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Standard

ISO 19880-8

**Gaseous hydrogen — Fuelling
stations —**

**Part 8:
Fuel quality control**

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

**Second edition
2024-12**

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

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

This second edition cancels and replaces the first edition (ISO 19880-8:2019), which has been technically revised. It also incorporates the Amendment ISO 19880-8:2019/AMD 1:2021.

The main changes are as follows:

- aligned with the revision of ISO 14687, in particular the change in the specifications of Grade D, the indicators required for risk assessment have been mainly changed;
- due to the change in the document structure of ISO 14687, the rationale for each of the ISO 14687, Grade D specifications has been moved to ISO 14687.

A list of all parts in the ISO 19880 series can be found on the ISO website.

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

Introduction

This document was developed to specify how the quality of gaseous hydrogen fuel for road vehicles which use proton exchange membrane (PEM) fuel cells can be assured to meet the impurity levels in Grade D of ISO 14687. 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 in ISO 14687, Grade D.^[1] ISO 19880-9 outlines requirements for sampling from hydrogen refuelling stations for samples taken at the dispenser.

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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 19880-9, *Gaseous hydrogen — Fuelling stations — Part 9: Sampling for fuel quality analysis*

ISO 14687, *Hydrogen fuel quality — Product specification*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

constituent

component (or compound) found within a hydrogen fuel mixture

3.2

contaminant

impurity (3.7) that adversely affects the components within the *fuel cell powertrain* (3.4) or the hydrogen storage system

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

3.3

filter

equipment to remove undesired *particulates* (3.14) from the hydrogen

3.4

fuel cell powertrain

power system used for the generation of electricity on a *fuel cell vehicle* (3.5)

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

3.5

fuel cell vehicle

FCV

vehicle which stores hydrogen on-board and uses a *fuel cell powertrain* (3.4) to generate electricity for propulsion

3.6

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.

3.7

impurity

non-hydrogen component in the gas stream

3.8

indicator species

one or more *constituents* (3.1) 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

3.9

monitoring

act of measuring the *constituents* (3.1) of a hydrogen stream or process controls of a hydrogen production system on a continuous or semi-continuous basis by on-site equipment

3.10

non-routine

not in accordance with established procedures

3.11

on-site supply

hydrogen fuel supplying system with a hydrogen production system in the same site

3.12

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

3.13

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 powertrain* (3.4)

3.14

purifier

equipment to remove undesired *constituents* (3.1) from the hydrogen

Note 1 to entry: Hydrogen purifiers may comprise purification vessels, dryers, *filters* (3.3), and separators.

3.15

quality assurance

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

3.16

quality control

part of quality management focused on fulfilling quality requirements

3.17

quality plan

documentation of quality management

3.18

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

3.19

risk

combination of the probability of occurrence of harm and the *severity* (3.24) of that harm, encompassing both the uncertainty about and severity of the harm

3.20

risk assessment

determination of quantitative or qualitative value of *risk* (3.19) related to a specific situation and a recognized threat

Note 1 to entry: A recognized threat can also be referred to as a hazard.

3.21

risk level

assessed magnitude of the *risk* (3.19)

3.22

routine

in accordance with established procedures

3.23

sampling

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

3.24

severity

measure of the possible consequences for fuel cell vehicles if filled with H₂ containing a higher level of *impurities* (3.7) than the threshold value

4 Abbreviated terms

Abbreviated term	Definition
ATR	autothermal reaction
Halogens	halogenated compounds
HDS	hydrodesulfurization
MS	molecular sieve
OC	occurrence class
PEM	proton exchange membrane
Pox	partial oxidation
PSA	pressure swing adsorption
PSL	process safety limit
SC	severity class
SMR	steam methane reforming
HC	hydrocarbons
S	sulfur compounds
TSA	temperature swing adsorption
UD	undetermined

5 Hydrogen specifications

The quality requirements of hydrogen fuel dispensed to PEM fuel cells for road vehicles shall comply with Grade D of ISO 14687.

6 Quality control approaches

6.1 General

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

6.2 Sampling

Periodic 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 19880-9. The advantage of periodic sampling is that a more detailed laboratory analysis can be conducted on the sample. The disadvantage of periodic sampling is that it is not continuous and results in a detailed analysis at 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 an indicator species or control parameter can be 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 complements periodic 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 C](#).

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 described 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. A prescriptive methodology may be used as described in [8.2](#) or a risk assessment methodology may be used ([8.3](#)). Examples of these approaches: a) risk assessment and b) prescriptive approach for hydrogen quality, are presented in [Annexes A](#) and [B](#), 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.

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.

