



ISO/TC 197  
Hydrogen technologies

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The formatting of this CD needs to be revised, but due to time constraints it was decided to proceed with the CD Ballot in order to get comments on the technical content.

In this draft there are many references to ISO/IEC that should only refer to ISO, but due to the template that was used by WG 28, I was unable to remove the references to IEC. This will be corrected for the next draft.

As well, the Annexes are missing from the Contents and the definitions are not properly formatted. This also will be corrected for the next draft.

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## **Gaseous Hydrogen — Fueling Stations — Part 8: Fuel Quality Control**

*Hydrogène gazeux — Stations de remplissage — Partie 8: Contrôle qualité du carburant*

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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.

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.

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.

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

ISO 19880 will consist of the following parts, which are in the process of being developed, under the general title *Gaseous hydrogen – Fueling stations*

- *Part 1: General requirements*
- *Part 2: Dispensers*
- *Part 3: Valves*
- *Part 4: Compressors*
- *Part 5: Hoses*
- *Part 6: Fittings*
- *Part 7: (reserved for future use)*
- *Part 8: Hydrogen quality control*

## Introduction

This document was developed to document how the hydrogen quality 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. TC/158 is developing analytical methods to measure the level of contaminants found in the gaseous hydrogen fuel.

# Gaseous Hydrogen — Fueling Stations — Part 8: Fuel Quality Control

## 1 Scope

This International standard specifies the protocol for ensuring the quality of the gaseous hydrogen quality at hydrogen distribution bases and hydrogen fueling stations for proton exchange membrane (PEM) fuel cells for road vehicles.

## 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 14697-2, Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles

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.

### 3.1

#### **Authority having Jurisdiction (AHJ) (SOURCE: ISO 19880-1)**

organization, office or individual responsible for approving a facility along with an equipment, an installation or a procedure

### 3.1

#### **Canary Species**

A canary species can serve as an indicator of the presence of other chemical constituents because it has the highest probability of presence in a fuel produced by a given process.

### 3.2

#### **Constituent (SOURCE: ISO 14687)**

component (or compound) found within a hydrogen fuel mixture

### 3.3

#### **Contaminate (SOURCE: ISO 14687)**

impurity that adversely affects the components within the fuel cell system or the hydrogen storage system (14687)

NOTE An adverse effect can be reversible or irreversible.

- 3.4**  
**Detection limit (SOURCE: ISO 14687)**  
lowest quantity of a substance that can be distinguished from the absence of that substance with a stated confidence limit
- 3.5**  
**Filter**  
equipment to remove undesired particulates from the hydrogen
- 3.6**  
**Fuel cell system (SOURCE: ISO 14687)**  
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 and water management
- 3.7**  
**Fuel Cell Vehicle (FCV)**  
A vehicle which stores hydrogen on-board and uses a fuel cell system to generate electricity for propulsion
- 3.8**  
**Hydrogen Refueling Station (HRS) (SOURCE: ISO 19880-1)**  
facility for the dispensing of compressed hydrogen vehicle fuel, often referred to as a hydrogen fueling station (HRS) or hydrogen filling station, including the supply of hydrogen, and hydrogen compression, storage, and dispensing systems
- 3.9**  
**Impurity**  
A non-hydrogen component in the gas stream
- 3.10**  
**Irreversible damage or effect (SOURCE: ISO 14687)**  
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**  
the act of measuring the constituents 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**  
not in accordance with established procedures
- 3.13**  
**On-site supply (SOURCE: ISO 14687)**  
hydrogen fuel supplying system with a hydrogen production system in the same site
- 3.14**  
**Off-site fuel supply (SOURCE: ISO 14687)**  
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 (SOURCE: ISO 14687)**  
solid or aerosol particle that can be entrained somewhere in the delivery, storage, or transfer of the hydrogen fuel

**3.16****Purifier**

equipment to remove undesired constituents from the hydrogen

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

**3.17****Quality Assurance (SOURCE: ISO 9000)**

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

**3.18****Quality Control (SOURCE: ISO 9000)**

part of quality management focused on fulfilling quality requirements

**3.19****Quality Plan**

documentation of quality management

**3.20****Reversible damage or effect (SOURCE: ISO 14687)**

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

**3.21****Risk [SOURCE: ISO/IEC Guide 51]**

combination of the probability of occurrence of harm and the severity of that harm; encompassing both the uncertainty about and severity of the harm

**3.22****Risk Assessment (SOURCE: ISO 19880-1)**

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

**3.23****Risk Level**

assessed magnitude of the risk

**3.24****Routine**

in accordance with established procedures

**3.25****Sampling**

the act of capturing a measured amount of hydrogen for chemical analysis by external equipment

## 4 Symbols and abbreviated terms

Acronym/Abbreviation	Definition
AHJ	Authority having Jurisdiction
Ar	Argon
CO	Carbon Monoxide
CO <sub>2</sub>	Carbon Dioxide
FCV	Fuel Cell Vehicle
H <sub>2</sub> O	Water
Halogens	Total halogenated compounds
HCHO	Formaldehyde
HCOOH	Formic Acid
He	Helium
HRS	Hydrogen Refueling Station
N <sub>2</sub>	Nitrogen
O <sub>2</sub>	Oxygen
PEM	Proton Exchange Membrane
PSA	Pressure Swing Adsorption
SMR	Steam Methane Reforming
THC	Total Hydrocarbons (non-methane)
TS	Total Sulfur Compounds
TSA	Temperature Swing Adsorption

## 5 Hydrogen specifications

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

## 6 Quality Control Approaches

There are two primary methods of quality control at a HRS: Sampling and Monitoring. These methods can be used individual or together to ensure hydrogen quality levels.

### 6.1 Sampling

Sampling at a HRS 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 follow the requirements in ISO TC/197 19880-1.

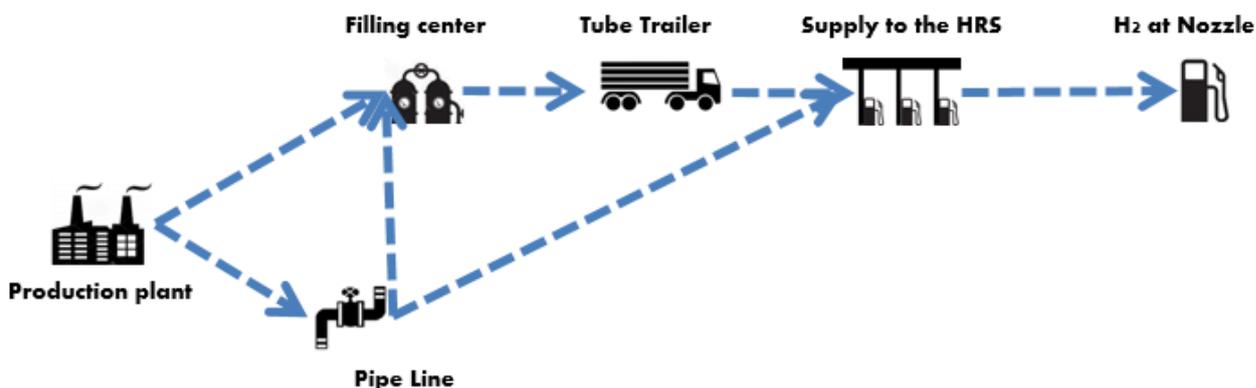
### 6.2 Monitoring

A HRS 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 canary species are used to alert of potential issues with the hydrogen production or purification process. Gas detection equipment is installed in-line with the hydrogen gas stream and shall meet the process requirements of the HRS, as well as be calibrated on a periodic basis.

