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# Gaseous hydrogen — Fuelling stations —

## Part 8: Fuel quality control

*Hydrogène gazeux — Stations de remplissage —*

*Partie 8: Contrôle qualité du carburant*



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# Foreword

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



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# Introduction

This document was developed to specify how the quality of gaseous hydrogen fuel for road vehicles which use PEM fuel cells can be assured. The document discusses hydrogen quality control approaches for routine and non-routine conditions, as well as quality assurance plans. It is based upon best practices and experience from the gaseous fuels and automotive industry. ISO 21087 describes the requirements for analytical methods to measure the level of contaminants found in the gaseous hydrogen fuel.



 

# Gaseous hydrogen — Fuelling stations —

## Part 8: Fuel quality control

## 1 Scope

This document specifies the protocol for ensuring the quality of the gaseous hydrogen at hydrogen distribution facilities and hydrogen fuelling stations for proton exchange membrane (PEM) fuel cells for road vehicles.

## 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 19880-1, *Gaseous hydrogen — Fuelling stations — Part 1: General requirements*



## 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 https://www.iso.org/obp

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

**3.1**
**authority having jurisdiction**
AHJ
organization, office or individual responsible for approving a facility along with an equipment, an installation, or a procedure

**3.2**
**indicator species**
one or more *constituents* (3.3) in the gas stream which can signal the presence of other chemical constituents because it has the highest probability of presence in a fuel produced by a given process

**3.3**
**constituent**
component (or compound) found within a hydrogen fuel mixture

**3.4**
**contaminant**
*impurity* (3.9) that adversely affects the components within the *fuel cell system* (3.6) or the hydrogen storage system

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

**3.5**
**filter**
equipment to remove undesired *particulates* (3.15) from the hydrogen

 

**3.6**
**fuel cell system**
power system used for the generation of electricity on a *fuel cell vehicle* (3.7), typically containing the following subsystems: fuel cell stack, air processing, fuel processing, thermal management, and water management

**3.7**
**fuel cell vehicle**
**FCV**
vehicle which stores hydrogen on-board and uses a *fuel cell system* (3.6) to generate electricity for propulsion

**3.8**
**fuelling station**
facility for the dispensing of compressed hydrogen vehicle fuel, including the supply of hydrogen, and hydrogen compression, storage, and dispensing systems

Note 1 to entry: Fuelling station is often referred to as hydrogen fuelling station or hydrogen filling station.

**3.9**
**impurity**
non-hydrogen component in the gas stream

**3.10**
**irreversible damage**
**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



**3.11**
**monitoring**
act of measuring the *constituents* (3.3) of a hydrogen stream or process controls of a hydrogen production system on a continuous or semi-continuous basis by on-site equipment

**3.12**
**non-routine**, adjective
not in accordance with established procedures

**3.13**
**on-site supply**
hydrogen fuel supplying system with a hydrogen production system in the same site

**3.14**
**off-site supply**
hydrogen fuel supplying system without a hydrogen production system in the same site, receiving hydrogen fuel which is produced out of the site

**3.15**
**particulate**
solid or liquid such as oil mist that can be entrained somewhere in the delivery, storage, or transfer of the hydrogen fuel entering a *fuel cell system* (3.6)

**3.16**
**purifier**
equipment to remove undesired *constituents* (3.3) from the hydrogen

Note 1 to entry: Hydrogen purifiers may comprise purification vessels, dryers, *filters* (3.5), and separators.

**3.17**
**quality assurance**
part of quality management focused on providing confidence that quality requirements will be fulfilled

**3.18**
**quality control**
part of quality management focused on fulfilling quality requirements

**3.19**
**quality plan**
documentation of quality management

**3.20**
**reversible damage**
**reversible effect**
effect, which results in a non-permanent degradation of the fuel cell power system performance that can be restored by practical changes of operational conditions and/or gas composition

**3.21**
**risk**
combination of the probability of occurrence of harm and the *severity* (3.26) of that harm, encompassing both the uncertainty about and severity of the harm

**3.22**
**risk assessment**
determination of quantitative or qualitative value of *risk* (3.21) related to a specific situation and a recognized threat also called a hazard

**3.23**
**risk level**
assessed magnitude of the *risk* (3.21)



**3.24**
**routine**, adjective
in accordance with established procedures



**3.25**
**sampling**
act of capturing a measured amount of hydrogen for chemical analysis by external equipment

**3.26**
**severity**
measure of the possible consequences for fuel cell cars if filled with $H_2$ containing higher level of *impurities* (3.9) than the threshold value

## 4 Abbreviated terms

| Abbreviated term | Definition |
|---|---|
| Halogens | total halogenated compounds |
| HDS | hydrodesulphurization |
| PEM | proton exchange membrane |
| PSA | pressure swing adsorption |
| SC | severity class |
| SMR | steam methane reforming |
| THC | total hydrocarbons |
| TS | total sulphur compounds |
| TSA | temperature swing adsorption |

# 5 Hydrogen specifications

The quality requirements of hydrogen fuel dispensed to PEM fuel cells for road vehicles are listed in ISO 14687-2.

