example, hydrogen sulfide (H_2S), carbonyl sulfide (COS), carbon disulfide (CS_2) and mercaptans.

[d] Includes, for example, hydrogen bromide (HBr), hydrogen chloride (HCl), chlorine (Cl_2) and organic halides (R-X).

[e] Approved, standard test methods are not available for detecting many of the non-hydrogen constituents at the levels cited. There are some independent laboratories that can perform hydrogen analysis at the levels cited using non-consensus-based test methods and procedures. Standard Development Organizations such as ASTM are in the process of developing consensus-based test methods to analyze for non-hydrogen constituents at the levels cited.

7. NOTES

7.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE INTERFACE WORKING GROUP
OF THE SAE FUEL CELL STANDARDS COMMITTEE

APPENDIX A - ADDITIONAL DEFINITIONS

The objective of this appendix is to document the terms used when discussing hydrogen fuel quality from the perspective of the members of the IWG-HQTF working on this topic.

Terms not defined herein follow the definitions found in standard dictionaries or in SAE J2574.

A.1 DEFINITIONS

A.1.1 Condensable

An impurity that may undergo a phase-change from gas to liquid or solid at any point during the delivery, storage, or use of the hydrogen fuel.

A.1.2 Constituent

A component (or compound) found within a hydrogen fuel mixture

A.1.3 Contaminant

An impurity that adversely affects the components within the fuel cell system or the hydrogen storage system by reacting with its components. An adverse effect can be reversible or irreversible.

A.1.4 Diluent

An impurity which reduces the concentration of hydrogen, and may be a contaminant or non-reactive in nature.

A.1.5 Hydrogen Fuel Index

The fraction or percentage of a fuel mixture that is hydrogen. It is a value established by the subtraction of the total non hydrogen constituents, specifically detected, from 100 percent hydrogen or by direct measurement of the hydrogen concentration. Note that the total (300 ppm) of all non hydrogen constituents is less than the sum of the maximum allowable limits of all non hydrogen constituents shown in Table 1.

A.1.6 Hydrogen Quality

A description of hydrogen fuel that includes the hydrogen fuel index and the concentration of specific impurities.

A.1.7 Impurity

A non-hydrogen constituent in hydrogen fuel.

A.1.8 Impurity Limit

The concentration threshold level of each specific impurity analyzed in a hydrogen fuel. Impurity limits are designated in micromoles per mole of fuel (μmol/mol) with the exception of particulates, which are designated by size (in micrometres) and mass concentrations (micrograms per liter of hydrogen fuel at 0 °C, 1 atm pressure: μg/L @NTP).

A.1.9 Inert Gas

Non-reactive gases in the noble gas family including argon, helium, krypton, neon, radon, and xenon.

A.1.10 Irreversible Effect

The degradation of the fuel cell power system performance that cannot be restored by practical changes of operational conditions and/or fuel composition.