## 7 Potential Sources of Impurities

For a given HRS, the contaminants listed in the hydrogen specification referred to Clause 5 may or may not be potentially present. There are several parts of the supply chain where impurities can be introduced. This section describes the potential impurities in each step of the supply chain. An example of typical supply chains is given in the figure below:

Figure 1 — Example of typical HRS supply chain



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 at article 8.

### 7.1 Production

The contaminants that may be introduced at production depend on the production technology and on the barriers and control implemented.

#### 7.1.1 Reforming

Reforming is the most common H<sub>2</sub> production method today. It uses various type of feedstocks, such as, natural gas, biogas, naphtha, methanol, and NH<sub>3</sub>. The feedstock is usually converted into a synthetic gas (Syngas), and shift reacted to produce more H<sub>2</sub> and CO<sub>2</sub>, then purified. The most common purification way is by pressure swing adsorption (PSA).

The contaminant potentially present in the hydrogen are depending on the process technology and on the purification. It should be investigated on a case by case basis for each production source.

Annex A.1 on centralized Steam Methane Reforming (SMR) of natural gas with PSA purification gives an example on how to investigate the potential contaminants related to a very widely used H<sub>2</sub> production route. As a result:

Table 1 — Impurities potentially present in H<sub>2</sub> produced by SMR

Possibility of Impurity over threshold	Impurity
Potentially present	N <sub>2</sub> , Ar, CH <sub>4</sub> , CO
Very Unlikely	O <sub>2</sub> , CO <sub>2</sub> , H <sub>2</sub> O, He, TS, NH <sub>3</sub> , THC (except methane), HCOOH, Halogens

**7.1.2 Alkaline Electrolysis**

Alkaline electrolysis has been used for more than a century to produce H<sub>2</sub> from H<sub>2</sub>O using electricity. The hydrogen produced at the anode is usually purified from the remaining O<sub>2</sub> through a catalytic reactor and then dried through a Temperature Swing Adsorption (TSA). Table 2 investigates the potential sources of contaminations. Such contaminations are mainly coming from the H<sub>2</sub>O and the air.

**Table 2 — Impurities potentially present in H<sub>2</sub> produced by Alkaline Electrolysis**

Possibility of Impurity over threshold	Impurity
Potentially present	O <sub>2</sub> , N <sub>2</sub> , H <sub>2</sub> O, Ar
Very Unlikely	CO <sub>2</sub> , CO, CH <sub>4</sub> , He, TS, NH <sub>3</sub> , THC, HCHO, HCOOH, Halogens

**7.1.3 Proton exchange membrane electrolysis**

PEM electrolysis is the electrolysis of H<sub>2</sub>O in a cell equipped with a solid polymer electrolyte that is responsible for the conduction of protons, separation of product gases, and electrical insulation of the electrodes. Table 3 investigates the potential sources of contaminations. Such contaminations are mainly coming from the H<sub>2</sub>O and the air.

**Table 3 — Impurities potentially present in H<sub>2</sub> produced by PEM Electrolysis**

Possibility of Impurity over threshold	Impurity
Potentially present	O <sub>2</sub> , N <sub>2</sub> , H <sub>2</sub> O, Ar, Particulates
Very Unlikely	CO <sub>2</sub> , CO, CH <sub>4</sub> , He, TS, NH <sub>3</sub> , THC, HCHO, HCOOH, Halogens

**7.1.4 Byproducts**

Hydrogen may be obtained through purification of H<sub>2</sub> rich effluent byproduct of chemical /petrochemical industry. Given the large variety of potential feeds to be purified and processes involved, a specific dedicated analysis is required for each source to identify the potential contaminants and associated probabilities.

**7.1.5 New production methods**

There are a number of new production methods under investigation such as photoelectrolysis, algae, bacterial, etc. Each of them shall be the object of a dedicated evaluation if the produced H<sub>2</sub> is used for the supply of a HRS.

**7.2 Transportation**

This article relates to additional contaminants that may be introduced in the H<sub>2</sub> during transportation.

**7.2.1 Pipeline**

When transported in pipelines, H<sub>2</sub> is usually at relatively high pressure (>40 bar). Contamination of any kind during normal operation is “very unlikely”.

During maintenance, the potential source of contamination are:

- N<sub>2</sub> if insufficiently purged after maintenance
- H<sub>2</sub>O if insufficiently dried after maintenance

Normal criteria for N<sub>2</sub> purging after maintenance is O<sub>2</sub> below 2%. This is what is required for safety reasons before allowing to fill the system with H<sub>2</sub>. If H<sub>2</sub> purging is done to reach 100 ppm N<sub>2</sub> before putting into operation, the O<sub>2</sub> levels will be less than 2ppm. If improper purging occurs, and the O<sub>2</sub> levels exceed 5 ppm, at 2% concentration, then the N<sub>2</sub> levels will be greater than 250 ppm. This implies that the probabilities to exceed threshold due to wrong purging are in the same order of magnitude for both O<sub>2</sub> and N<sub>2</sub>.

**Table 4 — Impurities potentially introduced during Pipeline Transportation**

Possibility of Impurity over threshold	Impurity
Potentially present	N <sub>2</sub> ,O <sub>2</sub> ,
Very Unlikely	CO <sub>2</sub> , CO, CH <sub>4</sub> , He, TS, NH <sub>3</sub> , THC, HCHO, HCOOH, Halogens

### 7.2.2 Filling center and Tube Trailer

Filling center may be attached to a production site or to a pipeline network. They are used to fill gaseous pressurized tube trailers. Contamination during normal operation is “very unlikely”.

During maintenance, the potential source of contamination are:

- O<sub>2</sub> or N<sub>2</sub> if insufficiently purged after maintenance
- H<sub>2</sub>O if insufficiently dried after maintenance

Normal criteria for N<sub>2</sub> purging after maintenance is O<sub>2</sub> below 2%. This is what is required for safety reasons before allowing to fill the system with H<sub>2</sub>.

Starting with a system containing N<sub>2</sub> with less than 2% O<sub>2</sub>, if H<sub>2</sub> purging is done to reach 100 ppm N<sub>2</sub> before putting into operation, the O<sub>2</sub> levels will be less than 2ppm. If improper purging occurs, and the O<sub>2</sub> levels exceed 5 ppm, at 2% concentration, then the N<sub>2</sub> levels will be greater than 250 ppm. This implies that the probabilities to exceed threshold due to wrong purging are in the same order of magnitude for both O<sub>2</sub> and N<sub>2</sub>.

