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**Hydrogen fuel quality — Product  
specification**

*Qualité du carburant hydrogène — Spécification de produit*

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Published in Switzerland

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## 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.

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](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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](http://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](http://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<sup>[1], [3] to [15]</sup>:

- 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.

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# 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 <sup>a,b</sup>	—	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			

<sup>a</sup> 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.

<sup>b</sup> 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 <sup>a,b</sup>	—	PEM fuel cells for road vehicles	5
III Slush	—	—	Aircraft and space-vehicle on-board propulsion	7

<sup>a</sup> 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.

<sup>b</sup> 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 <sup>a</sup> (assay)	Type I, Type II grade D
Hydrogen fuel index (minimum mole fraction) <sup>b</sup>	99,97 %
Total non-hydrogen gases (maximum)	300 µmol/mol
<b>Maximum concentration of individual contaminants</b>	
Water (H <sub>2</sub> O)	5 µmol/mol
Total hydrocarbons except methane <sup>c</sup> (C1 equivalent)	2 µmol/mol
Methane (CH <sub>4</sub> )	100 µmol/mol
Oxygen (O <sub>2</sub> )	5 µmol/mol
Helium (He)	300 µmol/mol

<sup>a</sup> 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.

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

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

<sup>d</sup> The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

<sup>e</sup> As a minimum, total sulphur compounds include H<sub>2</sub>S, COS, CS<sub>2</sub> and mercaptans, which are typically found in natural gas.

<sup>f</sup> 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).

<sup>g</sup> 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 <sup>a</sup> (assay)	Type I, Type II grade D
Nitrogen (N <sub>2</sub> )	300 µmol/mol
Argon (Ar)	300 µmol/mol
Carbon dioxide (CO <sub>2</sub> )	2 µmol/mol
Carbon monoxide (CO) <sup>d</sup>	0,2 µmol/mol
Total sulphur compounds <sup>e</sup> (S1 equivalent)	0,004 µmol/mol
Formaldehyde (HCHO) <sup>d</sup>	0,2 µmol/mol
Formic acid (HCOOH) <sup>d</sup>	0,2 µmol/mol
Ammonia (NH <sub>3</sub> )	0,1 µmol/mol
Halogenated compounds <sup>f</sup> (Halogen ion equivalent)	0,05 µmol/mol
Maximum particulate concentration <sup>g</sup>	1 mg/kg

<sup>a</sup> 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.

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

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

<sup>d</sup> The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

<sup>e</sup> As a minimum, total sulphur compounds include H<sub>2</sub>S, COS, CS<sub>2</sub> and mercaptans, which are typically found in natural gas.

<sup>f</sup> 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).

<sup>g</sup> 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.

## 6 Hydrogen and hydrogen-based fuels, quality requirements for PEM fuel cell stationary applications

### 6.1 Fuel quality specification

The quality of hydrogen and hydrogen-based fuels, supplied to stationary PEM fuel cell appliances, shall meet the requirements of [Table 3](#) at the boundary point set between the hydrogen fuel supply equipment and the PEM fuel cell power system.

NOTE 1 [Annex A](#) provides guidance for the selection of the boundary point.

NOTE 2 [Annex B](#) provides the rationale for the selection of the impurities specified in [Table 3](#).

Type I, grade E hydrogen and hydrogen-based fuels, for PEM fuel cell applications for stationary appliances, specify the following subcategories in order to meet the needs of different stationary applications, depending on the requirements specified by the manufacturer:

- Type I, grade E, category 1 (hydrogen-based fuel; high efficiency/low power applications).
- Type I, grade E, category 2 (hydrogen-based fuel; high power applications).
- Type I, grade E, category 3 (gaseous hydrogen; high power/high efficiency applications).

