# INTERNATIONAL STANDARD

# ISO 14687-3

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## Hydrogen fuel — Product specification —

## Part 3:
## Proton exchange membrane (PEM) fuel cell applications for stationary appliances



*Carburant hydrogène - Spécification de produit —*

*Partie 3: Applications des piles à combustible à membrane à échange de protons (PEM) pour appareils stationnaires*



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# Foreword

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The committee responsible for this document is ISO/TC 197, *Hydrogen technologies.*

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



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

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

— *Part 3: Proton exchange membrane (PEM) fuel cell applications for stationary appliances*

 

# Introduction

This part of ISO 14687 provides an initial, albeit incomplete, basis for describing a common fuel to be used by proton exchange membrane (PEM) fuel cell applications for stationary appliances in the near term.

A large number of fuel cells are presently commercialized as power sources for stationary applications, such as distributed, supplementary, and back-up power generation and as stationary heat and power cogeneration systems. Most stationary fuel cells are equipped with a fuel processing system which converts fossil fuel to hydrogen-rich fuel composed primarily of hydrogen and carbon dioxide. Some of the stationary fuel cells use hydrogen fuel of high purity supplied through high pressure tanks or pipeline from a distant hydrogen production plant.

The purpose of this part of ISO 14687 is to establish an international standard of quality characteristics of hydrogen fuel for stationary fuel cells.

Types of fuel cells other than proton exchange membrane fuel cells (PEMFC), such as phosphoric acid fuel cell (PAFC), molten carbonate fuel cells (MCFC) and solid oxide fuel cells (SOFC), may require similar standards in future. Thus, it is anticipated that in the future PAFC, MCFC and SOFC hydrogen fuel quality requirements will be added as amendments to this part of ISO 14687.

This part of ISO 14687 is intended to consolidate the hydrogen fuel product specification needs anticipated by PEM fuel cell manufacturers and hydrogen fuel suppliers as both industries proceed toward achieving wide-spread commercialization. Monitoring hydrogen fuel quality is necessary because specific impurities will adversely affect the fuel cell power system. In addition, there may be performance implications in the fuel cell power system if certain non-hydrogen constituent levels are not controlled. Methods to monitor the hydrogen fuel quality that is delivered to these stationary appliances are addressed.



This part of ISO 14687 specifies one grade of hydrogen, Type I, grade E, with three categories for different target applications. Quality verification should be determined at the inlet point of a PEM fuel cell power system.

Since PEM fuel cell applications for stationary appliances and related technologies are developing rapidly, this part of ISO 14687 will be revised according to technological progress as necessary. Additionally, some of the impurity limits are dictated by current analytical capabilities, which are also in the process of development. Technical Committee ISO/TC 197, *Hydrogen technologies*, will monitor this technology trend. It is also noted that this part of ISO 14687 has been prepared to assist in the development of PEM fuel cell applications for stationary appliances and related technologies.

Further research and development efforts should focus on, but not be limited to:

— 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; and,

— Stationary fuel cell demonstration results.

# Hydrogen fuel — Product specification —

## Part 3:
## Proton exchange membrane (PEM) fuel cell applications for stationary appliances

## 1 Scope

This part of ISO 14687 specifies the quality characteristics of hydrogen fuel in order to ensure uniformity of the hydrogen product for utilization in stationary proton exchange membrane (PEM) fuel cell power systems.

## 2 Normative references

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

ISO 6142, *Gas analysis — Preparation of calibration gas mixtures — Gravimetric method*



ISO 6145 (all parts), *Gas analysis — Preparation of calibration gas mixtures using dynamic methods*

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



ISO 14687-2, *Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*

IEC/TS 62282-1, *Fuel cell technologies — Terminology*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14687-1, IEC/TS 62282-1 and the following apply.

**3.1**
**boundary point**
point between the hydrogen fuel supply equipment and the PEM fuel cell power system 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 component parts within the fuel cell power system or the hydrogen storage system

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

**3.4**
**customer**
party responsible for sourcing hydrogen fuel in order to operate the fuel cell power system

**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**
**hydrogen fuel**
gas containing a concentration of hydrogen equal to or larger than 50 % used for stationary fuel cell applications

**3.9**
**hydrogen fuel index**
fraction or percentage of a fuel mixture that is hydrogen



**3.10**
**hydrogen fuel supply equipment**
equipment used for the transportation or on-site generation of hydrogen fuel, and subsequently for delivery to the fuel cell power system, including additional storage, vaporization, and pressure regulation as appropriate



**3.11**
**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

**3.12**
**particulate**
solid or aerosol particle, including oil mist, that may be entrained in the hydrogen entering a fuel cell

**3.13**
**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

**3.14**
**stationary proton exchange membrane (PEM) fuel cell power system**
self-contained assembly of integrated PEM fuel cell systems used for the generation of electricity which is fixed in place in a specific location, typically containing the following subsystems: fuel cell stack, air processing, thermal management, water management, and automatic control system and which is used in applications such as: distributed power generation, back-up power generation, remote power generation, electricity and heat co-generation for resident and commercial applications

Note 1 to entry: For the purposes of this part of ISO 14687, the PEM fuel cell power system does not contain a fuel processing system due to the location of the boundary point.

**3.15**
**system integrator**
integrator of equipment between the PEM fuel cell power system and the hydrogen supply

 

# 4 General design requirements

## 4.1 Classification

Hydrogen fuel for PEM fuel cell applications for stationary appliances shall be classified as Type I, grade E, gaseous hydrogen fuel for PEM fuel cell stationary appliance systems.