Note: Tube trailers may be filled at different sources. It is necessary to take into account the risk of contamination due to the residual H<sub>2</sub> contained in a tube trailer coming from a different location if this is relevant at the considered HRS. This shall be taken into account if necessary in the risk analysis.

**Table 5 — Impurities potentially introduced during centralized distribution and tube trailer transportation**

Possibility of Impurity over threshold	Impurity
Potentially present	N <sub>2</sub> ,O <sub>2</sub>
Very Unlikely	CO <sub>2</sub> , CO, CH <sub>4</sub> , He, TS, NH <sub>3</sub> , THC, HCHO, HCOOH, Halogens

### 7.3 HRS

Contamination during normal operation shall be assessed with consideration of the technology used on a case by case basis. During maintenance, the potential source of contamination are:

- N<sub>2</sub> if insufficiently purged after maintenance
- H<sub>2</sub>O if insufficiently dried after maintenance

**Table 6 — Impurities potentially introduced at HRS**

Possibility of Impurity over threshold	Impurity
Potentially present	TBD
Very Unlikely	TBD

**7.4 Particulates**

Particulate may be originated due to various phenomenom at each level of the supply chain. By default, they shall be considered as potentially present for each of them, except if specific design measures (filtering) permit to demonstrate the opposite.

**8 Hydrogen Quality Assurance Methodology**

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 developed the quality assurance plan can vary, This document contains two examples: a prescriptive and a risk assessment approach. The general description of these two approaches are described in part 8.1 and 8.2. Examples of these approaches are presented in Annex A, B and C.

It is important to understand that product quality should be maintained throughout the product complete supply chain (from production source to HRS 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. 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 may include sampling and monitoring. Additionally, use of quality assurance can improve the decision making if a quality problem arises.

If no quality assurance plan can be defined either by a prescriptive or a risk assessment approach, , the full list of impurities given in the define quality specification (clause 5) shall be controlled.

**8.1 Prescriptive Approach**

Prescriptive approach can be applied for the clearly identified supply chain. The approach to conducting a quality analysis of the contaminants listed in Clause 5 is to consider the potential sources of contaminants, and establish protocol for analyzing potential contaminants.

Prescriptive quality assurance plan shall be determined taking into account all exiting hydrogen production methods, hydrogen transportation methods and non-routine procedures.

Note: Annex-B is the summary of Japanese Hydrogen Quality Guideline which is an example of prescriptive quality assurance plans.

**8.2 Risk Assessment for H2 quality**

Risk assessment consists of the identification of the probability to have each impurity above the threshold values of specifications given in clause 5 and the evaluation of severity of each impurity for the fuel cell car. As an aid to clearly defining the risk(s) for risk assessment purposes, three fundamental questions are often helpful:

- What might go wrong: which event can cause the impurities to be above the threshold value?
- What is the likelihood (probability of occurrence) that impurities can be above the threshold value?
- What are the consequences (severity) for the fuel cell car?

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. For the probability of occurrence of the event: impurities in hydrogen exceed the threshold value, the following table of occurrence classes has been defined:

**Table 7 — Occurrence classes for an impurity**

OCCURRENCE CLASS	CLASS NAME	OCCURRENCE OR FREQUENCY
0	Very unlikely (Practically impossible)	Contaminant above threshold never been observed for this type of source in the industry
1	Very rare	Heard in the Industry for the type of source/ Supply chain considered
2	Rare	Has happened more than once/year in the Industry
3	Possible	Has happened repeatedly for this type of source at a specific location
4	Frequent	Happens on a regular basis

The range of severity level (level of damage for vehicle) is defined by the following table:

**Table 8 — Severity levels for an impurity**

SEVERITY CLASS	FCEV Performance impact or damage	Impact categories		
		Performance impact	Hardware impact temporary	Hardware impact permanent
0	No impact	No	No	No
1	Minor impact temporary loss of power No impact on hardware Car still operates	Yes	No	No
2	Reversible damage Requires specific procedure, light maintenance. Car still operates.	Yes or No	Yes	No
3	Reversible damage Requires specific procedure, light maintenance. Car stops.	Yes	Yes	No
4	Irreversible damage Requires major repair (e.g. stack change)	Yes	Yes	Yes

The final risk is defined by the acceptability table build by combination of both above tables as following:

Table 9 — Example combined risk assessment

		Severity				
		0	1	2	3	4
Occurrence As the combined probabilities of occurrence along the whole supply chain	4					
	3					
	2					
	1					
	0					
Key	Unacceptable risk ; additionnal control or barriers are required		Further investigations are needed: existing barriers or control may not be enough		Acceptable risk area Existing controls acceptable	

For each impurity of the specification and for a given HRS (including the supply chain of hydrogen), a risk assessment shall be applied to define the global risk. 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 might 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, decision has to be taken in order to either refuse the risk and then 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 (yellow or red zone in Table 9). Risk reduction might include actions taken to mitigate the severity and/or probability of occurrence.

## 9 Routine Quality Control

Routine analysis is performed on a periodic basis once every specified time period or once for each lot or batch. Quality control based on the individual contaminants listed in ISO 14687-2 is presumed upon clearly identified production, purification and transportation methods of hydrogen. If the hydrogen supply method of a HRS is unclear or unidentified, the quality shall be assured by analyzing all potential contaminants. Additionally, if multiple production or transportation methods are used for a HRS, the constituents to be analyzed or monitored shall be selected by considering potential sources of contamination for each method to ensure quality.

### 9.1 Production

As a general rule, the product quality of a plant is consistent, as long as the input and the operating conditions are consistent. If there are no changes in the input and the operating conditions over a long period of time, only one quality analysis shall be needed per operation period. On the other hand, if there are changes in the input and the operating conditions, quality analysis shall be needed for each condition.

### 9.2 Transportation

#### 9.2.1 Storage and transportation of hydrogen in compressed state

When hydrogen produced at a centralized production site is transported by compressing and filling it into transport cylinders, there is minimal risk that its components are altered by chemical reactions. However, one

cannot rule out the possibility of contamination by residual or condensed contaminants that are present in the cylinders in the first place. The risk of contamination is higher when the cylinders, while used exclusively for hydrogen transportation, are used for hydrogen produced from a different feedstock every time, or when the cylinders are new or were recently opened up for inspection.

As a rule, additional routine analyses are deemed unnecessary when the cylinders are used exclusively for FCV hydrogen (compliant with ISO 14687-2), or when the possibility of contamination has been eliminated by repeated purge cycles using FCV hydrogen even if the cylinders were used to transport hydrogen other than FCV hydrogen.

### 9.2.2 Storage and transportation of liquid hydrogen

When hydrogen is transported or stored in liquid state, there is no risk of significant contamination since the hydrogen is purified to a super high level by a PSA or adsorption system upstream of the liquefaction system to prevent any problems caused by solid deposits, regardless of the production method used.

### 9.2.3 Pipeline transportation

When hydrogen is transported via pipelines from a production facility, it is clear that, in general, there is no risk of contamination as demonstrated by the example of city gas transport. Therefore, in principle, no additional routine analyses are required within the pipelines.