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 B](#) 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. 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. Conservative values should be taken if the data is unknown or has a high level of uncertainty. The risk analysis should be updated as the data is updated. 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 ^a
0	Very unlikely (Practically impossible)	Contaminant above threshold never been observed for this source/supply chain/station	1 per 10 000 000 fuellings
1	Unlikely	Known to occur at least once for this source/supply chain/station	1 per 1 000 000 fuellings
2	Possible	Has happened once a year for this source/supply chain/station	1 per 100 000 fuellings
3	Likely	Has happened more than once a year for this type of source/supply chain/station	1 out of 10 000 fuellings
4	Very likely	Happens on a regular basis for this type of source/supply chain/station	More than 1 out of 1 000 fuellings

^a Based on a fuelling station supplying 100 000 fuellings per year. In case the actual refuelling use of the subject HRS is known at a yearly base, the occurrence corresponding to all the occurrence classes should be proportionally adjusted so that occurrence class 2 reflects one occurrence per year

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

Severity class	FCV performance impact or damage	Impact categories		
		Performance impact	Hardware impact temporary	Hardware impact permanent
0	— No impact	No	No	No
1	— Minor impact	Yes	No	No
	— Temporary loss of power			
	— No impact on hardware			
	— Vehicle still operates			
2	— Reversible damage	Yes or No	Yes	No
	— Requires specific light maintenance procedure			
	— Vehicle still operates			
3	— Reversible damage	Yes	Yes	No
	— Requires specific immediate maintenance procedure			
	— Gradual power loss that does not compromise safety			
4 ^a	— Power loss or vehicle stop that compromises safety	Yes	Yes	No
	— Irreversible damage		No	Yes
	— Requires major repair procedure (e.g., stack change)			

^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.

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

Table 3 — Combined risk assessment

Occurrence class name	Occurrence class	Severity				
		0	1	2	3	4
Very likely	4	+	o	*	*	*
Likely	3	+	o	o	*	*
Possible	2	+	+	o	o	*
Unlikely	1	+	+	+	o	o
Very unlikely (Practically Impossible)	0	+	+	+	+	+
Key	+	Acceptable risk area: Existing controls sufficient		o	Unacceptable risk; additional control or barriers required	
				Further investigations are needed to ensure the risks is reduced to as low as reasonably practicable		

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.

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 can 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.

In the "0" zone, the risk can be acceptable but redesign or other changes should be considered if reasonably practicable.

Further investigation should be performed to give better estimate of the risk. When assessing the need of remedial actions, the number of events of this risk level should be taken into consideration in order to be as low as reasonably practicable.

8.4 Impact of impurities on fuel cell powertrain

It is necessary to evaluate the possible consequences on a fuel cell vehicle if any impurity exceeds the threshold value in [Clause 5](#). The impact for the vehicle 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 concentration above the ISO 14687 Grade D threshold values at which the severity increases (if applicable) is named "Level 1" and is given in column 5 for each impurity where the "severity

class" is not already 4. 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.

Table 4 — Impact of impurities on fuel cell powertrain

Impurity		ISO 14687 Grade D threshold value ^a [μmol/mol]	Severity class (from ISO 14687 Grade D threshold value to Level 1)	Level 1 value [μmol/mol]	Severity class (greater than Level 1 threshold)
Total non-H ₂ gases		300	1	500	4
Helium	He	300	1	500	4
Nitrogen	N ₂	300	1	500	4
Argon	Ar	300	1	500	4
Oxygen	O ₂	5	1	50	4
Carbon dioxide	CO ₂	2	1	3	4
Carbon monoxide	CO	0,2	2-3 ^b	1	4
Methane	CH ₄	100	1	300	4
Water	H ₂ O	5	4	NA	4
Sulfur compounds	H ₂ S equiva- lent	0,004	4	NA	4
Ammonia	NH ₃	0,1	4	NA	4
Hydrocarbons except methane	CH ₄ equiva- lent	2	1-2 ^b	5	4
Formaldehyde	HCHO	0,2	2-3 ^b	1	4
Halogens		0,05	4	NA	4
Maximum particulate concentration (liquid and solid) ^c		1 mg/kg	4	NA	4
Key NA: not applicable ^a The threshold value is according to hydrogen specification of Grade D of ISO 14687. ^b A higher value is to be considered for risk assessment approach until more specific data is available. ^c Particulates are based upon mass density mg/kg.					

9 Routine quality control

Routine analysis is performed on a periodic basis once every specified time period or once for each specified number of deliveries. The methodology selected in the hydrogen quality assurance plan determines the type and frequency of the routine analysis. A prescriptive methodology may be used as described in [8.1](#) or a risk assessment methodology may be used ([8.2](#)). Information on the routine analysis for each step of the supply chain is provided in [Annex D](#).

10 Non-routine quality control

The hydrogen quality plan shall:

- include sampling and analysis when a new fuelling station is commissioned;

- b) identify any other reasonably foreseeable non-routine conditions requiring subsequent sampling and analysis actions.

Some common non-routine conditions include the following:

- a new production system is constructed at a production site or a new fuelling station is first commissioned;
- the production system at a production site or fuelling station 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 fuelling station;
- any severe malfunctions of a transportation system of compressed hydrogen, liquid hydrogen, and hydrogen pipeline occur;
- 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 fuelling station, 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.