**Table 3 — Fuel quality specification for PEM fuel cell stationary applications**

Constituents <sup>a</sup> (assay)	Type I, grade E		
	Category 1	Category 2	Category 3
Hydrogen fuel index <sup>b</sup> (minimum mole fraction)	50 %	50 %	99,9 %
Total non-hydrogen gases (maximum mole fraction)	50 %	50 %	0,1 %
Water (H <sub>2</sub> O) <sup>c</sup>	Non-condensing at any ambient conditions	Non-condensing at any ambient conditions	Non-condensing at any ambient conditions
Maximum concentration of individual contaminants <sup>d</sup>			
Total hydrocarbons except methane <sup>e</sup> (C <sub>1</sub> equivalent)	10 µmol/mol	2 µmol/mol	2 µmol/mol
Methane (CH <sub>4</sub> )	5 %	1 %	100 µmol/mol
Oxygen (O <sub>2</sub> )	200 µmol/mol	200 µmol/mol	50 µmol/mol
Sum of nitrogen (N <sub>2</sub> ), argon (Ar) and helium (He) (mole fraction)	50 %	50 %	0,1 %

<sup>a</sup> 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.

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

<sup>c</sup> Each site shall be evaluated to determine the appropriate maximum water content based on the lowest expected ambient temperature and the highest expected storage pressure.

<sup>d</sup> The maximum concentration of impurities against the total gas content shall be determined on a dry basis.

<sup>e</sup> Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmolC/mol).

<sup>f</sup> The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

<sup>g</sup> As a minimum, total sulphur compounds include H<sub>2</sub>S, COS, CS<sub>2</sub> and mercaptans, which are typically found in natural gas.

<sup>h</sup> Halogenated compounds includes, for example, hydrogen chloride (HCl) and organic chlorides (R-Cl). Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

Table 3 (continued)

Constituents <sup>a</sup> (assay)	Type I, grade E		
	Category 1	Category 2	Category 3
Carbon dioxide (CO <sub>2</sub> )	Included in total non-hydrogen gases	Included in total non-hydrogen gases	2 µmol/mol
Carbon monoxide (CO)	10 µmol/mol	10 µmol/mol	0,2 µmol/mol <sup>f</sup>
Total sulphur compounds <sup>g</sup> (S1 equivalent)	0,004 µmol/mol	0,004 µmol/mol	0,004 µmol/mol
Formaldehyde (HCHO)	3,0 µmol/mol	0,2 µmol/mol	0,2 µmol/mol <sup>f</sup>
Formic acid (HCOOH)	10 µmol/mol	0,2 µmol/mol	0,2 µmol/mol <sup>f</sup>
Ammonia (NH <sub>3</sub> )	0,1 µmol/mol	0,1 µmol/mol	0,1 µmol/mol
Halogenated compounds <sup>h</sup> (halogen ion equivalent)	0,05 µmol/mol	0,05 µmol/mol	0,05 µmol/mol
Maximum particulate concentration	1 mg/kg	1 mg/kg	1 mg/kg
Maximum particle diameter	75 µm	75 µm	75 µm

<sup>a</sup> 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.

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

<sup>c</sup> Each site shall be evaluated to determine the appropriate maximum water content based on the lowest expected ambient temperature and the highest expected storage pressure.

<sup>d</sup> The maximum concentration of impurities against the total gas content shall be determined on a dry basis.

<sup>e</sup> Total hydrocarbons except methane include oxygenated organic species. Total hydrocarbons except methane shall be measured on a C1 equivalent (µmolC/mol).

<sup>f</sup> The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol.

<sup>g</sup> As a minimum, total sulphur compounds include H<sub>2</sub>S, COS, CS<sub>2</sub> and mercaptans, which are typically found in natural gas.

<sup>h</sup> Halogenated compounds includes, for example, hydrogen chloride (HCl) and organic chlorides (R-Cl). Halogenated compounds shall be measured on a halogen ion equivalent (µmol/mol).

## 6.2 Quality verification

### 6.2.1 General requirements

Quality verification requirements shall be determined at the boundary point using the sampling methods specified in 6.3.

The selection of relevant fuel contaminants for analysis as specified in Table 3 should be carried out based on the hydrogen production method.

All analyses conducted under this document shall be undertaken using gaseous calibration standards (or other calibration devices) that are traceable to the International System of Units (SI) via national standards, where such standards are available.

NOTE ISO 21087 provides guidance for analytical methods.

### 6.2.2 Analytical requirements of the qualification tests

The frequency of testing and analytical requirements for the qualification tests shall be determined based on the agreement between the supplier and the customer. Consideration shall be given to the consistency of hydrogen supply in determining the test frequency and constituents to be tested.