## 9.3 Hydrogen Refueling Station

### 9.3.1 Delivered Hydrogen

Hydrogen received from off-site hydrogen production is subject to a routine analysis for the chemical constituents that have not been covered by the centralized hydrogen production and distribution facility and for those that may infiltrate the gas after it is accepted by the HRS. For individual contaminant species that may enter after HRS acceptance, the frequency of analysis may be reduced, provided that the possibility of infiltration is deemed eliminated by having a good operation and control program at the HRS, such as a purge procedure.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fueling nozzle to the extent that no changes occur to the quality of hydrogen. (See 6.1)

### 9.3.2 On-Site Hydrogen Generation

When an on-site hydrogen generator (such as reformer or H<sub>2</sub>O electrolysis apparatus) is operated, the quality of the hydrogen gas produced may fluctuate over time. If this occurs, then contamination of FCV may occur without notice unless the quality of gas is analyzed or monitored frequently or continuously. On site hydrogen generation shall require a minimum of one analysis per day. But the frequency of analysis may be reduced, provided that the possibility of contamination is deemed eliminated by the good operation and control of the HRS, such as when on-site storage is filled after the canary species is continuously monitored for quality control on a daily basis following the start-up the generator.

A canary species is a constituent with the highest concentration level in a hydrogen production method. In other words, if it is confirmed that the concentration of the canary species of a given production method is less than its specified limit, other impurities are deemed to have met the standard requirements. For example, in the case of SMR and PSA production and purification, CO serves as the canary species.

## 10 Non-routine Quality Control

A non-routine analysis is to be conducted for those constituents deemed necessary if: shall be required if any of the conditions listed below are encountered. The impurities to be analysed shall be based upon the hydrogen quality plan listed in Clause 8.

- a new production system is constructed at a production site or a new HRS is first commissioned;
- the production system at a production site or HRS is modified;
- a routine or non-routine open inspection, repair, catalyst exchange, or the like is performed on a production system at the production site or HRS;
- a question concerning quality is raised when, for example, there is a problem with a vehicle because of hydrogen supplied at the production site or HRS, and a claim is received from a user directly or indirectly;
- an issue concerning quality emerges when, for example, a voluntary audit raises the possibility that quality control is not administered properly; or
- analysis is deemed necessary for testing, research or any other purposes.

### **10.1 H2 Production**

If any of the above conditions in a production site occurs, quality analysis shall be required.

### **10.2 Transportation**

After any severe malfunctions of transportation system of compressed hydrogen, liquid hydrogen and hydrogen pipeline, quality analysis shall be required.

### **10.3 HRS**

If any of the above conditions occur in an HRS, quality analysis shall be required.

## **11 Reporting**

If a HRS dispenses or has the potential of dispensing hydrogen which does not meet the requirements in Clause 5, the HRS shall immediately prevent any further dispensing until repaired and notify station owner/operator and authorities having jurisdiction as soon as possible.

## Annex A (informative)

### Example of Risk Assessment

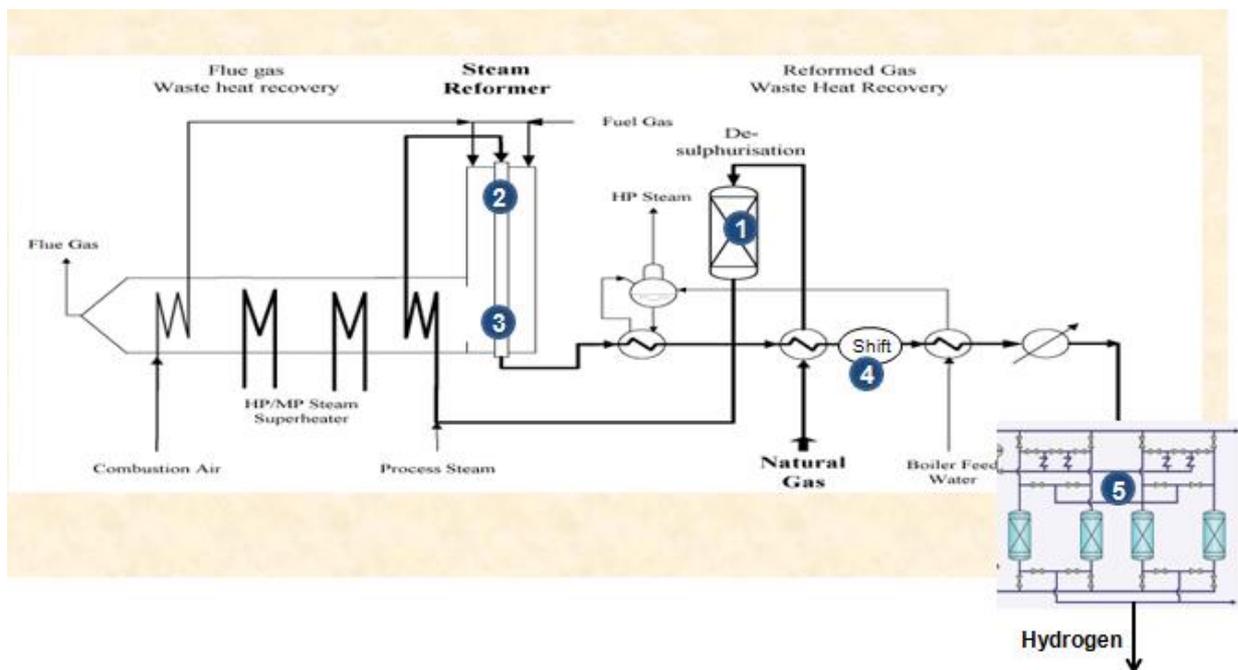
#### A.1 Centralized production, pipeline transportation

The different steps for elaborating the quality assurance plan of one HRS are illustrated using the following case: one HRS delivered by pipeline from an off site SMR.

The solutions selected in this example to decrease the risk when necessary are given as a possible solution for this specific case. Other solutions may be chosen depending on each HRS.

Following the procedure described in Clause 8, the risk assessment is performed on the identification of the probability to have each impurity above the threshold values of specifications and the evaluation of severity for the fuel cell car, assuming some values of impurities above the specification. This risk assessment is done for each part of the supply chain: SMR, pipeline distribution and HRS itself (see following tables)

