TECHNICAL SPECIFICATION

ISO/TS 14687-2

First edition
2008-03-01

Hydrogen fuel — Product specification —

Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles

Carburant hydrogène — Spécification de produit —

Partie 2: Applications pour piles à combustible de membrane pour échange de protons (MEP) pour les véhicules routiers

Reference number
ISO/TS 14687-2:2008(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 14687-2 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*.

ISO/TS 14687 consists of the following parts, under the general title *Hydrogen fuel — Product specification*:

— *Part 1: All applications except proton exchange membrane (PEM) fuel cells for road vehicles*

— *Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*

Introduction

This Technical Specification provides an initial, albeit incomplete, basis for describing a common fuel to be used by Proton exchange membrane (PEM) fuel cell road vehicles (FCV) during demonstration programs presently being conducted or envisioned in the near term. A Technical Specification is a normative document that can be published in shorter timeframes than an amendment to a published standard, and it will provide guidance for those who may have to manage small fleets of FCV.

This Technical Specification is intended to consolidate the hydrogen fuel product specification needs anticipated by FCV manufacturers and hydrogen fuel suppliers as both industries proceed toward achieving commercial viability. In this consolidation process, methods to monitor the hydrogen quality that is delivered to these vehicles will also be addressed. Monitoring and controlling hydrogen quality are necessary because specific impurities will adversely affect the fuel cell system and/or on-board hydrogen storage system performance. In addition, there may be performance implications in the fuel cell system if certain non-hydrogen constituent levels are not controlled. A Technical Specification for hydrogen fuel quality can serve as a starting point for all of the participating entities to learn what technology improvements and developments are necessary as well as the impacts of such improvements and developments on commercial viability.

This Technical Specification defines two new grades of hydrogen fuel, “Type I, Grade D” and “Type II, Grade D.” These new grades are intended to apply to the pre-commercial demonstration of PEM FCV on a limited scale. The purpose of this Technical Specification is to establish hydrogen fuel quality supplied at the above-mentioned scale so that the development of FCV as well as the infrastructure of hydrogen fuel can be implemented in a prompt and efficient manner toward the practical use of FCV. Quality verification requirements should be determined at the dispenser nozzle or other location by written agreement between the supplier and the customer. Because ISO 14687:1999 includes other grades of hydrogen fuel of lower quality, and in the absence of ISO standards for hydrogen fuelling stations and installation of hydrogen equipment, it is important to note that appropriate measures should be taken to prevent cross-contamination of these fuels.

Since the FCV and related technology are developing rapidly, this Technical Specification needs to be revised according to technological progress as necessary. Technical Committee ISO/TC 197, will monitor this technology trend. It is also noted that this Technical Specification has been prepared to assist in the development of FCV and related technologies.

Research and development are required to generate specific information so that a final consensus can be reached. These efforts should focus on, but not be limited to,

— PEM catalyst and fuel cell tolerance to hydrogen fuel impurities,

— effects/mechanisms of impurities on fuel cell systems and components,

— impurity detection and measurement techniques for laboratory, production, and in-field operations,

— onboard hydrogen storage technology, and

— vehicle demonstration results.

Because of the aforementioned rapid development, ISO/TC 197 will continue its work to prepare an International Standard in a manner that reflects technological advancements by incorporating the lessons learned from ongoing research, development, and demonstration activities. Any application of this Technical Specification should take technological progress into account.

Hydrogen fuel — Product specification —

Part 2:
Proton exchange membrane (PEM) fuel cell applications for road vehicles

1 Scope

This Technical Specification specifies the quality characteristics of hydrogen fuel in order to assure uniformity of the hydrogen product as dispensed for utilization in PEM fuel cell road vehicle systems.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14687-1, *Hydrogen fuel — Product specification — Part 1: All applications except proton exchange membrane (PEM) fuel cells for road vehicles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14687-1 and the following apply.

3.1
constituent
component (or compound) found within a hydrogen fuel

3.2
contaminant
constituent that adversely affects the components within the fuel cell system or the hydrogen storage system

NOTE An adverse effect can be reversible or irreversible.