11 Remedial measures and reporting

If a fuelling station dispenses hydrogen which does not meet the requirements in [Clause 5](#), the fuelling station operator shall immediately prevent any further dispensing until repaired. The station operator shall notify the station owner and authorities having jurisdiction, as soon as possible. The station operator and owner shall also make an effort to notify those affected by the contamination, as soon as possible. This may include providing notifications to:

- vehicle manufacturer or dealerships;
- users of the station;
- industry groups, station status databases, social media.

The fuelling station owner/operator shall also review and update quality assurance methodologies to prevent future contamination.

Annex A (informative)

Example of risk assessment

A.1 Centralized production, pipeline transportation

The different steps for elaborating the quality assurance plan of one fuelling station are illustrated using the following case: one fuelling station 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 fuelling station.

Following the procedure described in [Clause 8](#), the risk assessment is performed on the following.

- The identification of the probability to have each impurity above the threshold values of specifications but always below or equal to the level one defined in [Table 4](#) or this document
- The evaluation of severity for the fuel cell vehicle, assuming values of impurities between the specification and the level 1, also given in [Table 4](#). For the impurities for which the severity is at level 4 whatever is the concentration above the threshold, level 1 is not applicable in [Table 4](#).
- This risk assessment is done for each part of the supply chain: SMR, pipeline distribution and fuelling station itself (see [Table A.1](#), [Table A.2](#), and [Table A.3](#)).

A.2 Steam methane reforming

A.2.1 General

In this process, methane from natural gas and steam reacts at a high temperature to produce synthesis gas (or syngas). Syngas is a mixture consisting mainly of hydrogen and carbon monoxide.

In order to achieve the reaction between natural gas and steam, catalysts and a high temperature are required. These catalysts are poisoned by any trace of sulfur or chlorinated compounds. It is then necessary to remove all sulfur components from natural gas before the SMR reaction. The purification system, named hydrodesulfurisation is a two steps process: first transformation of all sulfur species in H_2S and then adsorption of H_2S in specific adsorbents. At the outlet of this purification step, the natural gas contains less than $0,05 \mu\text{mol/mol}$ of H_2S by design and less than $0,01 \mu\text{mol/mol}$ in normal conditions.

After the reforming reaction, the carbon monoxide is further reacted with steam in a water gas shift reaction. It produces carbon dioxide and hydrogen and it increases the hydrogen yield. An additional separation step is mandatory to provide hydrogen with a purity suitable for FCV application.

A.2.2 Purification by pressure swing adsorption

Pressure swing adsorption is a non-cryogenic gas separation process which uses adsorbent technology to purify hydrogen from a gas mixture. PSA principle is based on preferential adsorption of some gaseous components to others on highly porous materials. The PSA ability to trap impurities depends on the affinity between the adsorbent and the gas molecule. Typically, a PSA column is filled with multiple adsorbents with very high surface area to volume ratios. Typical adsorbents include silica, alumina, molecular sieves, and activated carbons, which have different relative strength of adsorption depending on the gaseous compounds.

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

Im-puri-ty	Threshold μmol/mol	Possible causes sources of contamination SMR + PSA	Typical barriers employed in this process	Level 1 μmol/mol	OC ^a
Inert gas N₂	300	Present in natural gas and syngas PSA malfunction	— PSA — Double analysis PSA outlet <400 μmol/mol with 3 levels of alarms	500	2
Inert gas Ar	300	Only ATR and POx present in O ₂ typical 0,6 % (mole fraction) in syngas from ATR	— PSA, Not sized to remove Ar. Ar content may be higher if H ₂ comes from ATR, POX or feeds with high Ar content	500	1
O₂	5	Not present in syngas. O ₂ is unstable in the condition of reforming and shift reactions. Combines with H ₂ , CO, and CH ₄	— PSA cannot be used with significant O ₂ content for safety reasons	50	0
CO₂	2	Present in syngas (% (mole fraction))	— PSA adsorption strength of MS, activated carbon, silicagel higher for CO ₂ than CO. A CO content lower than 10 μmol/mol insures a CO ₂ content lower than 2 μmol/mol	3	0
CO	0,2	Normal operation below threshold. Occasional peaks at μmol/mol level	— Double analysis at the PSA outlet + trip if the CO>1-10 μmol/mol at PSA outlet	1	4
CH₄	100	Present in syngas at % (mole fraction) level	— In most cases CO is sizing the PSA, therefore CO<10 μmol/mol ==> CH ₄ < 100 μmol/mol depending on users' specification (Europe pipeline 2 μmol/mol).	300	2
H₂O	5	Syngas saturated in H ₂ O	— PSA adsorbed in alumina and MS adsorption strength higher than CO ₂ . A CO content lower than 10 μmol/mol insures a H ₂ O content lower than 5 μmol/mol.	NA	0
Key NA: Not applicable because the severity is 4 above the threshold value. a: Occurrence class for impurity between threshold limit and Level 1.					

