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**Fuel cell technologies –
Part 6-100: Micro fuel cell power systems – Safety**

**Technologies des piles à combustible –
Partie 6-100: Systèmes à micropiles à combustible – Sécurité**

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INTERNATIONAL
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FUEL CELL TECHNOLOGIES –**Part 6-100: Micro fuel cell power systems –
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105/255/FDIS	105/261/RVD

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FUEL CELL TECHNOLOGIES –

Part 6-100: Micro fuel cell power systems – Safety

1 Scope

1.1 General

- a) This consumer safety standard covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that are wearable or easily carried by hand, providing d.c. outputs that do not exceed 60 V d.c. and power outputs that do not exceed 240 VA. Portable fuel cell power systems that provide output levels that exceed these electrical limits are covered by IEC 62282-5-1.
- b) Externally accessible circuitry is therefore considered to be safety extra low voltage (SELV) circuitry as defined in IEC 60950-1:2005, and as limited power circuits if further compliance with 2.5 of IEC 60950-1:2005 is demonstrated. Micro fuel cell power systems or units that have internal circuitry exceeding 60 V d.c. or 240 VA should be appropriately evaluated in accordance with the separate criteria of IEC 60950-1:2005.
- c) This consumer safety standard covers all micro fuel cell power systems, micro fuel cell power units and fuel cartridges. This standard establishes requirements for all micro fuel cell power systems, micro fuel cell power units and fuel cartridges to ensure a reasonable degree of safety for normal use, reasonably foreseeable misuse, and consumer transportation of such items. The fuel cartridges covered by this standard are not intended to be refilled by the consumer. Fuel cartridges refilled by the manufacturer or by trained technicians shall meet all requirements of this standard.
- d) These products are not intended for use in hazardous areas as defined by IEC 426-03-01.

1.2 Fuels and technologies covered

- a) A micro fuel cell power system block diagram is shown in Figure 1.
- b) All portions of this standard, including all annexes, apply to micro fuel cell power systems, micro fuel cell power units and fuel cartridges as defined in Subclause 1.1 above.
- c) Clauses 1 through 7 of this standard cover direct methanol fuel cells using methanol or methanol and water solutions as fuel. Clauses 1 through 7 cover specific requirements for direct methanol fuel cells using proton exchange membrane technologies. Clauses 1 through 7 also cover general requirements applicable to all fuel cell technologies and all fuels covered in Annexes A through H.
- d) Annexes A through H cover fuels and fuel cell technologies as follows.
 - 1) Annex A covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use formic acid in water solutions – that are comprised of less than 85 % formic acid by weight – as fuel. These systems and units use direct formic acid fuel cell technologies.
 - 2) Annex B covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use hydrogen gas – that has been stored in a hydrogen absorbing metal alloy – as fuel. These systems and units use proton exchange membrane fuel cell technologies.
 - 3) Annex C covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that convert methanol or methanol and water solutions through a reformer into hydrogen rich methanol reformat – which is then immediately fed to the fuel cell or fuel cell stack – as fuel. These systems and units use proton exchange membrane fuel cell technologies.

- 4) Annex D covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use methanol or methanol and water solutions – derived from methanol clathrate compounds – as fuel. These systems and units use direct methanol fuel cell technologies.
- 5) Annex E covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges using hydrogen produced from Class 8 (corrosive) borohydride compounds as fuel. These systems and units use proton exchange membrane fuel cell technologies. The designs may include fuel processing subsystems to derive hydrogen gas from the borohydride compound fuel.
- 6) Annex F covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges using hydrogen produced from Class 4.3 (water reactive) borohydride compounds as fuel. These systems and units use proton exchange membrane fuel cell technologies. The designs may include fuel processing subsystems to derive hydrogen gas from the borohydride compound fuel.
- 7) Annex G covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use Class 8 (corrosive) borohydride compounds as fuel. These systems and units use direct borohydride fuel cell technologies.
- 8) Annex H covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use butane and butane/propane mixtures – consisting of at least 75 % butane by mass – as fuel. These systems and units use solid oxide fuel cell technologies.