NOTE Annex C provides a recommended practice of the quality assurance for steam methane reforming (SMR) hydrogen production processes using pressure swing adsorption (PSA) purification.

### 6.2.3 Report results

The detection limits and the determination limits for analytical methods and instruments used shall be reported along with the results of each test and the date the sample was taken.

## 6.3 Sampling

### 6.3.1 Sample size

Where possible, the quantity of hydrogen in a single sample container should be sufficient to perform the analyses for the hydrogen fuel quality specification. If a single sample does not contain a sufficient quantity of hydrogen to perform all of the analyses required to assess the quality level, additional samples from the same lot shall be taken under similar conditions. A large sample or sample with a greater pressure, where applicable, may be required if multiple tests are to be conducted.

### 6.3.2 Selection of the sampling point

A boundary point shall be established so that gaseous samples are representative of the hydrogen supplies to the PEM fuel cell power systems.

NOTE [Annex A](#) provides guidance to assist in the identification of the party responsible for the quality of hydrogen at the boundary point and also the selection of the boundary point.

### 6.3.3 Sampling procedure

Gaseous hydrogen samples shall be representative of the hydrogen supply, withdrawn from the boundary point through a suitable connection into an appropriately sized sample container. No contamination of the hydrogen fuel shall be introduced between the boundary point and the sample container (a suitable purge valve may be used).

The residual gases inside the sample container shall be evacuated to ensure that the sampled hydrogen is not contaminated. If evacuation is not possible, the sample container shall be cleaned using repeated purge cycles.

Sampled gases are flammable. Measures shall be taken to avoid hazardous situations. Guidance is given in ISO/TR 15916.

### 6.3.4 Particulates in gaseous hydrogen

Particulates in hydrogen shall be sampled from the boundary point, using a filter, if practical, under the same conditions (pressure and flow rate) as employed in the actual hydrogen supplying condition. Appropriate measures shall be taken for the sample gas not to be contaminated by particulates coming from the connection device and/or the ambient air.

## 7 Hydrogen quality requirements for applications other than PEM fuel cell road vehicle and stationary applications

### 7.1 Fuel quality specification

The quality of hydrogen supplied to the example specifications for applications other than PEM fuel cell road vehicles and stationary applications shall meet the requirements of [Table 4](#). A blank indicates no maximum limiting characteristic. The absence of a maximum limiting characteristic in a listed quality level does not imply that the component is or is not present, but merely indicates that there is no limitation regarding this component for compliance with this document.

NOTE Other specifications can be equally suitable for these applications.

**Table 4 — Fuel quality specification for applications other than PEM fuel cell road vehicle and stationary applications**

Constituents (assay)	Type I			Type II	Type III
	Grade A	Grade B	Grade C	Grade C	
Hydrogen fuel index <sup>a</sup> (minimum mole fraction, %)	98,0 %	99,90 %	99,995 %	99,995 %	99,995 %
<i>Para</i> -hydrogen (minimum mole fraction, %)	NS	NS	NS	95,0 %	95,0 %
<b>Impurities</b> (maximum content)					
Total gases	20 000 μmol/mol	1 000 μmol/mol	50 μmol/mol	50 μmol/mol	
Water (H <sub>2</sub> O) (mole fraction, %)	Non-condensing at all ambient conditions <sup>b</sup>	Non-condensing at all ambient conditions	c	c	
Total hydrocarbon	100 μmol/mol	Non-condensing at all ambient conditions	c	c	
Oxygen (O <sub>2</sub> )	b	100 μmol/mol	d	d	
Argon (Ar)	b		d	d	
Nitrogen (N <sub>2</sub> ),	b	400 μmol/mol	c	c	
Helium (He)			39 μmol/mol	39 μmol/mol	
Carbon dioxide (CO <sub>2</sub> )			e	e	
Carbon monoxide (CO)	1 μmol/mol		e	e	
Mercury (Hg)		0,004 μmol/mol			
Sulfur (S)	2,0 μmol/mol	10 μmol/mol			
Permanent particulates	g	f	f	f	
Density					f
<b>Key</b>					
NS: Not specified					
<sup>a</sup> The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" expressed in mole percent, from 100 mole percent.					
<sup>b</sup> Combined water, oxygen, nitrogen and argon: maximum mole fraction of 1,9 % (19 000 μmol/mol).					
<sup>c</sup> Combined nitrogen, water and hydrocarbon: maximum 9 μmol/mol.					
<sup>d</sup> Combined oxygen and argon: maximum 1 μmol/mol.					
<sup>e</sup> Total CO <sub>2</sub> and CO: maximum 1 μmol/mol.					
<sup>f</sup> To be agreed between the supplier and the customer.					
<sup>g</sup> The hydrogen shall not contain dust, sand, dirt, gums, oils or other substances in an amount sufficient to damage the fuelling station equipment or the vehicle (engine) being fuelled.					