Table A.1 (continued)

Im-puri-ty	Threshold μmol/mol	Possible causes sources of contamination SMR + PSA	Typical barriers employed in this process	Level 1 μmol/mol	OC ^a
S	0,004	Sulfur from natural gas	— Desulfuration upstream reformer (typical values: normal < 10 nmol/mol, maximum < 20 nmol/mol, guarantee < 50 nmol/mol)	NA	0
			— Typical dilution factor 2,5 (1 mol natural gas produces 2,5 mole H ₂)		
			— Pre-reformer catalyst poisoning by sulfur is irreversible. Sulfur trapped at this stage. In case of breakthrough, process condition cannot be achieved		
			— Reformer catalyst poisoning by sulfur is irreversible. Sulfur trapped at this stage. In case of breakthrough, process condition cannot be achieved		
			— Shift catalyst poisoning by sulfur is irreversible. Sulfur trapped at this stage. In case of breakthrough, process condition cannot be achieved		
			— PSA adsorption of H ₂ S before CO, CO ₂ , species — H ₂ S adsorption in pipe and vessels. Strong affinity with steel		
NH₃	0,1	Traces present in syngas	— PSA adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10 μmol/mol insures a NH ₃ content lower than 0,1 μmol/mol	NA	0
HC	2	Traces of C2+ after reforming reaction	— PSA C2 C3, C4, C5+adsorbed by activated carbon layer. A CO content lower than 10 μmol/mol insures a HC (CH ₄ excluded) content lower than 2 μmol/mol	5	0
Key NA: Not applicable because the severity is 4 above the threshold value. a: Occurrence class for impurity between threshold limit and Level 1.					

Table A.1 (continued)

Im-puri-ty	Threshold μmol/mol	Possible causes sources of contamination SMR + PSA	Typical barriers employed in this process	Level 1 μmol/mol	OC ^a
HCHO	0,2	May be present in syngas. essentially liquid	— PSA. Formaldehyde adsorption strength of alumina and molecular sieve higher than CO. A CO content lower than 10 μmol/mol insures a HCHO content lower than 0,1 μmol/mol. To guarantee 0,01 μmol/mol would require more experience of measuring at those levels — Any Cl present in natural gas would be stopped by HDS	1	0
Halo-gens	0,05	Present in natural gas	— Pre-reformer catalyst poisoning by Cl irreversible. Cl trapped at this stage. If breakthrough, process condition cannot be achieved — Reformer catalyst poisoning by Cl irreversible. Cl trapped at this stage. I break through, process condition cannot be achieved — Shift catalyst poisoning by Cl irreversible. Cl trapped at this stage. I break through, process condition cannot be achieved — PSA adsorption of Cl before CO, CO ₂ , species	NA	0
He	300	Not present in natural gas in N Europe (<10 μmol/mol). Passes through the whole process. Dilution factor 2,5		500	0
Key NA: Not applicable because the severity is 4 above the threshold value. a: Occurrence class for impurity between threshold limit and Level 1.					

Table A.2 — Probability of occurrence for pipeline

Impurity	Threshold μmol/mol	Possible source of contamination pipeline	Typical barriers employed in this process	Level 1 μmol/mol	OC ^a
Inert gas N₂	300	Air intake if some areas are at negative pressure From seal gas or purge gas Wrong purging after maintenance	Inlet pressure PSL trip on compressors	500	1
Inert gas Ar	300	No potential	1 % (mole fraction Ar in the air. 100 μmol/mol would mean 1 % (mole fraction) air in the pipe Never been observed	500	0
O₂	5	Air intake if some areas are at negative pressure	Inlet pressure PSL trip on compressors	50	1
CO₂	2	From Air: CO ₂ at 400 μmol/mol in the air	2 μmol/mol of CO ₂ would mean 0,5 % (mole fraction) air in the pipe Never been observed	3	0
CO	0,2	No potential		1	0
CH₄	100	No potential		300	0
H₂O	5	Wrong drying after pressure hydraulic test	H ₂ > 40 bar ==> leak from H ₂ O to H ₂ unlikely during operation.	NA	1
S	0,004	No potential		NA	0
NH₃	0,1	No potential		NA	0
HC	2	No potential		5	0
HCHO	0,2	No potential		1	0
Halogens	0,05	From cleaning material after maintenance		NA	1
He	300	No potential		500	0
Key NA: Not applicable because the severity is 4 above the threshold value. a: Occurrence class for impurity between threshold limit and Level 1.					