3.3
fuel cell system
power system used for the generation of electricity on a fuel cell vehicle, typically containing the following subsystems: fuel cell stack, air processing, fuel processing, thermal management, water management, and automatic control system

3.4
hydrogen fuel index
measure of hydrogen fuel quality based on the presence of listed non-hydrogen constituents

3.5
irreversible effect
effect, which results in a permanent degradation of the fuel cell power system performance that cannot be restored by practical changes of operational conditions and/or gas composition

3.6
non-hydrogen constituent
component (or compound) other than hydrogen found within a hydrogen fuel

3.7
particulate
solid or aerosol particle, including oil-mist, potassium and sodium compounds that may be entrained somewhere in the delivery, storage, or transfer of the hydrogen fuel

3.8
reversible effect
effect, which results in a temporary degradation of the fuel cell power system performance that can be restored by practical changes of operational conditions and/or gas composition

4 Requirements

4.1 Classification

Hydrogen fuel for PEM fuel cell applications for road vehicles shall be classified according to the following types and grade designations:

- Type I (grade D): Gaseous hydrogen
- Type II (grade D): Liquid hydrogen

4.2 Applications

The following information characterizes representative applications of each type and grade of hydrogen fuel. It is noted that suppliers commonly transport hydrogen of a higher quality than some users may require.

Type I, grade D Gaseous hydrogen fuel for PEM fuel cell road vehicle systems

Type II, grade D Liquid hydrogen fuel for PEM fuel cell road vehicle systems

NOTE 1 Type I (grades A, B, and C), Type II (grade C) and Type III, which are applicable for all applications except PEM fuel cells for road vehicles, are defined in ISO 14687-1.

NOTE 2 There is no equivalent grade A and B for Type II fuels.

4.3 Limiting characteristics

The directory of limiting characteristics outlined in Table 1 specifies the requirements applicable to the aforementioned grades of hydrogen fuel.

5 Quality Verification

5.1 Hydrogen fuel qualification test

5.1.1 General requirements

Quality verification requirements shall be determined at the dispenser nozzle or other location by written agreement between the supplier and the customer.

5.1.2 Analytical requirements of the qualification tests

The analytical requirements for the qualification tests shall be determined by agreement between the supplier and the customer.

5.1.3 Report results

The detectable limits for analytical methods and instruments used shall be reported along with the results of each test. These detectable limits shall be below the threshold limit for each constituent. All limiting characteristics of the hydrogen fuel specified in Table 1 shall meet the requirements therein. When applicable, means should be provided to test for other contaminants not listed in Table 1, but identified as potentially harmful to the fuel cell system.

NOTE Annex A provides the rationale for the selection of the non-hydrogen constituents specified in Table 1.

5.2 Lot acceptance tests

Lot acceptance requirements shall be determined by agreement between the supplier and the customer.

