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Hydrogen fuel quality — Product specification

Qualité du carburant hydrogène — Spécification de produit

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*.

This first edition of ISO 14687 cancels and replaces ISO 14687-1:1999, ISO 14687-2:2012 and ISO 14687-3:2014. It also incorporates the Technical Corrigenda ISO 14687-1:1999/Cor 1:2001 and ISO 14687-1:1999/Cor 2:2008.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

As mentioned in the Foreword, this document is a combination of three former standards for the specifications of hydrogen fuel, ISO 14687-1, ISO 14687-2 and ISO 14687-3, incorporating their revisions at the same time.

In recent years, PEM (proton exchange membrane) fuel cell technologies have shown a remarkable progress such as lowering of platinum (Pt)-loading, thinned electrolyte membrane, operation with high current density and operation under low humidity. With this progress, it has become necessary to reconsider the tolerances of hydrogen impurities for the PEM fuel cells which were previously specified in ISO 14687-2 and ISO 14687-3.

Therefore, this document has been mainly revised based on the research and development of PEM fuel cells focusing on the following items[1], [3] to [15]:

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

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

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

— fuel cell vehicle demonstration and stationary fuel cell demonstration results.

The grade D and the grade E of this document are intended to apply to PEM fuel cells for road vehicles and stationary appliances respectively. These aim to facilitate the provision of hydrogen of reliable quality balanced with acceptable lower cost for the hydrogen fuel supply.

This document reflects the state of the art at the date of its publication, but since the quality requirements for hydrogen technology applications are developing rapidly, this document may need to be further revised in the future according to technological progress.

Hydrogen fuel quality — Product specification

1 Scope

This document specifies the minimum quality characteristics of hydrogen fuel as distributed for utilization in vehicular and stationary applications.

It is applicable to hydrogen fuelling applications, which are listed in Table 1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 19880-8, *Gaseous Hydrogen — Fuelling stations — Part 8: Fuel Quality Control*

ISO 21087, *Gas analysis — Analytical methods for hydrogen fuel — Proton exchange membrane (PEM) fuel cell applications for road vehicles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
boundary point
<PEM *fuel cell* (3.7) for stationary applications> point between the *hydrogen fuel supply equipment* (3.13) and the PEM *fuel cell power system* (3.9) at which the quality characteristics of the hydrogen fuel are to be determined

3.2
constituent
component (or compound) found within a hydrogen fuel mixture

3.3
contaminant
impurity that adversely affects the components within the *fuel cell system* (3.8), the *fuel cell power system* (3.9) or the hydrogen storage system

Note 1 to entry: An adverse effect can be reversible or irreversible.

3.4
customer
<PEM *fuel cell* (3.7) for stationary applications> party responsible for sourcing hydrogen fuel in order to operate the *fuel cell power system* (3.9)

3.5
detection limit
lowest quantity of a substance that can be distinguished from the absence of that substance with a stated confidence limit

3.6
determination limit
lowest quantity which can be measured at a given acceptable level of uncertainty

3.7
fuel cell
electrochemical device that converts the chemical energy of a fuel and an oxidant to electrical energy (DC power), heat and other reaction products

3.8
fuel cell system
<PEM *fuel cell* (3.7) for road vehicle applications> power system used for the generation of electricity on a fuel cell vehicle

Note 1 to entry: The fuel cell system typically contains the following subsystems: fuel cell stack, air processing, fuel processing, thermal management and water management.

3.9
fuel cell power system
<PEM *fuel cell* (3.7) for stationary applications> self-contained fuel cell assembly used for the generation of electricity which is fixed in a place in a specific location

Note 1 to entry: The fuel cell power system typically contains the following subsystems: fuel cell stack, air processing, thermal management, water management and automatic control system. It is used in applications such as: distributed power generation, back-up power generation, remote power generation, electricity and heat co-generation for residential and commercial applications.

Note 2 to entry: For the purposes of the applications, the fuel cell power system does not contain a fuel processing system due to the location of the *boundary point* (3.1).

3.10
gaseous hydrogen
hydrogen under gaseous form, purified to a minimum mole fraction as specified in tables in this document

3.11
hydrogen-based fuel
<PEM *fuel cell* (3.7) for stationary applications> gas containing a concentration of hydrogen as specified in tables in this document used for PEM fuel cell for stationary applications

3.12
hydrogen fuel index
mole fraction of a fuel mixture that is hydrogen

3.13
hydrogen fuel supply equipment
equipment used for the transportation or on-site generation of hydrogen fuel, and subsequently for the delivery to the *fuel cell power system* (3.9), including additional storage, vaporization and pressure regulation as appropriate

3.14
irreversible effect
effect, which results in a permanent degradation of *the fuel cell system* (3.8) or the *fuel cell power system* (3.9) performance that cannot be restored by practical changes of operational conditions and/or gas composition

3.15
liquid hydrogen
hydrogen that has been liquefied, i.e. brought to a liquid state

3.16
particulate
solid or liquid such as oil mist that can be entrained somewhere in the production, delivery, storage or transfer of the hydrogen fuel to a *fuel cell system* (3.8) or a *fuel cell power system* (3.9)

3.17
reversible effect
effect, which results in a temporary degradation of *the fuel cell system* (3.8) or the *fuel cell power system* (3.9) performance that can be restored by practical changes of operational conditions and/or gas composition

3.18
slush hydrogen
hydrogen that is a mixture of solid and liquid at the eutectic (triple-point) temperature

3.19
system integrator
<PEM *fuel cell* (3.7) for stationary applications> integrator of equipment between the PEM *fuel cell power system* (3.9) and the hydrogen supply

4 Classification and application

4.1 Classification

Hydrogen fuel shall be classified according to the following types and grade designations:

a) Type I (grades A, B, C, D and E): gaseous hydrogen and hydrogen-based fuel.

b) Type II (grades C and D): liquid hydrogen.

c) Type III: slush hydrogen.