Table A.3 — Probability of occurrence for fuelling station to be source of impurities

Impurity	Threshold μmol/mol	Causes possible For the source studied	Existing barriers	Level 1 μmol/mol	OC ^a
Inert gas N₂	300	N ₂ purging operation, air intake during normal operation or maintenance		500	3
Inert gas Ar	300	Air intake during normal operation or maintenance	1 % (mole fraction) Ar in the air. 100 μmol/mol would mean 1 % (mole fraction) air in the fuelling station. Never been observed	500	0
O₂	5	Air intake during normal operation or maintenance		50	2
CO₂	2	Air intake during normal operation or maintenance	2 μmol/mol CO ₂ would mean 0,5 % (mole fraction) air in the fuelling station. Never been observed	3	0
CO	0,2	No potential at fuelling station level		1	0
CH₄	100	No potential at fuelling station level		300	0
H₂O	5	Maintenance, leaks from compressor exchangers, improper pressure vessel drying after periodic inspection, H ₂ O coming from the vent in case of check valve malfunction, depending on fuelling station/compressor technology		NA	2
S	0,004	Materials gaskets, valve seats and tubing	Material specifications	NA	1
NH₃	0,1	No potential		NA	0
HC	2	Oil carryover from compressor (depending on compressor technology)		5	2
HCHO	0,2	No potential		1	0
Halogens	0,05	From degreasing material		NA	1
He	300	No potential at fuelling station level	If pure He is not used for maintenance	500	0

Key

NA: Not applicable because the severity is 4 above the threshold value.

a: Occurrence class for impurity between threshold limit and Level 1.

When the study has been conducted for each step within the supply chain (i.e., production, distribution, and fuelling) the highest probability is selected as the compounded probability. [Table A.4](#) gives an example.

To define the severity class of each impurity as it is presented in [Table A.4](#), some assumptions are made concerning the impurity levels above the threshold value. These impurity levels are assumed to be reached for a short period of time.

Table A.4 — Combined risk assessment

ISO specification		Supply chain probability			Compound- ed probab- ility	Sev- er-ity	Citi- cal-ity	Additional risk reduction measures	Residual		
Impurity	Thresh- old $\mu\text{mol}/\text{mol}$	Produc- tion SMR	Pipeline distribu- tion	Fuel- ling station					OC ^a	Sever- ity	Critical- ity
Inert gas N ₂	300	2	1	3	3	1	0	Systematic N ₂ analysis after shutdown before resuming operation or specific purging procedure at HRS		1	0
Inert gas Ar	300	1	0	0	1	1	+		1	1	+
O ₂	5	0	1	2	2	1	+		2	1	+
CO ₂	2	0	0	0	0	1	+		0	1	+
CO	0,2	4	0	0	4	3	*	CO absorber at fuelling station design margin 100 % (mole fraction) + operation procedure for replacement when H ₂ quantity purified = 50 % (mole fraction) of design capacity.	1	3	0
CH ₄	100	2	0	0	2	1	+		2	1	+
H ₂ O	5	0	1	2	2	4	*	At HRS check H ₂ O 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	1	4	+
S	0,004	0	0	1	1	4	0	At HRS check S at commissioning and after main- tenance involving parts modification (piping, valves, seals, gaskets). Not required for part replaced by identical component	0	4	+
NH ₃	0,1	0	0	0	0	4	+		0	4	+
HC	2	0	0	2	2	2	0	Oil/grease cleaning at commissioning and after maintenance. Compressor surveillance depending on compressor technology (coalescing filter) HC analysis or commissioning and after maintenance	0	2	+
HCHO	0,2	0	0	0	0	2	+		0	2	+

Table A.4 (continued)

ISO specification		Supply chain probability				Compound- ed probab- ility	Sev- er-ity	Crite- ri- cal-ity	Additional risk reduction measures	Residual		
Impurity	Thresh- old μmol/ mol	Produc- tion SMR	Pipeline distribu- tion	Fuel- ling station	OC ^a					Sever- ity	Critical- ity	
Halogens	0,05	0	1	1	1	1	4	*	Halogenated analysis at commissioning (species shall be defined) or after maintenance	0	4	0
He	300	0	0	0	0	0	1	+		0	1	+
Key a: Occurrence class for impurity be- tween threshold limit and Level 1.						+		Further investigations are needed to ensure the risks is reduced to as low as reasonably practicable		* Unacceptable risk; additional control or barriers required		

[Table A.4](#) is used to define the criticality for each impurity.

When the result is light grey or "+", the H₂ quality is under control and the risk of having an issue with the vehicle using this hydrogen is considered acceptable. No additional barrier is necessary and this impurity has no reason to be controlled at the fuelling station nozzle.

When the result is medium grey or "o", which is the case for N₂, the conclusion is to further investigate the means to decrease the occurrence probability. For instance, in addition to the existing analysis at SMR plant, measure N₂ at the commissioning of the fuelling station and after each maintenance where some parts of the system are open to air or apply a specific purge procedure which guarantees reaching a value within the specification.

When the result is dark grey or "*", 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 fuelling station (at pipeline connection).

For H₂O the conclusion is to measure H₂O at the commissioning of the fuelling station and after each maintenance open vessels or piping or replace one of them. This analysis can be done at low pressure to have more sensitivity.

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

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

In conclusion:

- for commissioning: measure N₂, H₂O, HC, S, and halogens;
- after maintenance: measure N₂, H₂O, HC.