# 6 Quality control approaches

## 6.1 General

There are two common methods to control the quality of hydrogen at a fuelling station, by spot sampling and continuous monitoring. These methods can be used individually or together to ensure hydrogen quality levels.

## 6.2 Sampling

Spot sampling at a fuelling station involves capturing a measured amount for chemical analysis. Sampling is used to perform an accurate and comprehensive analysis of impurities which is done externally, typically at a laboratory. Since the sampling process involves drawing a sample of gas, it is typically done on a periodic basis and requires specialized sampling equipment and personnel to operate it. Sampling procedures shall conform to ISO 19880-1. The advantage of spot sampling is that a more detailed laboratory analysis can be conducted on the sample. The disadvantage of spot sampling is that it is not continuous and results in a detail analysis of a single point in time.

## 6.3 Monitoring

A fuelling station can have real time monitoring of the hydrogen gas stream for one or more impurities on a continuous or semi-continuous basis. A critical impurity can be monitored to ensure it does not exceed a critical level, or monitoring of indicator species are used to alert of potential issues with the hydrogen production or purification process. Monitoring equipment is installed in line with the hydrogen gas stream and shall meet the process requirements of the fuelling station, as well as be calibrated on a periodic basis. Continuous monitoring compliments spot sampling by offsetting the disadvantages.



# 7 Potential sources of impurities

For a given fuelling station, the contaminants listed in the hydrogen specification referred to in Clause 5 may or may not be potentially present. There are several parts of the supply chain where impurities can be introduced. The potential impurities in each step of the supply chain are described in Annex D.

When a contaminant is classified as potentially present, it shall be taken into account in the quality assurance methodology (risk assessment or prescriptive approach) described in Clause 8.

# 8 Hydrogen quality assurance methodology

## 8.1 General

A quality assurance plan for the entire supply chain shall be created to ensure that the hydrogen quality will meet the requirements listed in Clause 5. The methodology used to develop the quality assurance plan can vary but shall include one of the two approaches described in this document. The general description of these two approaches are described in 8.2 and 8.3. Examples of these approaches 1) prescriptive approach and 2) risk assessment for hydrogen quality, are presented in Annexes A, B and C, respectively. The quality assurance plan for the fuelling station shall include the following to ensure hydrogen quality is properly maintained:

— identification of potential impurities;

 

— methods to control and remove these impurities;

— sampling impurities and frequency;

— monitoring of impurities or process controls;

— description of solid and liquid particulate filters;

— cleanliness and maintenance procedures.

It is important to understand that quality should be maintained throughout the complete supply chain of the product (from production source to fuelling station nozzle), such that the impurities that are given in the specification remain below the threshold values.

Each component of the supply chain shall be investigated taking into account the already existing barriers for a given contaminant.

NOTE An effective quality control approach can further ensure the quality of the hydrogen by providing a proactive means to identify and control potential quality issues which can include sampling and monitoring. Additionally, use of quality assurance can improve the decision making if a quality problem arises.

## 8.2 Prescriptive methodology

The prescriptive approach to hydrogen quality assurance considers potential sources of contaminants and establishes a fixed protocol for analysing and addressing potential contaminants. The prescriptive approach can be applied for the clearly identified supply chain.



The prescriptive quality assurance plan shall be determined taking into account all hydrogen production methods, hydrogen transportation methods and non-routine procedures which exists in the area where the assurance plan is applicable.



NOTE Annex C presents Japanese hydrogen quality guidelines which is an example of a prescriptive quality assurance plan.

## 8.3 Risk assessment methodology

The risk assessment approach determines the probability to have each impurity above the threshold values of specifications given in Clause 5 and evaluates severity of each impurity for the fuel cell vehicle (see Annex A). As an aid to clearly defining the risk(s) for risk assessment purposes, three fundamental questions are often helpful:

— What can go wrong: which event can cause the impurities to be above the threshold value?

— What is the likelihood (probability of occurrence expressed relative to the number of fuelling events) that impurities can be above the threshold value?

— What are the consequences (severity) for the fuel cell vehicle?

In doing an effective risk assessment, the robustness of the data set is important because it determines the quality of the output. Revealing assumptions and reasonable sources of uncertainty will enhance confidence in this output and/or help identify its limitations. The output of the risk assessment is a qualitative description of a range of risk. To determine the probability of the occurrence that impurities in hydrogen exceed the threshold value, Table 1 defines the occurrence classes.