Table 1 — Directory of limiting characteristics

Characteristics (assay)	Type I Grade D	Type II Grade D	Laboratory test methods[a]
Hydrogen fuel index (minimum mole fraction) [b]	99,99 %	99,99 %	
Para-hydrogen (minimum mole fraction)	Not specified	95,0 %	
Maximum concentration of non-hydrogen constituents			
Total gases [c]	100 µmol/mol	100 µmol/mol	
Water (H_2O)	5 µmol/mol	5 µmol/mol	ASTM D6348, ASTM D5454, ASTM (D1946 & D5466) [h] JIS K 0225
Total hydrocarbons [d] (C_1 basis)	2 µmol/mol	2 µmol/mol	EPA T012, EPA T015, ASTM (D1946 & D5466) [h], ASTM D6968, JIS K 0114
Oxygen (O_2)	5 µmol/mol	5 µmol/mol	ASTM (D1946 & D5466) [h], JIS K 0225
Helium (He), Nitrogen (N_2), Argon (Ar)	100 µmol/mol	100 µmol/mol	ASTM (D1946 & D5466) [h], JIS K 0114
Carbon dioxide (CO_2)	2 µmol/mol	2 µmol/mol	ASTM (D1946 & D5466) [h], JIS K 0114, JIS K 0123
Carbon monoxide (CO)	0,2 µmol/mol	0,2 µmol/mol	EPA 25C, ASTM (D1946 & D5466) [h], JIS K 0114, JIS K 0123
Total sulfur compounds [e]	0,004 µmol/mol [g]	0,004 µmol/mol [g]	ASTM (D1946 & D5466) [h], ASTM D5504, JIS K 0127
Formaldehyde (HCHO)	0,01 µmol/mol	0,01 µmol/mol	EPA Method 11, NIOSH 2541, EPA T015, ASTM (D1946 & D5466) [h], JIS K 0114, JIS K 0124, JIS K 0123
Formic acid (HCOOH)	0,2 µmol/mol [g]	0,2 µmol/mol [g]	ASTM (D1946 & D5466) [h], JIS K 0123, JIS K 0127
Ammonia (NH_3)	0,1 µmol/mol [g]	0,1 µmol/mol [g]	ASTM (D1946 & D5466) [h], EPA T015, JIS K 0127
Total halogenated compounds	0,05 µmol/mol	0,05 µmol/mol	EPA 200.7, JIS K 0101
Maximum particulates size [f]	10 µm	10 µm	SCAQMD Method 301-91
Maximum particulates concentration [f]	1 µg/L at 20 °C and 101,325 kPa	1 µg/L at 20 °C and 101,325 kPa	Gravimetric (EPA 625/R-96/010A)

NOTE 1 It is recognized that the margin between the lower detectable limit and the acceptable limit for several potential non-hydrogen constituents is based on the limited state of development of PEM fuel cell technology as of the date of this Technical Specification.

NOTE 2 For the constituents that are additive, such as total hydrocarbons and total sulfur compounds, the sum of the constituents are to be less than or equal to the acceptable limit. The tolerances in the applicable gas testing method are to be the tolerance of the acceptable limit.

[a] The test methods (e.g. ASTM, EPA, SCAQMD, JIS) were selected on the basis that they can detect the non-hydrogen constituents at levels equal to or below the listed threshold concentrations. Other nationally or internationally accepted test methods may also be used, provided both the customer and the supplier agree and the selected alternative methods are suitable to detect and measure the constituent in question at the same or lower concentration threshold level.

[b] The hydrogen fuel index is determined by subtracting the total content of non-hydrogen gaseous constituents listed in Table 1 (Total gases), expressed in mole percent, from 100 mole percent. It is less than the sum of the maximum allowable limits of all non-hydrogen constituents shown in Table 1.

[c] The value of total gases is summation of the values of the non-hydrogen constituents listed in Table 1 except the particulates.

[d] Total hydrocarbons include oxygenated organic species. Total hydrocarbons are measured on a carbon basis (µmolC/mol). Total hydrocarbons may exceed 2 µmol/mol due only to the presence of methane, provided that the total gases do not exceed 100 µmol/mol.

[e] As a minimum, testing shall include H2S, COS, CS2 and mercaptans, which are typically found in natural gas.

[f] Recommended value for particulates is subject to sampling under realistic operational conditions and improved standardized analytical procedures.

[g] These values are based on detection limits of available instrumentation and test methods and serve as a basis for subsequent improvements in test methods and instrumentation. Recommended values for these constituents are subject to additional testing under realistic operational conditions and improved analytical procedures suitable for standardization.

[h] A new ASTM standard (WK4548) that will combine relevant portions of these two existing test methods and will utilize gas chromatography/mass spectrometry (GC/MS) to determine trace contaminants in hydrogen is under development.

Annex A
(informative)

Rationale for the selection of non-hydrogen constituents

A.1 Water content

Water (H_2O) generally does not affect the function of fuel cell, however, it provides a transport mechanism for water-soluble contaminants such as K^+ and Na^+ when present as an aerosol. Both K^+ and Na^+ are recommended not to exceed 0,05 µmol/mol. In addition, it may pose a concern for onboard vehicle fuel systems. At the maximum allowable concentration, water will remain gaseous throughout the operating conditions of fuel cell systems.