Figure A.1 — Typical SMR Process



**Table A.1 — Probability of occurrence for off site SMR**

Contaminant	Threshold ppm	Causes possible For the source studied	Existing barriers	P
<b>Inert gas N2</b>	100	Present in Nat gas and Syngas PSA malfunction	<ul style="list-style-type: none"> <li>•PSA</li> <li>•Double analysis + trip at xx ppm at PSA outlet xx&lt;100 ppm</li> </ul>	3
<b>Inert Gas Ar</b>		Only ATR and POx Present in O2 typical 0,6% in Syngas	<ul style="list-style-type: none"> <li>•PSA. Not sized to remove Ar. Ar content may be higher if H2 comes from ATR, POX or feeds with high Ar content</li> </ul>	2
<b>O2</b>	5	Not present in Syngas. O2 is unstable in the condition of reforming and shift reactions. Combines with H2, CO CH4,	<ul style="list-style-type: none"> <li>•PSA cannot be used with significant O2 content for safety reasons</li> </ul>	0
<b>CO2</b>	2	Present in Syngas (%)	<ul style="list-style-type: none"> <li>•PSA Adsorption strength of MS, Activated carbon, Silicagel higher for CO2 than CO. A CO content lower than 10ppm insures a CO2 content lower than 2 ppm</li> </ul>	0
<b>CO</b>	0.2	Normal operation below threshold. Occasional peaks at ppm level	<ul style="list-style-type: none"> <li>•Double analysis + trip at xx ppm at PSA outlet (xx&lt;10)</li> </ul>	4
<b>Methane</b>	100	Present in Syngas at % level	<ul style="list-style-type: none"> <li>•In most cases CO is sizing the PSA, therefore CO&lt;10ppm ==&gt; CH4 &lt; xx ppm depending on users spec (Europe pipeline 2 ppm. In some cases CH4 is sizing the PSA and there is a continuous analysis + trip related to CH4 purity.</li> </ul>	2
<b>H2O</b>	5	Syngas saturated in H2O	<ul style="list-style-type: none"> <li>•PSA Adsorbed in Alumina and MS Adsorption strength higher than CO2. A CO content lower than 10ppm insures a H2O content lower than 5 ppm.</li> </ul>	0
<b>TS</b>	0.004	TS from Natural Gas	<ul style="list-style-type: none"> <li>•Desulfuration upstream reformer (typical values) Normal &lt; 10 ppb, Max &lt; 20 ppb, Guarantee &lt; 50 ppb, Dilution factor 2,5</li> <li>•Pre-reformer Catalyst poisoning by sulfur irreversible. Sulfur trapped at this stage. In case of breakthrough, process condition cannot be achieved</li> <li>•Reformer Catalyst poisoning by sulfur irreversible Sulfur trapped at this stage. In case of breakthrough, process condition cannot be achieved</li> <li>•Shift Catalyst poisoning by sulfur irreversible. Sulfur trapped at this stage. In case of breakthrough, process condition cannot be achieved</li> <li>•PSA Adsorption of H2S before CO, CO2, species</li> <li>•H2S Adsorption in pipe and vessels strong affinity with steel.</li> </ul>	0
<b>NH3</b>	0.1	Traces present in Syngas.	<ul style="list-style-type: none"> <li>•PSA Adsorption strength of Alumina, MS Higher than CO. A CO content lower than 10ppm insures a NH3 content lower than 0,1 ppm</li> </ul>	0
<b>THC</b>	2	Traces of C2+ after reforming reaction	<ul style="list-style-type: none"> <li>•PSA C2 C3, C4, C5+adsorbed by Activated Carbon layer. A CO content lower than 10ppm insures a THC (CH4 excluded) content lower than 2 ppm</li> </ul>	0
<b>HCHO</b>	0.01	Idem Acide Formique...Arreté par PSA	<ul style="list-style-type: none"> <li>•PSA. Adsorption strength of Alumina, MS Higher than CO. A CO content lower than 10 ppm insures a HCHO content lower than 0.1 ppm. To guarantee 0,01 ppm would require more experience of measuring at those levels.</li> </ul>	1
<b>HCOOH</b>	0.2	May be present in Syngas essentially liquid	<ul style="list-style-type: none"> <li>•PSA. Formic Adsorption strength of Alumina, MS Higher than CO. A CO content lower than 10ppm insures a HCOOH content lower than 0,2ppm</li> </ul>	0
<b>Halogens</b>	0.05	Present in Natural Gas	<ul style="list-style-type: none"> <li>•Any Cl present in Nat gas would be stopped by HDS</li> <li>•Pre-reformer Catalyst poisoning by Cl irreversible Cl trapped at this stage. I break through, process condition cannot be achieved</li> <li>•Reformer Catalyst poisoning by Cl irreversible. Cl trapped at this stage. I break through, process condition cannot be achieved</li> <li>•Shift Catalyst poisoning by Cl irreversible. Cl trapped at this stage. I break through, process condition cannot be achieved</li> <li>•PSA Adsorption of Cl before CO, CO2, species</li> </ul>	0
<b>He</b>	300	Not present in Nat Gas in N Europe (<10 ppm). Passes through the whole process. Dilution factor 2,5		0

Table A.2 — Probability of occurrence for pipeline

Contaminant	Threshold ppm	Causes possible For the item studied	Existing barriers	P
<b>Inert gases : N2</b>	100	From Air: N2 can be sucked if some area are at negative pressure Are there labyrinth seals turbo comp? Wrong purging after maintenance	Inlet pressure PSL trip on compressors	1
<b>Inert gases : Ar</b>		No potential	1% Ar in the air. 100 ppm would mean 1% air in the pipe Never been observed	0
<b>O2</b>	5	From air:O2 can be sucked if some area are at negative pressure	Inlet pressure PSL trip on compressors	1
<b>CO2</b>	2	From Air:CO2 at 400 ppm in the air	2 ppm of CO2 would mean 0,5% air in the pipe Never been observed	0
<b>CO</b>	0.2	No potential		0
<b>Methane (CH4)</b>	100	No potential		0
<b>H2O</b>	5	Exchanger leak Wrong drying after pressure vessel hydraulic test	H2 >40 bar ==> leak from H2O to H2 unlikely during operation.	0
<b>TS</b>	0.004	No potential		0
<b>NH3</b>	0.1	No potential		0
<b>THC</b>	2	No potential		0
<b>HCHO</b>	0.01	No potential		0
<b>HCOOH</b>	0.2	No potential		0
<b>Halogens</b>	0.05	From H2O?		0
<b>He</b>	300	No potential		0

**Table A.3 — Probability of occurrence for HRS**

Contaminant	Threshold ppm	Causes possible For the source studied	Existing barriers	P
<b>Inert gases : N2</b>	100	N2 purging operation, air intake during normal operation or maintenance		2
<b>Inert Gas Ar</b>		air intake during normal operation or maintenance	1% Ar in the air. 100 ppm would mean 1% air in the pipe Never been observed	0
<b>O2</b>	5	air intake during normal operation or maintenance		2
<b>CO2</b>	2	2 ppmv CO2 suppose air intake at 0,5%		0
<b>CO</b>	0.2	No potential at HRS level		0
<b>Methane (CH4)</b>	100	No potential at HRS level		0
<b>H2O</b>	5	Maintenance, leaks from compressor exchangers,... improper Pressure vessel drying after periodic inspection, H2O coming from the vent in case of check valve malfunction Depends on HRS/Compressor Technology		1
<b>TS</b>	0.004	Materials gaskets, valve seats releasing ppb level of TS in H2?	Material specifications	1
<b>NH3</b>	0.1	No potential		0
<b>THC</b>	2	oil carryover from compressor (depends on Compressor technology)		2
<b>HCHO</b>	0.01	No potential		0
<b>HCOOH</b>	0.2	No potential		0
<b>Halogens</b>	0.05	From H2O? From degreasing material (freons)		1
<b>He</b>	300	No intake downstream sources		0

When the study is achieved part per part, a combination of all probability of occurrence is done and combined In the following table A4 the first part is the calculation of the combined probability which is the highest one of the three parts of supply chain.