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

NOTE 2 Type I, grade D and Type II, grade D, which are applicable for PEM fuel cells for road vehicles are defined in ISO 14687-2.

## 4.2 Categories

Type I, grade E hydrogen fuel for PEM fuel cell applications for stationary appliances specifies the following subcategories for the convenience of both PEM fuel cell manufacturers and hydrogen fuel suppliers:

— Type I, grade E, Category 1

— Type I, grade E, Category 2

— Type I, grade E, Category 3

These categories are defined to meet the needs of different stationary applications, depending on the requirements specified by the manufacturer.



## 4.3 Limiting characteristics

The fuel quality at the boundary point set between the hydrogen fuel supply equipment and the PEM fuel cell power system, as applicable to the aforementioned grades of hydrogen fuel for stationary appliance systems, shall meet the requirements of Table 1.

NOTE 1 Please see Annex A for the selection of the boundary point.

NOTE 2 Annex B provides the rationale for the selection of the impurities specified in Table 1.

**Table 1 — Directory of limiting characteristics**

| Characteristics[a] (assay) | Type I, grade E | | |
|---|---|---|---|
| | **Category 1** | **Category 2** | **Category 3** |
| Hydrogen fuel index (minimum mole fraction) | 50 % | 50 % | 99,9 % |
| Total non-hydrogen gases (maximum mole fraction) | 50 % | 50 % | 0,1 % |
| Water ($H_2O$)[b] | Non-condensing at all ambient conditions | Non-condensing at all ambient conditions | Non-condensing at all ambient conditions |
| **Maximum concentration of individual contaminants** | | | |
| Total hydrocarbons ($C_1$ basis)[c] | 10 µmol/mol | 2 µmol/mol | 2 µmol/mol |
| Oxygen ($O_2$) | 200 µmol/mol | 200 µmol/mol | 50 µmol/mol |
| Nitrogen ($N_2$), Argon (Ar), Helium (He) (mole fraction) | 50 % | 50 % | 0,1 % |
| Carbon dioxide ($CO_2$) | 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 |
| Total sulfur compounds[d] | 0,004 µmol/mol | 0,004 µmol/mol | 0,004 µmol/mol |
| Formaldehyde (HCHO) | 3,0 µmol/mol | 0,01 µmol/mol | 0,01 µmol/mol |
| Formic acid (HCOOH) | 10 µmol/mol | 0,2 µmol/mol | 0,2 µmol/mol |
| Ammonia ($NH_3$) | 0,1 µmol/mol | 0,1 µmol/mol | 0,1 µmol/mol |
| Total halogenated compounds[e] | 0,05 µmol/mol | 0,05 µmol/mol | 0,05 µmol/mol |
| Maximum particulates concentration | 1 mg/kg | 1 mg/kg | 1 mg/kg |
| Maximum particle diameter | 75 µm | 75 µm | 75 µm |

NOTE For the constituents that are additive (i.e. total hydrocarbons, total sulfur compounds and total halogenated compounds), the sum of the constituents shall be less than or equal to the specifications in the table. It is therefore important that the analytical method used measures the *total* concentration of these families of compounds, and not the concentration of single compounds within these families, which are subsequently summed to give a total amount of fraction. The latter approach risks a false negative being reported. For more details, see Clause 7.

a Maximum concentration of impurities against the total gas content shall be determined on a dry-basis.

b 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.

c Total hydrocarbons are measured on a carbon basis (µmolC/mol). The specification for total hydrocarbons includes oxygenated hydrocarbons. The measured amount fractions of all oxygenated hydrocarbons shall therefore contribute to the measured amount fraction of total hydrocarbons. Specifications for some individual oxygenated hydrocarbons (e.g. formaldehyde and formic acid) are also given in the table. These, however, also contribute to the measured amount fraction of total hydrocarbons. These species have been assigned their own specifications based on their potential to impair the performance of PEM fuel cells. Total hydrocarbons may exceed the limit due only to the presence of methane, in which case the methane shall not exceed 5 % for Category 1, 1 % for Category 2 or 100 µmol/mol of hydrogen fuel for Category 3.

d As a minimum, total sulfur compounds include $H_2S$, COS, $CS_2$ and mercaptans, which are typically found in natural gas.

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



## 4.4 Hydrogen production guidance

Hydrogen fuel may be produced in a number of ways, including reformation of natural gas or other fossil or renewable fuels, the electrolysis of water and numerous biological methods. Hydrogen fuel 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.

NOTE Biological sources of hydrogen can contain additional species that affect fuel cell performance (e.g. siloxanes and mercury). Such species are not included in Table 1 due to insufficient data.

# 5 Quality verification

## 5.1 General requirements

Quality verification requirements shall be determined at the boundary point using the sampling and analytical methods specified in Clauses 6 and 7 respectively. Alternatively, the quality verification may be performed at other locations or under other methods by written agreement between the supplier and the customer.

Analysis of all limiting characteristics in Table 1 may not be necessary for all hydrogen production methods, if acceptable to the customer.

All analyses conducted in this part of ISO 14687 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.

## 5.2 Analytical requirements of the qualification tests

The frequency of testing and analytical requirements for the qualification tests shall be specified by the supplier and the customer. Consideration shall be given to the consistency of hydrogen supply in determining 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.



## 5.3 Report results

The detection and 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 Sampling

## 6.1 Sample size

Where possible, the quantity of hydrogen in a single sample container should be sufficient to perform the analyses for the limiting characteristics. 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.

## 6.2 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.