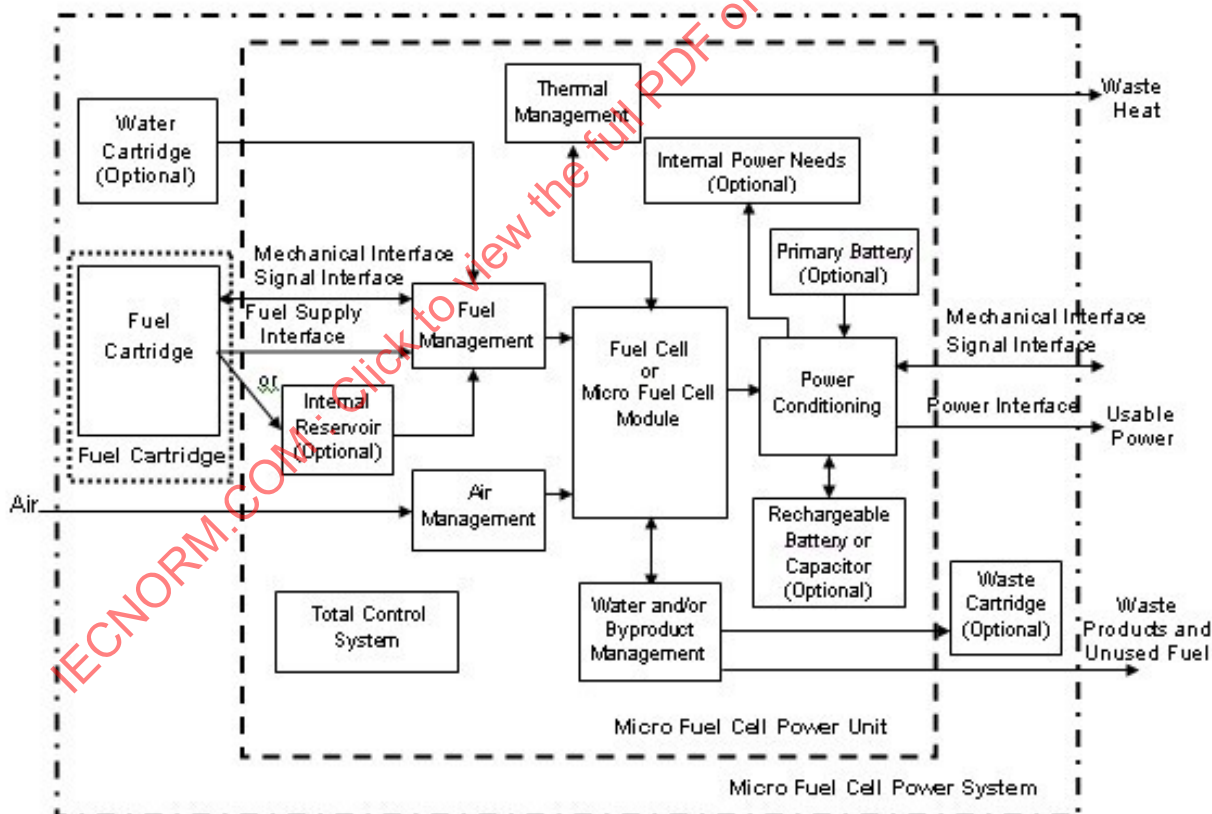


Figure 1 – Micro fuel cell power system block diagram

1.3 Equivalent level of safety

- a) The requirements of this standard are not intended to constrain innovation. The manufacturer may consider fuels, materials, designs or constructions not specifically dealt with in this standard. These alternatives should be evaluated as to their ability to yield levels of safety equivalent to those prescribed by this standard.
- b) It is understood that all micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall comply with applicable country and local requirements including, but not limited to, those concerning transportation, child-resistance and storage, where required.

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.

IEC 60050-426:2008, *International Electrotechnical Vocabulary – Part 426: Equipment for explosive atmospheres*

IEC 60079-15:2005, *Electrical apparatus for explosive gas atmospheres – Part 15: Construction, test and marking of type of protection 'n' electrical apparatus*

IEC 60086-4, *Primary batteries – Part 4: Safety of lithium batteries*

IEC 60086-5, *Primary batteries – Part 5: Safety of batteries with aqueous electrolyte*

IEC 60695-1-1: *Fire hazard testing – Part 1-1: Guidance for assessing the fire hazard of electrotechnical products – General guidelines*

IEC 60695-2-11, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60730-1:1999, *Automatic electrical controls for household and similar use – Part 1: General requirements*
Amendment 1 (2003)
Amendment 2 (2007)¹⁾

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 62133:2002, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*

IEC 62281:2004, *Safety of primary and secondary lithium cells and batteries during transport*

ISO 175, *Plastics – Methods of test for determination of the effects of immersion in liquid chemicals*

ISO 188, *Rubber, vulcanized or thermoplastic – Accelerated ageing and heat resistance tests*

ISO 1817, *Rubber, vulcanized – Determination of the effect of liquids*

¹⁾ There exists a consolidated edition 3.2 (2007) that comprises IEC 60730-1 (1999), its Amendment 1 (2003) and its Amendment 2 (2007).