To define the severity level of each impurity as it is presented in the following table, some assumptions are made concerning the impurities levels above the threshold value. These impurities levels are assumed to be reached for a short period of time

Table A.4 — Combined risk assessment

ISO spec		Supply Chain			Compounded probability	Severity	Criticality	Additional risk reduction measures	Severity reduction measures	Residual		
Contaminant	Threshold ppm	Production SMR	Pipeline Distribution	HRS						P	S	C
Inert gases : N2	100	3	1	2	3	1	Systematic N2 analysis after shutdown before resuming operation Or specific purging procedure		1	1		
Inert Gas Ar		2	0	0	2	1			2	1		
O2	5	0	1	2	2	0			2	0		
CO2	2	0	0	0	0	1			0	1		
CO	0.2	4	0	0	4	2	CO adsorber at HRS design margin 100% + Operation procedure for replacement when H2 quantity purified = 50% of design capacity.		1	2		
Methane (CH4)	100	2	0	0	2	1			2	1		
H2O	5	0	0	1	1	4	Check H2O at commissioning and after maintenance involving opening of vessels or piping. Measurement shall be done at appropriate location downstream of the considered vessel or piping.		0	4		
TS	0.004	0	0	1	1	4			0	4		
NH3	0.1	0	0	0	0	4	Check TS at commissioning and after maintenance involving parts modification (piping, valves, seals, gaskets). Not required for part replaced by identical component.		0	4		
THC	2	0	0	2	2	4			0	4		
HCHO	0.01	1	0	0	1	2	Oil/grease cleaning at commissioning and after maintenance. Compressor surveillance depending on compressor technology (coalescing filter?) THC analysis or commissioning and after maintenance		1	2		
HCOOH	0.2	0	0	0	0	2			0	2		
Halogens	0.05	0	0	1	1	4	Halogenated analysis at commissioning (species shall be defined) or after maintenance		0	4		
He	300	0	0	0	0	1			0	1		

Then the table 9 is used to define the criticality for each impurity.

When the result is green, the H2 quality is under control and the risk to have an issue with the car using this hydrogen is considered as acceptable. No additional barrier is necessary and this impurity has no reason to be controlled at the HRS nozzle.

When the result is yellow, which is the case for N2, the conclusion is to further investigate the means to decrease the occurrence probability. For instance, in addition of the existing analysis at SMR plant, to measure N2 at the commissioning of the HRS and after each maintenance where some parts of the system are open to air. Or applying specific purge procedure which guarantees to reach a value within specification.

When the result is red, it is necessary to reduce the probability of occurrence or to decrease the severity to bring back the risk at an acceptable limit. Additional barriers shall be added. These barriers are studied case by case.

For CO the conclusion in this example of risk assessment may be:

- To add a purifier with proper capacity of purification and to define a strict procedure for the purifier replacement, or.
- to add a continuous analysis and shutoff valve at the inlet of the HRS ( at pipeline connection)

For H<sub>2</sub>O the conclusion is to measure H<sub>2</sub>O at the commissioning of the HRS and after each maintenance involving opening of vessels or piping or replacement of one of them. This analysis could be done at low pressure to have more sensitivity.

For THC, depending of the compressor type, add a coalescing filter and proper maintenance procedure. Measure THC after commissioning or maintenance operation involving cleaning/degreasing.

For Halogens, make analysis at commissioning on a list of predefined components.

In conclusion

- For commissioning : measure N<sub>2</sub>, H<sub>2</sub>O, THC, TS , and Halogens
- After maintenance: measure N<sub>2</sub>, H<sub>2</sub>O, THC

The analysis of other impurities is not mandatory as soon as there is analysis of CO and N<sub>2</sub> at production site.

## **Annex B** (informative)

### Summary of the Japanese Hydrogen Quality Guideline

The following section is a condensed version of the Japanese quality control guideline developed in Japan and is intended to be an example of a prescriptive approach to hydrogen quality assurance.

#### **B.1 Approaches to administration of Japanese quality control guideline**

The approach to conducting a quality analysis of the contaminants listed in ISO 14687-2 is to first consider the potential sources of contaminants, and, second, establish protocol for analyzing potential contaminants.

- Potential sources of contaminants
  - Sampling procedures
  - Characteristics of hydrogen production method(s)
  - Characteristics of hydrogen transport method(s)
  - Non-routine procedure (for example maintenance, major production system change)
- Analysis of possible contaminants
  - Possible quantification

#### **B.2 Hydrogen production methods , hydrogen purification methods and hydrogen transportation methods**

##### **B.2.1 Hydrogen production methods**

We evaluated potential sources of contaminants for below hydrogen production methods.

- -Steam reforming (off-site/on-site)
- -Partial oxidation (off-site)
- -Autothermal reforming (off-site)
- -Water gas shift reaction (WGSR)
- -Catalytic reforming (off-site)
- -Coke-oven gas (COG) (off-site)
- -Steam cracking for ethylene by-product (off-site)
- -Chloralkali process (off-site)
- -Electrolysis of H<sub>2</sub>O (on-site/off-site)

##### **B.2.2 Hydrogen purification methods**

We evaluated potential sources of contaminants for below hydrogen purification methods.

- -Adsorption
- -Membrane separation
- -Solvent absorption
- -Cryogenic separation
- -Methanation
- -Selective CO oxidation

### B.2.3 Hydrogen transportation methods

We evaluated potential sources of contaminants for below hydrogen transportation methods.

- Transportation of hydrogen in compressed state
- Transportation of hydrogen in liquid form
- Pipeline transportation
- Transportation by storage materials

### B.3 Constituents requiring analysis (Potential sources of contaminants)

Analysis is to be conducted on constituents that may contaminate hydrogen regardless of which hydrogen production method is used, as well as those constituents that may contaminate hydrogen due to the unique nature of a given hydrogen production method.

#### B.3.1 All hydrogen production methods

**Table B.1 — Constituents requiring analysis for all production methods**

Name of constituent	Hydrogen production method to be analyzed	Approach
N <sub>2</sub>	All hydrogen production methods	Perform analysis on all production methods since there is a risk of contamination through the equipment in case of hydrogen sampling
O <sub>2</sub>	All hydrogen production methods	Same as above
H <sub>2</sub> O	All hydrogen production methods	Same as above
Ar	All hydrogen production methods	Same as above. The ISO standard specifies the limit as a total combined value of N <sub>2</sub> and Ar.