4.2 Application

Table 1 characterizes representative applications of each type and grade of hydrogen fuel.

Table 1 — Hydrogen and hydrogen-based fuel classification by application

Type	Grade	Category	Applications	Clause
I Gas	A	—	Gaseous hydrogen; internal combustion engines for transportation; residential/commercial combustion appliances (e.g. boilers, cookers and similar applications)	7
	B	—	Gaseous hydrogen; industrial fuel for power generation and heat generation except PEM fuel cell applications	7
	C	—	Gaseous hydrogen; aircraft and space-vehicle ground support systems except PEM fuel cell applications	7
	D[a,b]	—	Gaseous hydrogen; PEM fuel cells for road vehicles	5
	E	PEM fuel cells for stationary appliances		6
		1	Hydrogen-based fuel; high efficiency/low power applications	
		2	Hydrogen-based fuel; high power applications	
		3	Gaseous hydrogen; high power/high efficiency applications	

[a] Grade D may be used for other fuel cell applications for transportation including forklifts and other industrial trucks if agreed upon between supplier and customer.

[b] Grade D may be used for PEM fuel cell stationary appliances alternative to grade E category 3.

Table 1 *(continued)*

Type	Grade	Category	Applications	Clause
II Liquid	C	—	Aircraft and space-vehicle on-board propulsion and electrical energy requirements; off-road vehicles	7
	D[a,b]	—	PEM fuel cells for road vehicles	5
III Slush	—	—	Aircraft and space-vehicle on-board propulsion	7

[a] Grade D may be used for other fuel cell applications for transportation including forklifts and other industrial trucks if agreed upon between supplier and customer.

[b] Grade D may be used for PEM fuel cell stationary appliances alternative to grade E category 3.

NOTE Biological sources of hydrogen can contain additional constituents (e.g. siloxanes or mercury) that can affect the performance of the various applications, particularly PEM fuel cells. However, these are not included in most of the following specifications due to insufficient information.

5 Hydrogen quality requirements for PEM fuel cell road vehicle application

5.1 Fuel quality specification

The quality of hydrogen at dispenser nozzle for grade D hydrogen (see Table 1) shall meet the requirements of Table 2. The fuel specifications are not process-dependent or feed-stock-specific. Non-listed contaminants have no guarantee of being benign.

NOTE ISO 19880-8:2019, Annex A provides the rationale for the selection of the impurities specified in Table 2.

Table 2 — Fuel quality specification for PEM fuel cell road vehicle application

Constituents[a] (assay)	**Type I, Type II grade D**
Hydrogen fuel index (minimum mole fraction)[b]	99,97 %
Total non-hydrogen gases (maximum)	300 µmol/mol
Maximum concentration of individual contaminants	
Water (H_2O)	5 µmol/mol
Total hydrocarbons except methane[c] (C1 equivalent)	2 µmol/mol
Methane (CH_4)	100 µmol/mol
Oxygen (O_2)	5 µmol/mol
Helium (He)	300 µmol/mol

[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the constituents shall be less than or equal to the acceptable limit.

[b] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[c] Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmol/mol).

[d] The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

[e] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[f] All halogenated compounds which could potentially be in the hydrogen gas [for example, hydrogen chloride (HCl) and organic chlorides (R-Cl)] should be determined by the hydrogen quality control plan discussed in ISO 19880-8. Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

[g] Particulate includes solid and liquid particulates comprises of oil mist. Large particulates can cause issues with vehicle components and should be limited by using filter as specified in ISO 19880-1. No visible oil shall be found in fuel at a nozzle.

Table 2 *(continued)*

Constituents[a] (assay)	Type I, Type II grade D
Nitrogen (N_2)	300 µmol/mol
Argon (Ar)	300 µmol/mol
Carbon dioxide (CO_2)	2 µmol/mol
Carbon monoxide (CO)[d]	0,2 µmol/mol
Total sulphur compounds[e] (S1 equivalent)	0,004 µmol/mol
Formaldehyde (HCHO)[d]	0,2 µmol/mol
Formic acid (HCOOH)[d]	0,2 µmol/mol
Ammonia (NH_3)	0,1 µmol/mol
Halogenated compounds[f] (Halogen ion equivalent)	0,05 µmol/mol
Maximum particulate concentration[g]	1 mg/kg

[a] For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the constituents shall be less than or equal to the acceptable limit.

[b] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[c] Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmol/mol).

[d] The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

[e] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[f] All halogenated compounds which could potentially be in the hydrogen gas [for example, hydrogen chloride (HCl) and organic chlorides (R-Cl)] should be determined by the hydrogen quality control plan discussed in ISO 19880-8. Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

[g] Particulate includes solid and liquid particulates comprises of oil mist. Large particulates can cause issues with vehicle components and should be limited by using filter as specified in ISO 19880-1. No visible oil shall be found in fuel at a nozzle.

5.2 Analytical method

The analytical methods for measuring constituents in Table 2 shall meet the requirements of ISO 21087.

5.3 Sampling

Guidance on hydrogen sampling methods for gaseous hydrogen fuelling stations is available in ISO 19880-1.

5.4 Hydrogen quality control

The means of assuring that the hydrogen quality meets the specification in 5.1 shall be based upon ISO 19880-8.