A.2 Total hydrocarbon content

Different hydrocarbons have different effects on fuel cell performance. Generally aromatic hydrocarbons adsorb more strongly on the catalyst surface than paraffinic molecules thus blocking its access to hydrogen. It should be noted that methane (CH_4) is considered inert since its only possible effect is to dilute the hydrogen gas.

A.3 Oxygen content

Oxygen (O_2) in low concentrations is considered an inert constituent, as it does not adversely affect the function of the fuel cell system; however, it may be a concern for onboard vehicle storage systems as it can generate water.

A.4 Helium, nitrogen and argon content

Constituents, such as helium (He), nitrogen (N_2) and argon (Ar) are inert and do not normally react with fuel cell components or a fuel cell system. However, they dilute the hydrogen gas and adversely affect fuel cell systems under operation.

A.5 Carbon dioxide content

Carbon dioxide (CO_2) acts largely as a non-reactive constituent for fuel cell systems. However, it may adversely affect onboard hydrogen storage systems using metal hydride alloys.

A.6 Carbon monoxide content

Carbon monoxide (CO) is a severe catalyst contaminant. However, the reaction is considered reversible.

A.7 Total sulfur compounds contents

Sulfur containing compounds are considered as severe contaminants causing irreversible fuel cell performance degradation. The minimum specific sulfur compounds that need to be included in the testing are: hydrogen sulfide (H_2S), carbonyl sulfide (COS), carbon disulfide (CS_2), methyl mercaptan (CH_3SH), which may be found in hydrogen reformed from natural gas. However, it is recommended to monitor total sulfur compounds.

A.8 Formaldehyde and formic acid contents

Formaldehyde (HCHO) and formic acid (HCOOH) have a similar effect on fuel cell performance as CO and are thus considered as reversible contaminants. The effect of HCHO and HCOOH on fuel cell performance is believed to be more severe than that of CO due to slower recovery kinetics.

A.9 Ammonia content

Ammonia (NH_3) causes irreversible fuel cell performance degradation by contaminating the proton exchange membrane/ionomer and reacting with protons in the membrane/ionomer to form NH_4^+ ions. The threshold value listed is based on available standardized analytical methodology. If more sensitive standardized methodologies become available, revised threshold values should be used after validation.

A.10 Total halogenated compounds contents

Halogenated compounds cause irreversible performance degradation. Sources include chlor-alkali production processes and refrigerants used in processing.

A.11 Particulates

A maximum particulate size diameter is specified because of concerns of gasket erosion in tanks. A maximum particulate concentration is specified to ensure that filters are not clogged and/or particulates do not enter the fuel system and affect operation of valves. Potassium and sodium ions present in aerosols cause irreversible performance degradation by contaminating the proton exchange membrane/ionomer.

Bibliography

[1] ASTM D1946-90 (2006), *Standard Practice for Analysis of Reformed Gas by Gas Chromatography*

[2] ASTM D5466-01 (2007), *Standard Test Method for Determination of Volatile Organic Chemicals in Atmospheres (Canister Sampling Methodology)*

[3] ASTM D6968-03, *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*

[4] ASTM D5504-01 (2006), *Standard Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Chemiluminescence*

[5] ASTM D6348-03, *Standard Test Method for Determination of Gaseous Compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy*

[6] ASTM D5454-04, *Standard Test Method for Water Vapor Content of Gaseous Fuels Using Electronic Moisture Analyzers*

[7] JIS K 0225:2002, *Testing methods for determination of trace components in diluent gas and zero gas*

[8] JIS K 0114:2000, *General rules for gas chromatographic analysis*

[9] JIS K 0123:2006, *General rules for analytical methods in gas chromatography/mass spectrometry*

[10] JIS K 0127:2001, *General rules for ion chromatographic analysis*

[11] JIS K 0124:2002, *General rules for high performance liquid chromatography*

[12] JIS K 0101:1998, *Testing methods for industrial water*

ICS 71.100.20

Price based on 7 pages