## B.3.2 Specific hydrogen production methods

Table B.2 — Constituents requiring analysis for specific production methods

Name of constituent	Hydrogen production method to be analyzed	Approach
He	All hydrogen production methods using natural gas as feedstock	Analysis is necessary since natural gas contains up to 300 ppm of He. Exclude a hydrogen production method if He has been removed from the natural gas used for the method.
NH <sub>3</sub>	NH <sub>3</sub> production process generating excess hydrogen Biogas reforming Coal gasification generating hydrogen by-product NH <sub>3</sub> hydride method	
Halogens	Chloralkali process producing excess hydrogen * Biogas production from plastic waste generating hydrogen Coke oven gas Water electrolysis **	* Excludes ion-exchange-membrane method  ** Limited to cases where tap water is used as feedstock and the performance of H <sub>2</sub> O purification system cannot be warranted.
TS	Steam reforming * Catalytic reforming Partial oxidation Autothermal reforming Coal gasification generating hydrogen by-product Production methods using TS as odorant	* Since TS are found in the form of H <sub>2</sub> S, analysis of H <sub>2</sub> S, not total sulfur content, is sufficient.
THC	Production methods in which fossil fuels are present, such as steam reforming, catalytic reforming, partial oxidation, autothermal reforming, and coal gasification generating hydrogen by-product.	
CO	Steam reforming* Catalytic reforming Partial oxidation Autothermal reforming Coal gasification generating hydrogen by-product	
HCHO	Hydrogen production methods using city gas or petroleum as fuel other than steam reforming,	Rationale for excluding steam reforming methods using city gas or petroleum: it has been verified that the thermo-equilibrium concentration of HCHO in steam reforming is significantly lower than the ISO limit.
HCOOH	Hydrogen production methods using city gas or petroleum as fuel other than steam reforming,	Rationale for excluding steam reforming methods using city gas or petroleum: it has been verified that the thermo-equilibrium concentration of HCHO in steam reforming is significantly lower than the ISO limit.

## B.4 Constituents that do not require analysis

Listed below are constituents for which there is no scientific basis for conducting routine analysis, and the rationale for this conclusion, such as when there is no risk of contamination in any hydrogen production method (a framework is to be provided to conduct non-routine analysis, however):

**Table B.3 — Constituents that do not require analysis**

Substance	Rationale
Hydrogen	While it is clear that hydrogen is the main component, there is no method for directly determining its quantity to a required degree of accuracy. If the proportion of hydrogen is to be calculated by division, it would be necessary to determine the quantity of all contaminants.
All non-hydrogen gases	There is no method for directly determining their quantity. If the proportion of non-hydrogen gases is to be calculated by summation, a qualitative determination of all contaminants would be required.
Particulates	If a filter is installed in the flow path, contamination is highly unlikely. Generally speaking, particulates found at demonstration HRS have been lower than the standard upper limit by two digits. (See C9.)

## B.5 Administration of quality control

### B.5.1 Frequency of routine analysis

#### B.5.1.1 Routine analysis at a centralized production and distribution facility

As a general rule, the product quality of a plant is consistent regardless of the size of its production system, as long as the input and the operating conditions are consistent. If there are no changes in the input and the operating conditions over a long period of time, only one quality analysis shall be needed per operation period. On the other hand, if there are changes in the input and the operating conditions, quality analysis shall be needed for each condition.

When the input and the operating conditions have not changed and if it can be assured that the possibility of contamination is eliminated by the good operation and control of the distribution facility by, for example, continuously monitoring the canary species before shipping, the test frequency may be reduced to as low as once per year.

#### B.5.1.2 Routine analysis at HRS

##### B.5.1.2.1 Off-site HRS

Hydrogen received by an off-site HRS is subject to a routine analysis for the chemical constituents that have not been covered by the centralized hydrogen production and distribution facility and for those that may infiltrate the gas after it is accepted by the HRS. For individual contaminant species that may enter after HRS acceptance, the frequency of analysis may be reduced to as low as once per year, provided that the possibility of infiltration is deemed eliminated by having a good operation and control program at the HRS, such as a purge procedure.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fueling nozzle to the extent that no changes occur to the quality of hydrogen.

##### B.5.1.2.2 On-site HRS

When a hydrogen generator (such as reformer or H<sub>2</sub>O electrolysis apparatus) is operated in the daily start and shut mode (DSS), the quality of the hydrogen gas produced fluctuates on a daily basis according to the

principle described in 9.3.2. Such operation therefore calls for one analysis per day. As in the case of the centralized production and distribution facilities in 9.3.2, the frequency of analysis may be reduced to as low as once per year, provided that the possibility of infiltration is deemed eliminated by the good operation and control of the HRS, such as when accumulators are filled after the canary species is continuously monitored for quality control on a daily basis following the start-up the generator.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fueling nozzle to the extent that no changes occur to the quality of hydrogen.

### **B.5.2 Frequency of non-routine analysis**

After above conditions (10. (1)-(6)), quality analysis of all cases shall be needed.

## **B.6 Administration of analysis and monitoring records**

### **B.6.1 Forms for analysis and monitoring records and reports**

A typical form used to record and report the analysis and monitoring activities is shown in Annex F. Using Annex F as a reference, each operator is to design and administer forms for records of analyses at its centralized production and distribution facilities, records of sampling and analyses at HRS, and records of monitoring.

### **B.6.2 Safekeeping and recording**

Centralized production or distribution facilities and HRS are to safekeep their own records of analyses at the facility, of samples collected at the HRS, and of monitoring in an appropriate manner.

The records are to be kept for a period of ten years. Such records may be kept at the department (or headquarters) that oversees the operation other than the applicable facilities or HRS.

## **B.7 Routine analysis work**

Table C7-1 provides the routine analysis work defined on the basis of the attitudes stated in C3, C4 and C5.1. The table gives the analytical species and the minimum analysis frequencies classified by hydrogen dispensing sites and hydrogen production, purification and transportation methods

## **B.8 Non-routine analysis work**

Table C8-1 provides the routine analysis work defined on the basis of the attitudes stated in C3, C4 and C5.2. The table gives the analytical species classified by hydrogen dispensing sites and hydrogen production, purification and transportation methods

## **B.9 Approaches to particulates requirements**

As per the requirements of particulates are to be no more than 1 mg/kg in concentration. According to ISO 14687-2, hydrogen is to be sampled from a dispenser nozzle of the HRS under conditions that are as close to the actual fueling conditions as possible. The weight of the particulates collected in a filter is measured.

However, past analyses of particulates collected by filters at HRS have demonstrated that particulates occur intermittently, and not always consistently, from such sources as pieces of sealing tapes for threaded parts, particles found in new equipment, and friction from movable parts. Therefore it is questionable whether the concentration of the samples collected by the method described above can be considered representative of a

given period of time. For this reason, filters are to be installed at HRS to remove particulates in lieu of conducting routine analysis of particulate concentration levels.

A survey of demonstration HRS systems indicated that all HRS had filters installed near dispenser nozzles, and most of the filters had an aperture of 10 µm (nominal), except one HRS that had 2 µm (nominal).

The weight of particulates at demonstration HRS ranged from 0.009 to 0.047 mg/kg, lower than the ISO upper limit of 1 mg/kg by about two digits.<sup>1</sup> The fact that there has been no report of problems with FCVs caused by particulate contamination during the 10-year demonstration period indicates that the hydrogen supplied for FCVs at demonstration HRS was of appropriate quality.