## 7.2 Quality verification

### 7.2.1 General requirements

The supplier shall assure, by standard practice, the verification of the quality level of hydrogen. The sampling and control procedures are described in [7.3](#).

NOTE ISO 21087 can be used as guidance for validation protocol for analytical methods for the contaminants in [Table 4](#).

## 7.2.2 Production qualification tests

Production qualification tests are a single analysis or a series of analyses that shall be performed on the product to assure the reliability of the production facility to supply hydrogen of the required quality level. This production qualification may be achieved by verifying the analytical records of product from the supplier, or, if required, by performing analyses of representative samples of the product from the facility at appropriate intervals as agreed between the supplier and the customer. Production qualification tests may be performed by the supplier or by a laboratory agreed upon between the supplier and the customer.

## 7.3 Sampling

### 7.3.1 Sample size

The quantity of hydrogen in a single sample container shall be sufficient to perform the analyses for the fuel quality specifications. If a single sample does not contain a sufficient quantity of hydrogen to perform all of the analyses required to assess the quality level, additional samples from the same lot shall be taken under similar conditions.

### 7.3.2 Gaseous samples

Gaseous samples shall be representative of the hydrogen supply. Samples shall be obtained using one of the following procedures:

- a) Fill the sample container and delivery containers at the same time, on the same manifold and in the same manner.
- b) Withdraw a sample from the supply container through a suitable connection into the sample container.

For safety reasons, the sample container and sampling system shall have a rated service pressure at least equal to the pressure in the supply container.

- c) Connect the container being sampled directly to the analytical equipment using a suitable pressure regulator to prevent over-pressurizing this equipment.
- d) Select a representative container from the containers filled in the lot.

### 7.3.3 Liquid samples (vaporized)

Vaporized liquid samples shall be representative of the liquid hydrogen supply. Samples shall be obtained using one of the following procedures:

- a) by vaporizing, in the sampling line, liquid hydrogen from the supply container;
- b) by flowing liquid hydrogen from the supply container into or through a suitable container in which a representative sample is collected and then vaporized.

## Annex A (informative)

### Guidance on the selection of the boundary point for PEM fuel cell stationary applications

#### A.1 Purpose

The following guidance is provided to assist in the identification of the boundary point and who is responsible for the quality of hydrogen at the boundary point.

#### A.2 Hydrogen production guidance

Hydrogen, and hydrogen-based fuel, may be produced in a number of ways, including reformation of fossil fuels or other hydrocarbons, the electrolysis of pure water or alkaline water, and numerous biological methods. Hydrogen, and hydrogen-based fuels, can be generated on-site, generally in relatively small quantities, or in a larger scale production system off-site, then transported under pressure or as a liquid to the point of use.

#### A.3 Identification of the party responsible for hydrogen quality at the sampling point

It is recognized that provision of hydrogen to a fuel cell power system may involve numerous parties.