The analysis of other impurities is not mandatory if there is an analysis of CO and N₂ at the production site.

A.3 Alkaline electrolysis

[Table A.5](#) shows the probability of occurrence of different contaminants for hydrogen produced by alkaline electrolysis.

Table A.5 — Probability of occurrence for alkaline electrolysis

Impurity	Threshold μmol/mol	Possible causes For the source studied	Typical barriers employed in this process	Level 1 μmol/mol	OC ^a
Inert gas N ₂	300	Insufficient purging after shutdown	Electrolyser process control	500	UD ^a
Inert gas Ar	300	Insufficient purging after shutdown	If N ₂ below 1 % (mole fraction), Ar < 100 μmol/mol	500	UD ^a
O ₂	5	Insufficient purging after shutdown (does not apply to all sys- tems) O ₂ permeation through the membrane	Process control Deoxo O ₂ sensor	50	2
CO ₂	2			3	0
CO	0,2			1	0
C H ₄	100			300	0
H ₂ O	5	H ₂ from electrolyser is saturated.	Dryer plus water sensor downstream of electrolyser	NA	2
S	0,004			NA	0
NH ₃	0,1			NA	0
HC (excluding CH ₄)	2			NA	0
HCHO	0,2			1	UD ^a
Halogens	0,05	Cl from water?	Any trace of halogenat- ed compounds would be trapped in the dryer which has a stronger adsorption capacity for Cl than for H ₂ O	NA	0
He	300			500	0
Key NA: Not applicable because the severity is 4 above the threshold value. a: Occurrence class for impurity between threshold limit and Level 1.					

Annex B

(informative)

Example of Japanese hydrogen quality guidelines

B.1 General

This annex is a condensed version of the Japanese quality control guidelines developed in Japan and is intended to be an example of a prescriptive approach to hydrogen quality assurance.

B.2 Approaches to administration of Japanese quality control guidelines

The approach to conducting a quality analysis of the contaminants listed in Grade D of ISO 14687 is to first consider the potential sources of contaminants, and, second, establish a protocol for analysing 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.3 Hydrogen production methods, hydrogen purification methods and hydrogen transportation methods

B.3.1 Hydrogen production methods

Potential sources of contaminants are evaluated for the following hydrogen production methods:

- steam reforming (off-site/on-site);
- partial oxidation (off-site);
- autothermal reforming (off-site);
- water gas shift reaction;
- catalytic reforming (off-site);
- coke-oven gas (off-site);
- steam cracking for ethylene by-product (off-site);
- chloralkali process (off-site);
- electrolysis of H₂O (on-site/off-site).

B.3.2 Hydrogen purification methods

Potential sources of contaminants are evaluated for the following hydrogen purification methods:

- adsorption;
- membrane separation;
- solvent absorption;
- cryogenic separation;
- methanation;
- selective CO oxidation.

B.3.3 Hydrogen transportation methods

Potential sources of contaminants are evaluated for the following hydrogen transportation methods:

- transportation of hydrogen in compressed state;
- transportation of hydrogen in liquid form;
- pipeline transportation;
- transportation by storage materials.

B.4 Constituents requiring analysis (potential sources of contaminants)

B.4.1 General

An analysis shall 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 (see [Table B.1](#) and [Table B.2](#)).

B.4.2 All hydrogen production methods

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

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

B.4.3 Specific hydrogen production methods

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

Name of constituent	Hydrogen production method to be analysed	Approach
He	All hydrogen production methods using natural gas as feedstock	An analysis is necessary since natural gas contains up to 300 µmol/mol of He Exclude a hydrogen production method if He has been removed from the natural gas used for the method
NH ₃	NH ₃ production process generating excess hydrogen Biogas reforming Coal gasification generating hydrogen by-product NH ₃ 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 ₂ O purification system cannot be warranted
S	Steam reforming* Catalytic reforming Partial oxidation Autothermal reforming Coal gasification generating hydrogen by-product Production methods using S as odorant	*Since S are found in the form of H ₂ S, analysis of H ₂ S, not total sulfur content, is sufficient
HC	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

B.5 Constituents that do not require analysis

Listed below in [Table B.3](#) are constituents for which there is no scientific basis for conducting a routine analysis, and the rationale for this conclusion, such as when there is no risk of contamination in any hydrogen production method (a framework shall be provided to conduct a non-routine analysis, however).

Table B.3 — Constituents that do not require an 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 fuelling station have been lower than the standard upper limit by two digits. Particulates should be controlled as indicated in B.10

B.6 Administration of quality control

B.6.1 Frequency of routine analysis

B.6.1.1 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, a 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 indicator species before shipping, the test frequency may be reduced to as low as once per year.

B.6.1.2 Routine analysis at fuelling station

B.6.1.2.1 Off-site fuelling station

Hydrogen received by an off-site fuelling station 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 fuelling station. For individual contaminant species that may enter after fuelling station 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 fuelling station, 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 fuelling nozzle to the extent that no changes occur to the quality of hydrogen.