ISO 9772, *Cellular plastics – Determination of horizontal burning characteristics of small specimens subjected to a small flame*

ISO 15649, *Petroleum and natural gas industries – Piping*

ISO 16000-3, *Indoor air – Part 3: Determination of formaldehyde and other carbonyl compounds – Active sampling method*

ISO 16000-6, *Indoor air – Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID*

ISO 16017-1, *Indoor, ambient and workplace air – Part 1: Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography – Part 1: Pumped sampling*

3 Terms and definitions

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

3.1

attached cartridge

fuel cartridge, which has its own enclosure that connects to the device powered by the micro fuel cell power system

3.2

electrical enclosure

parts of the micro fuel cell power system intended to limit access to parts that may be at hazardous voltages or hazardous energy level

3.3

exterior cartridge

fuel cartridge, which has its own enclosure that forms a portion of the enclosure of the device powered by the micro fuel cell power system

3.4

fire enclosure

parts of the micro fuel cell power system intended to minimize the spread of fire or flames from within

3.5

fuel

any of the following substances:

- a) methanol or methanol and water solution;
- b) formic acid and water solution;
- c) hydrogen stored in hydrogen absorbing metal alloy;
- d) borohydride compounds;
- e) butane

NOTE Fuel a), methanol or methanol and water solution, is covered by Clauses 1 through 7 and Annexes C and D of the standard. Annex A, B, E, F, G and H cover fuels b) through e).

3.6

fuel cartridge

removable article that contains and supplies fuel to the micro fuel cell power unit or internal reservoir, not to be refilled by the user

3.7**fuel cell power system**

generator system that uses a fuel cell module(s) electrically and thermally connected to generate usable electric energy and/or thermal energy

3.8**hazardous liquid fuel**

any liquid fuel that has a methanol concentration greater than or equal to 4 %, or, for methanol concentrations less than 4 %, an amount greater than 5 ml. Other hazardous fuel definitions are given in Annexes A through H

3.9**insert cartridge**

fuel cartridge, which has its own enclosure and is installed within the enclosure of the device powered by the micro fuel cell power system

3.10**internal reservoir**

structure in a micro fuel cell power unit that stores fuel and cannot be removed

3.11**leakage**

accessible hazardous liquid fuel outside the micro fuel cell power system or fuel cartridge

3.12**limited power sources**

electrical supply either isolated from a mains supply or supplied by a battery or other device (i.e. fuel cell power unit) where the voltage, current and power levels are either inherently or non-inherently limited to levels that do not result in an electric shock or fire hazard

NOTE An inherently limited power source does not rely on a current-limiting device to meet limited power requirements although it may rely on an impedance to limit its output. However, a non-inherently limited power source relies upon a current-limiting device such as a fuse, etc. to meet limited power requirements.

3.13**toxic material**

any material having a toxic hazard rating of 2 (medium) or higher, in the Sax's dangerous properties of industrial materials 11th Edition, or related reference guide

3.14**mechanical enclosure**

parts of the micro fuel cell power system or micro fuel cell power unit intended to be a barrier to protect, shield, and control access to the internal components or material

3.15**micro fuel cell**

fuel cell that is wearable or easily carried by hand, providing a d.c. output that does not exceed 60 V d.c. and power outputs that do not exceed 240 VA

3.16**micro fuel cell power system**

micro fuel cell power unit and associated fuel cartridges that is wearable or easily carried by hand

3.17

micro fuel cell power unit

electric generator as defined in Figure 1, providing direct current output that does not exceed 60 V d.c. and continuous power output that does not exceed 240 VA

The micro fuel cell power unit does not include a fuel cartridge.

3.18

no accessible liquid

liquid fuel that is not subject to contact by consumers

3.19

no fuel vapour loss

vaporous fuel emission from fuel cartridge, non-operating micro fuel cell power system or unit limited to 0,08 g/h

Vaporous fuel emission for operating systems is limited to an amount defined in Subclause 7.3.12.