**Table 1 — Occurrence classes for an impurity**

| Occurrence class | Class name | Description | Occurrence or frequency |
|---|---|---|---|
| **0** | **Very unlikely (Practically impossible)** | Contaminant above threshold never been observed for this type of source in the industry | Never |

**Table 1** *(continued)*

| Occurrence class | Class name | Description | Occurrence or frequency |
|---|---|---|---|
| **1** | **Very rare** | Known to occur in the industry for the type of source/Supply chain considered | 1 per 1 000 000 fuellings |
| **2** | **Rare** | Has occurred more than once/ year in the Industry | 1 per 100 000 fuellings |
| **3** | **Possible** | Has occurred repeatedly for this type of source at a specific location | 1 out of 10 000 fuellings |
| **4** | **Frequent** | Occurs on a regular basis | Often |

If the occurrence class is unknown, then the risk assessment shall assume the worst case. In addition, the experience of the hydrogen supplier, station manufacturer/installer should be taken into account when performing the risk analysis.

The range of severity classes (level of damage for vehicle) is defined in Table 2.

**Table 2 — Severity classes for an impurity**

<table>
<tr><th rowspan="2">Severity class</th><th rowspan="2">FCV performance impact or damage</th><th colspan="3">Impact categories</th></tr>
<tr><th>Performance impact</th><th>Hardware impact temporary</th><th>Hardware impact permanent</th></tr>
<tr><td>0</td><td>— No impact</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>1</td><td>— Minor impact<br>— Temporary loss of power<br>— No impact on hardware<br>— Vehicle still operates</td><td>Yes</td><td>No</td><td>No</td></tr>
<tr><td>2</td><td>— Reversible damage<br>— Requires specific light maintenance procedure<br>— Vehicle still operates</td><td>Yes or No</td><td>Yes</td><td>No</td></tr>
<tr><td>3</td><td>— Reversible damage<br>— Requires specific immediate maintenance procedure<br>— Gradual power loss that does not compromise safety</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td rowspan="2">4[a]</td><td rowspan="2">— Power loss or Vehicle Stop that compromises safety<br>— Irreversible damage<br>— Requires major repair procedure (e.g. stack change)</td><td rowspan="2">Yes</td><td>Yes</td><td>No</td></tr>
<tr><td>No</td><td>Yes</td></tr>
<tr><td colspan="5">[a] Any damage, whether permanent or temporary, which compromises safety will be categorized as SC 4, otherwise temporary damage will be categorized as SC 1, 2 or 3.</td></tr>
</table>



The final risk is defined by the acceptability table (Table 3) which combines results from Tables 1 and 2:

**Table 3 — Combined risk assessment**

| Probability per one fuelling | Occurrence | Severity | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 |
| Frequent: Often | 4 | + | * | * | * | * |
| Possible: $10^{-4}$ | 3 | + | o | * | * | * |
| Rare: $10^{-5}$ | 2 | + | + | o | * | * |
| Very Rare: $10^{-6}$ | 1 | + | + | + | o | * |
| Practically Impossible | 0 | + | + | + | + | + |
| Key | + Acceptable risk area: Existing controls sufficient | | o Further investigation is needed: existing barriers or control may not be enough | | * Unacceptable risk; additional control or barriers required | |

NOTE 1 It is possible that contamination of a vehicle at severity class 1 or 2 is not noticeable immediately, thereby making it difficult to identify the source of the contamination.

If a vehicle is found to have hydrogen with contamination that exceeds the specification in Clause 5 and the source is unknown, the procedures in Clause 11 shall be followed.

For each impurity of the specification and for a given fuelling station (including the supply chain of hydrogen), a risk assessment shall be applied to define the global risk.



NOTE 2 Risk control includes decision making to reduce and/or accept risks. The purpose of risk control is to reduce the risk to an acceptable level.

The amount of effort used for risk control should be proportional to the significance of the risk. Decision makers might use different processes, including benefit-cost analysis, for understanding the optimal level of risk control. Risk control can focus on the following questions:



— Is the risk above an acceptable level?

— What can be done to reduce or eliminate risks?

— What is the appropriate balance among benefits, risks and resources?

For each level of risk, a decision shall be taken in order to either refuse the risk and find mitigation or barriers to reduce it, or accept the risk level as it is. Risk reduction focuses on processes for mitigation or avoidance of quality risk when it exceeds an acceptable level ("o" or "*" zone in Table 3). Risk reduction typically includes actions taken to mitigate the severity and/or probability of occurrence. However, this document only deals with the mitigation of probability of occurrence.

## 8.4 Impact of impurities on fuel cell powertrain

It is necessary to evaluate the possible consequences on a fuel cell car if each impurity exceeds the ISO 14687-2 threshold value. The impact for the car will depend on the concentration of the contaminant. Table 4 shows a summary of the concentration-based impact of the impurities on the fuel cell. The contaminants and their chemical formulas are given in the first two columns of Table 4.

An estimation of the exceeded concentration above the ISO 14687-2 threshold value for each impurity is named "Level 1" and is given in column 5. According to this concentration a severity class is given in column 4 for each impurity. This severity class covers the impact of this impurity above the threshold value up to this limit.

If higher concentrations that exceed Level 1 can be reached, the severity class is given in column 6.

 