B.6.1.2.2 On-site fuelling station

When a hydrogen generator (such as reformer or H₂O electrolysis apparatus) is operated in the daily start and shut mode, the quality of the hydrogen gas produced fluctuates on a daily basis. Such operation therefore calls for one analysis per day. However, 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 fuelling station, such as when accumulators are filled after the indicator species is continuously monitored for quality control on a daily basis following the start-up of the generator.

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

B.6.2 Frequency of non-routine analysis

After the conditions described in [Clause 10](#), a quality analysis of all cases is needed.

B.7 Administration of analysis and monitoring records

B.7.1 Forms for analysis and monitoring records and reports

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 fuelling station, and records of monitoring.

B.7.2 Safekeeping and recording

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

The records shall 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 fuelling station.

B.8 Routine analysis work

[Table B.4](#) provides the routine analysis work defined on the basis of the attitudes stated in [B.4](#), [B.5](#) and [B.6.1](#). The table gives the analytical species and the minimum analysis frequencies classified by hydrogen dispensing sites and hydrogen production, purification and transportation methods.

B.9 Non-routine analysis work

[Table B.5](#) provides the non-routine analysis work defined on the basis of the attitudes stated in [B.4](#), [B.5](#) and [B.6.2](#). The table gives the analytical species classified by hydrogen dispensing sites and hydrogen production, purification, and transportation methods.

B.10 Approaches to particulates requirements

According to Grade D of ISO 14687, the requirements of particulates are no more than 1 mg/kg in concentration. The hydrogen shall be sampled from a dispenser nozzle of the fuelling station under conditions that are as close to the actual fuelling conditions as possible. The weight of the particulates collected in a filter is measured.

However, past analyses of particulates collected by filters at the fuelling station 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 shall be installed at fuelling station to remove particulates in lieu of conducting a routine analysis of particulate concentration levels.

It is appropriate to install filters with an aperture of no more than 5 μm (nominal) downstream of dispenser components. Filters should be as close as possible to the nozzle or hose breakaway device. Filters shall be mesh-type because of the filter robustness.

Table B.4 — Routine analysis work

Category: Distribution				
Facility type	Sampling/ Monitoring point	Contaminant	Threshold ($\mu\text{mol/mol}$)	Reduced frequency
Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR, purification using refining equipment, and distribution	Downstream of the purifier	S ^a	0,004	Annual ^b
		HC as C1	2	Annual ^b
		CO	0,2	Annual ^b
		N ₂	300	Annual ^{b, c}
		Ar	300	Annual ^{b, c}
		H ₂ O	5	Annual ^b
		O ₂	5	Annual ^{b, c}
Electrolysis of NaCl for hydrogen, purification, and distribution	Downstream of the purifier	Halogens	0,05	Annual ^b
		N ₂	300	Annual ^b
		Ar	300	Annual ^b
		H ₂ O	5	Annual ^b
		O ₂	5	Annual ^b
Purification of coke-oven gas, and distribution	Downstream of the purifier	S	0,004	Annual ^b
		HC as C1	2	Annual ^b
		CO	0,2	Annual ^b
		Halogens	0,05	Annual ^b
		N ₂	300	Annual ^b
		Ar	300	Annual ^b
		H ₂ O	5	Annual ^b
		O ₂	5	Annual ^b
		NH ₃	0,1	Annual ^b
Purification of by-product hydrogen from ethylene plants, and distribution	Downstream of the purifier	HCHO	0,2	Annual ^b
		S	0,004	Annual ^b
		HC as C1	2	Annual ^b
		CO	0,2	Annual ^b
		N ₂	300	Annual ^b
		Ar	300	Annual ^b
		H ₂ O	5	Annual ^b
		O ₂	5	Annual ^b

^a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H₂S), H₂S analysis may be performed in lieu of sulfur analysis.

^b The minimum frequency of the analysis is premised on the combination of continuous analysis of the indicator species (CO for hydrocarbon cracking and O₂/H₂O 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.

^c If a container or piping maintenance has not been opened to air or purged since the last hydrogen analysis, it is not necessary for analysis.

^d If the 5 $\mu\text{mol/mol}$ (dew point of -66 °C or less) are satisfied by routine management, there is no need for analysis.

^e If the hydrogen on a pipeline contains odorant, the odorant shall be analysed with minimum frequency of once a year.

^f The batch analysis once a year is needed even if a continuous analysis is performed.