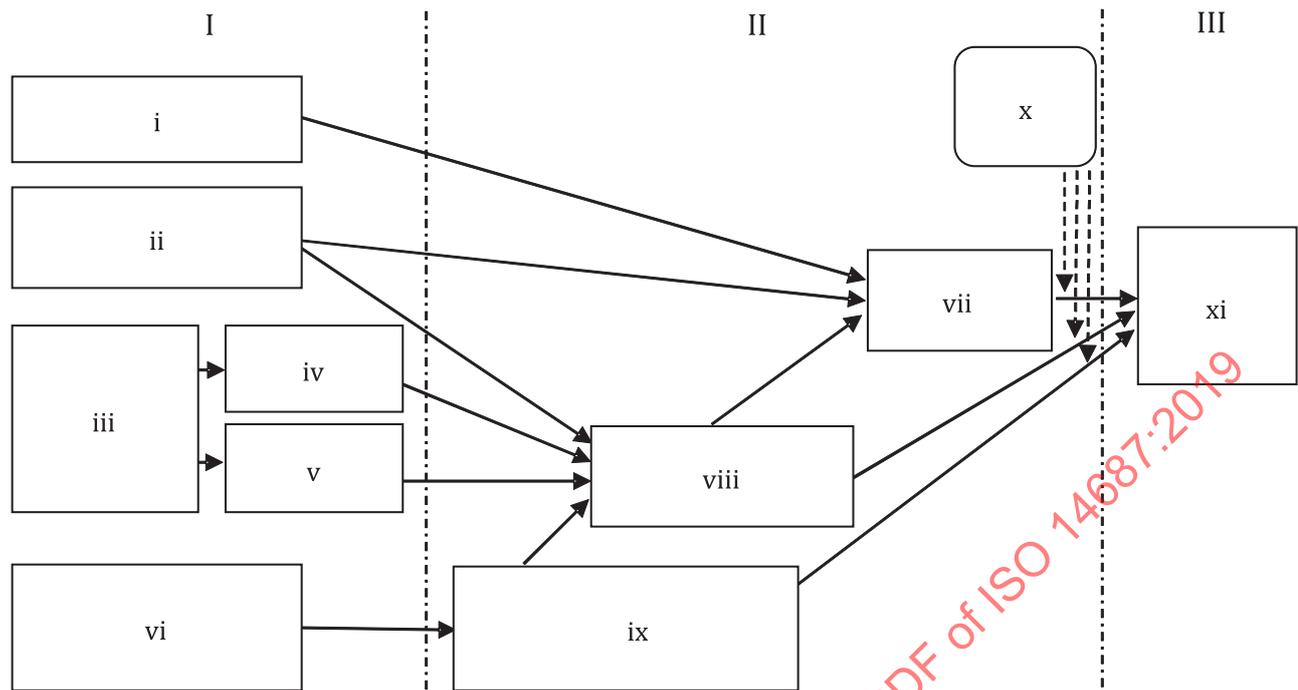
The following text and figure provide examples for information purposes, but are not intended to be comprehensive. Hydrogen delivery systems that incorporate different equipment or hydrogen feedstock should use these examples as a basis for determining the responsibility for the quality of hydrogen at the boundary point and, if appropriate, additional sampling points.

The following are examples of parties involved in and responsible for the supply of hydrogen:

- gaseous hydrogen supplier (for example, cylinders, bundles or tube trailers);
- liquid hydrogen supplier;
- hydrogen via pipeline distributor;
- reformer manufacturer;
- electrolyser manufacturer.

Depending on the form of the hydrogen supply, there may be a requirement for system integrators to provide equipment between the source of the hydrogen and the inlet to the fuel cell power system. Such equipment may comprise, as applicable, the following, shown in [Figure A.1](#):

- pressure regulators;
- liquid hydrogen storage, cryogenic pumps and vaporizers;
- gaseous hydrogen buffer storage;
- additional manifolds from hydrogen source to fuel cell power system inlet.



**Key**

- |      |  |    |   |     |                        |
|------|--|----|---|-----|------------------------|
| I    | hydrogen supply  | II | system integration                                  | III | fuel cell power system |
| i    | delivery by pipeline                                   | ii | delivery by cylinder or tube trailer                |     |                        |
| iii  | utility supply (natural gas, electricity, water, etc.) | iv | fuel processing system                              |     |                        |
| v    | electrolyser   | vi | delivery by truck (liquid hydrogen)                 | vii | pressure regulator     |
| viii | gaseous hydrogen buffer                                | ix | liquid hydrogen storage, cryogenics pump, vaporizer |     |                        |
| x    | boundary point (for sampling)                          | xi | PEM fuel cell power system                          |     |                        |

**Figure A.1 — Examples showing the supply of hydrogen to a fuel cell power system and position of the boundary point**

It should be recognized that the system integrator is responsible for the quality of hydrogen at the boundary point, immediately prior to the inlet of the fuel cell power system. If the system integrator and fuel cell power system operator are the same party, one or more appropriate alternative sampling points for meeting hydrogen quality characteristics should be determined by an agreement between the hydrogen supplier and the customer.