From the above, filters with an aperture of no more than 10 µm (nominal) installed at demonstration HRS are considered to have a sufficient capability at least in a short term to remove particulates so as to prevent FCV malfunctions. Therefore it is appropriate to install such filters in lieu of monitoring the concentration of particulates for quality control purposes.

Table B.4 — Routine analysis work

Category	Facility type	QC point	Parameter	Standard value	Reduced frequency
Distribution	Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR, purification using refining equipment, and distribution	Downstream of the purifier	TS <sup>1)</sup>	0.004 µmol/mol	Annual <sup>2)</sup>
			THC as C1	2 µmol/mol	Annual <sup>2)</sup>
			CO	0.2 µmol/mol	Annual <sup>2)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Annual <sup>2)</sup>
			O2	5 µmol/mol	Annual <sup>2)</sup>
	Electrolysis of NaCl for hydrogen, purification, and distribution	Downstream of the purifier	Halogens	0.05 µmol/mol	Annual <sup>2)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Annual <sup>2)</sup>
			O2	5 µmol/mol	Annual <sup>2)</sup>
	Purification of coke-oven gas, and distribution	Downstream of the purifier	TS	0.004 µmol/mol	Annual <sup>2)</sup>
			THC as C1	2 µmol/mol	Annual <sup>2)</sup>
			CO	0.2 µmol/mol	Annual <sup>2)</sup>
			Halogens	0.05 µmol/mol	Annual <sup>2)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Annual <sup>2)</sup>
			O2	5 µmol/mol	Annual <sup>2)</sup>
			NH3	0.1 µmol/mol	Annual <sup>2)</sup>
			HCHO	0.01 µmol/mol	Annual <sup>2)</sup>
	HCOOH	0.2 µmol/mol	Annual <sup>2)</sup>		
	Purification of byproduct hydrogen from ethylene plants, and distribution	Downstream of the purifier	TS	0.004 µmol/mol	Annual <sup>2)</sup>
THC as C1			2 µmol/mol	Annual <sup>2)</sup>	
CO			0.2 µmol/mol	Annual <sup>2)</sup>	
N2+Ar			100 µmol/mol	Annual <sup>2)</sup>	
H2O			5 µmol/mol	Annual <sup>2)</sup>	
O2			5 µmol/mol	Annual <sup>2)</sup>	

1) Since sulfur in steam reforming is mostly found as hydrogen sulfide (H<sub>2</sub>S), H<sub>2</sub>S analysis may be performed in lieu of total sulfur analysis.

2) The minimum frequency of the analysis is premised on the combination of continuous analysis of the canary species (CO for hydrocarbon cracking and O<sub>2</sub>/H<sub>2</sub>O for water electrolysis) and proper operation controls to make sure no mixing of impurities will occur. If that premise is not satisfied, the analysis shall be carried out once a day.

Category	Facility type	QC point	Parameter	Standard value	Reduced frequency
HRS	With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analyzed by the distributor		Annual <sup>2)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Annual <sup>2)</sup>
			O2	5 µmol/mol	Annual <sup>2)</sup>
	With off-site supply from hydrogen pipelines	Downstream of the deodorant equipment	(Those listed for the odorant)		Annual <sup>2)3)</sup>
		End of nozzle	Those not analyzed by the distributor		Annual <sup>2)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Annual <sup>2)</sup>
	With on-site supply of hydrogen produced from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR and purification using refining equipment	Downstream of the purifier	CO	0.2 µmol/mol	Continuous and Annual <sup>2)4)</sup>
		End of nozzle	TS <sup>1)</sup>	0.004 µmol/mol	Annual <sup>2)</sup>
			THC as C1	2 µmol/mol	Annual <sup>2)</sup>
			CO	0.2 µmol/mol	Annual <sup>2)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Annual <sup>2)</sup>
	With on-site supply from hydroelectrolysis and purification using refining equipment	Downstream of the purifier	O2	5 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Continuous and Annual <sup>2)4)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
		End of nozzle	Halogens	0.05 µmol/mol	Annual <sup>2)</sup>
			N2+Ar	100 µmol/mol	Annual <sup>2)</sup>
			H2O	5 µmol/mol	Annual <sup>2)</sup>
O2			5 µmol/mol	Annual <sup>2)</sup>	

3) If the hydrogen on a pipeline contains odorant, the odorant shall be analyzed with minimum frequency of once a year.  
 4) The batch analysis once a year is needed even if a continuous analysis is performed.

Table B.5 — Non-routine analysis work

Category	Facility type	QC point	Parameter	Standard value
Distribution	Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR, purification using refining equipment, and distribution	Downstream of the purifier	TS <sup>1)</sup>	0.004 µmol/mol
			THC as C1	2 µmol/mol
			CO	0.2 µmol/mol
			N2+Ar	100 µmol/mol
			H2O	5 µmol/mol
			O2	5 µmol/mol
	Electrolysis of Nacl for hydrogen, purification, and distribution	Downstream of the purifier	Halogens	0.05 µmol/mol
			N2+Ar	100 µmol/mol
			H2O	5 µmol/mol
			O2	5 µmol/mol
	Purification of coke-oven gas, and distribution	Downstream of the purifier	TS	0.004 µmol/mol
			THC as C1	2 µmol/mol
			CO	0.2 µmol/mol
			Halogens	0.05 µmol/mol
			N2+Ar	100 µmol/mol
			H2O	5 µmol/mol
			O2	5 µmol/mol
			NH3	0.1 µmol/mol
			HCHO	0.01 µmol/mol
			HCOOH	0.2 µmol/mol
	Purification of byproduct hydrogen from ethylene plants, and distribution	Downstream of the purifier	TS	0.004 µmol/mol
			THC as C1	2 µmol/mol
			CO	0.2 µmol/mol
			N2+Ar	100 µmol/mol
H2O			5 µmol/mol	
O2			5 µmol/mol	

Category	Facility type	QC point	Parameter	Standard value
HRS	With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analyzed by the distributor	
			N2+Ar	100 µmol/mol
			H2O	5 µmol/mol
			O2	5 µmol/mol
	With off-site supply from hydrogen pipelines	Downstream of the deodorant equipment	(Those listed for the odorant)	
		End of nozzle	Those not analyzed by the distributor	
			N2+Ar	100 µmol/mol
			H2O	5 µmol/mol
	With on-site supply of hydrogen produced from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR and purification using refining equipment	Downstream of the purifier	CO	0.2 µmol/mol
		End of nozzle	TS <sup>1)</sup>	0.004 µmol/mol
			THC as C1	2 µmol/mol
			CO	0.2 µmol/mol
			N2+Ar	100 µmol/mol
			H2O	5 µmol/mol
		With on-site supply from hydroelectrolysis and purification using refining equipment	Downstream of the purifier	H2O
	O2			5 µmol/mol
	End of nozzle		Halogens	0.05 µmol/mol
			N2+Ar	100 µmol/mol
			H2O	5 µmol/mol
			O2	5 µmol/mol