Table B.4 (continued)

Category: Distribution				
Facility type	Sampling/ Monitoring point	Contaminant	Threshold ($\mu\text{mol/mol}$)	Reduced frequency
With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analysed by the distributor		Annual ^b
		N ₂	300	Annual ^{b, c}
		Ar	300	Annual ^{b, c}
		H ₂ O	5	Annual ^{b, d}
		O ₂	5	Annual ^{b, c}
With off-site supply from hydrogen pipelines	Downstream of the deodorant equipment	(Those listed for the odorant)		Annual ^{b, e}
	End of nozzle	Those not analysed by the distributor		Annual ^b
		N ₂	300	Annual ^{b, c}
		Ar	300	Annual ^{b, c}
		H ₂ O	5	Annual ^{b, d}
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	Continuous and Annual ^{b, f}
	End of nozzle	S ^a	0,004	Annual ^b
		HC as C1	2	Annual ^b
		CO	0,2	Annual ^b
		N ₂	300	Annual ^{b, c}
		Ar	300	Annual ^{b, c}
		H ₂ O	5	Annual ^{b, d}
		O ₂	5	Annual ^{b, c}

^a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H₂S), H₂S analysis may be performed in lieu of sulfur analysis.

^b The minimum frequency of the analysis is premised on the combination of continuous analysis of the indicator species (CO for hydrocarbon cracking and O₂/H₂O 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.

^c If a container or piping maintenance has not been opened to air or purged since the last hydrogen analysis, it is not necessary for analysis.

^d If the 5 $\mu\text{mol/mol}$ (dew point of -66 °C or less) are satisfied by routine management, there is no need for analysis.

^e If the hydrogen on a pipeline contains odorant, the odorant shall be analysed with minimum frequency of once a year.

^f The batch analysis once a year is needed even if a continuous analysis is performed.

Table B.4 (continued)

Category: Distribution				
Facility type	Sampling/ Monitoring point	Contaminant	Threshold (μmol/mol)	Reduced frequency
With on-site supply from hydroelec- trolysis and purification using refining equipment	Downstream of the purifier	N ₂	300	Annual ^{b, c}
		Ar	300	Annual ^{b, c}
		H ₂ O	5	Continuous and Annual ^{b, f}
		O ₂	5	Continuous and Annual ^{b, f}
	End of nozzle	Halogens	0,05	Annual ^b
		N ₂	300	Annual ^b
		Ar	300	Annual ^{b, c}
		H ₂ O	5	Annual ^b
		O ₂	5	Annual ^b

^a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H₂S), H₂S analysis may be performed in lieu of sulfur analysis.

^b The minimum frequency of the analysis is premised on the combination of continuous analysis of the indicator species (CO for hydrocarbon cracking and O₂/H₂O 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.

^c If a container or piping maintenance has not been opened to air or purged since the last hydrogen analysis, it is not necessary for analysis.

^d If the 5 μmol/mol (dew point of -66 °C or less) are satisfied by routine management, there is no need for analysis.

^e If the hydrogen on a pipeline contains odorant, the odorant shall be analysed with minimum frequency of once a year.

^f The batch analysis once a year is needed even if a continuous analysis is performed.

Table B.5 — Non-routine analysis work

Category: Distribution			
Facility type	Sampling/ Monitoring point	Contaminant	Standard value (μmol/mol)
Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, or partial oxidation or ATR, followed by refinement	Downstream of the purifier	S ^a	0,004
		HC as C1	2
		CO	0,2
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5
Hydrogen production using brine electrolysis, followed by purification	Downstream of the purifier	Halogens	0,05
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5

^a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H₂S), H₂S analysis may be performed in lieu of sulfur analysis.

Table B.5 (continued)

Category: Distribution			
Facility type	Sampling/ Monitoring point	Contaminant	Standard value (μmol/mol)
Purification of coke-oven gas, and distribu- tion	Downstream of the purifier	S	0,004
		HC as C1	2
		CO	0,2
		Halogens	0,05
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5
		NH ₃	0,1
		HCHO	0,2
Purification of by-product hydrogen from ethylene plants, and distribution	Downstream of the purifier	S	0,004
		HC as C1	2
		CO	0,2
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5
With off-site supply of transported com- pressed or liquid hydrogen	End of nozzle	Those not analysed by the distributor	
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5
With off-site supply from hydrogen pipelines	Downstream of the deo- dorant equipment	(Those listed for the odorant)	
	End of nozzle	Those not analysed by the distributor	
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5
With on-site supply of hydrogen produced from hydrocarbons utilizing steam reform- ing, catalytic reforming, partial oxidation, or ATR and purification using refining equip- ment	Downstream of the purifier	CO	0,2
	End of nozzle	S ^a	0,004
		HC as C1	2
		CO	0,2
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5

^a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H₂S), H₂S analysis may be performed in lieu of sulfur analysis.

^a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H₂S), H₂S analysis may be performed in lieu of sulfur analysis.

Table B.5 (continued)

Category: Distribution			
Facility type	Sampling/ Monitoring point	Contaminant	Standard value (μmol/mol)
With on-site supply from hydroelectrolysis and purification using refining equipment	Downstream of the purifier	H ₂ O	5
		O ₂	5
	End of nozzle	Halogens	0,05
		N ₂	300
		Ar	300
		H ₂ O	5
		O ₂	5

^a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H₂S), H₂S analysis may be performed in lieu of sulfur analysis.