In some cases, the system integrator may also be the hydrogen supplier, in which case the responsibility for the hydrogen quality characteristics at the boundary point is that of the hydrogen supplier unless otherwise specified by an agreement between the hydrogen supplier and the customer.

Where the system integrator and hydrogen supplier are different parties, the responsibility for the hydrogen quality characteristics at the boundary point is that of the system integrator. In such cases, the analytical requirements (periodicity, impurities and appropriate interface test point) for the hydrogen supply should be determined by an agreement between the hydrogen supplier, the system integrator and the customer.

It may also be the case that the hydrogen supplier provides some aspects of on-site system integration but does not directly interface with the fuel cell power system. In such cases, the hydrogen supplier is responsible for meeting the hydrogen quality characteristics at the supplier interface to the additional

equipment that connects to the fuel cell power system, while the integrator interfacing with the fuel cell power system is responsible for the analytical requirements of the hydrogen quality at the boundary point. The analytical requirements (periodicity, impurities) at any additional sampling points appropriate to the system should be specified by an agreement between the system integrator and the hydrogen supplier.

Where system maintenance is to be carried out by an additional party, the requirements for hydrogen quality assurance following the completion of such maintenance should be determined by an agreement between the system integrator, the party responsible for maintenance and the fuel cell operator.

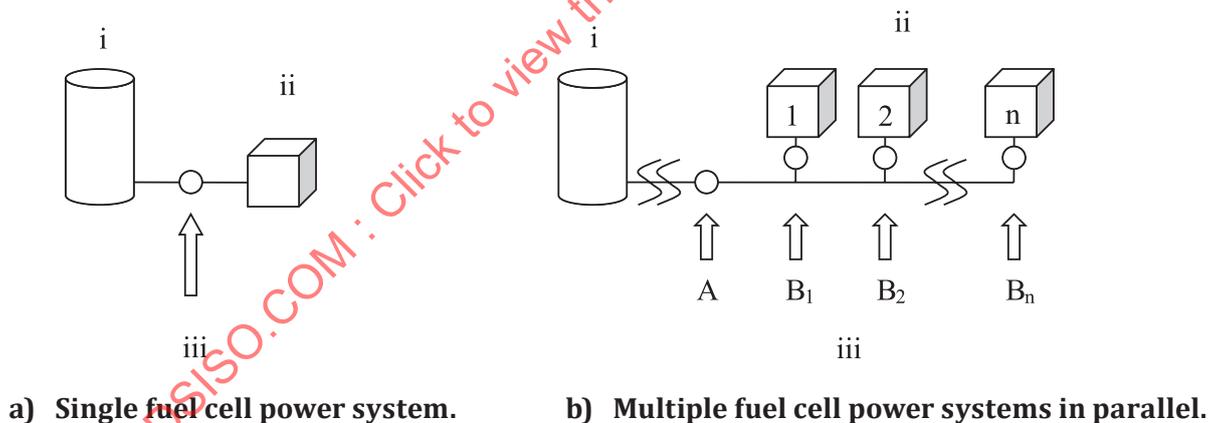
#### A.4 Selection of the sampling point

In the case of a single fuel cell power system, as shown in [Figure A.2 a\)](#), the boundary point should be as close as practical to the fuel inlet to the fuel cell power system.

In the case of multiple fuel cell power systems in parallel, as shown in [Figure A.2 b\)](#), the location of the boundary point should be determined by an agreement between the system integrator and the fuel cell operator.

Examples for the location of the sampling point may include:

- Boundary point A - the supply for fuel cell power systems 1 to n.
- A single boundary point between  $B_1$  and  $B_n$ , representing the worst case.
- All boundary points  $B_1$  through  $B_n$ .



#### Key

- i hydrogen and hydrogen-based fuel supply equipment
- ii PEM fuel cell power system(s)
- iii boundary point(s)

**Figure A.2 — Positioning of sampling point**