3.20

normal use conditions

range of conditions such as pressure, temperature, physical, chemical and thermal conditions of use as defined by the manufacturer

3.21

partially filled fuel cartridge

fuel cartridge that is approximately half filled with fuel (45 % – 55 % full)

3.22

rated power

manufacturer specified maximum continuous power capability of the micro fuel cell power system

3.23

satellite cartridge

fuel cartridge that is intended to be connected to and removed from the micro fuel cell power unit to transfer fuel to the internal reservoir inside the micro fuel cell power unit

3.24

refill valve

component of the non-user-refillable fuel cartridge that allows refilling the fuel cartridge only by trained technicians

3.25

shut-off valve

component of a fuel cartridge that controls the release of fuel

3.26

waste cartridge

cartridge that stores waste and byproducts from the micro fuel cell power unit

3.27

water cartridge

cartridge that is filled with water (no additives) to adjust fuel concentration

3.28**fuel management**

components that might be used to control fuel properties if needed to support micro fuel cell power system operation; e.g., flow, concentration, cleanliness, temperature, humidity, or pressure

Not all micro fuel cell power systems will include all functions. Some micro fuel cell power systems will include additional functions.

3.29**air management**

components that might be used to control air properties if needed to support micro fuel cell power system operation; e.g., flow, concentration, cleanliness, temperature, humidity, or pressure

Not all systems will include all functions. Some systems will include additional functions.

3.30**total control system**

components of the micro fuel cell power system that coordinate properties of the micro fuel cell power system and reactants using electrical, mechanical, and/or digital inputs, outputs, software, and/or functions to effect proper micro fuel cell power system start-up, operation and shutdown, when necessary

3.31**primary battery (optional)**

non-rechargeable battery

3.32**fuel cell**

electrochemical device that converts the energy of the chemical reaction between a fuel, such as hydrogen or hydrogen rich gases, alcohols, hydrocarbons and an oxidant, such as air or oxygen, to d.c. power, heat and other reaction products

3.33**micro fuel cell module**

assembly including a fuel cell stack(s) which electrochemically converts chemical energy to electric energy

3.34**fuel cell stack**

assembly of two or more fuel cells which are electrically connected

3.35**non-operating**

micro fuel cell power system or unit that is turned “off” or no longer operational

3.36**hazardous energy level**

available power level of 240 VA or more having a duration of 60 s or more, or a stored energy level of 20 J or more (for example, from one or more capacitors), at a potential of 2 V or more

[1.2.8.10 of IEC 60950-1:2005]

4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges

4.1 General

- a) Compliance with the requirements of Clause 4 shall be verified during the review of the safety FMEA and/or during type tests specified in Clause 7.
- b) The micro fuel cell power unit, when coupled to the fuel cartridge, shall be designed and constructed to avoid any credible risk of leakage, fire or explosion posed by the micro fuel cell power system itself or gases, vapours, liquids or other substances produced or used by the micro fuel cell power system.
- c) To prevent a fire or explosion hazard within the micro fuel cell power system, the manufacturer shall eliminate potential ignition source(s) within areas where fuel is present (or can be potentially released).
- d) Flammable, toxic or corrosive materials shall be kept within a closed containment system such as within fuel piping, in a reservoir, a fuel cartridge or similar enclosure.

4.2 FMEA / hazard analysis

4.2.1 A failure modes and effects analysis (FMEA) or equivalent reliability analysis shall be conducted by the manufacturer to identify faults which can have safety related consequences and the design features that serve to mitigate those faults. The analysis shall include failures that may result in leakage. Failures related to refilling of non-user refillable fuel cartridges, if anticipated by the manufacturer or trained technicians, shall be considered.

4.2.2 Guidance can be found in the following informative references: IEC 61025, *Fault tree analysis* and IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*.

4.2.3 It shall be the responsibility of the manufacturer to ensure that emissions from the micro fuel cell power system do not result in harmful or dangerous effects on the user or others during normal use, reasonably foreseeable misuse, and consumer transportation.

4.3 General materials

The materials and coating shall be resistant to degradation under the normal transportation and normal usage conditions over the manufacturer-defined life span of the product.

4.4 Selection of materials

4.4.1 Micro fuel cell power systems and units are expected to be exposed to a number of environmental conditions over the manufacturer-defined life span of the product such as vibration, shock, varying humidity levels and corrosive environments. Materials employed in the micro fuel cell power system or unit shall be resistant to these environmental conditions. If a micro fuel cell power system or unit is to be used in service where specific environmental conditions are beyond those accounted for in the required tests of this standard, then additional testing shall be performed to verify safety under those environmental conditions.

4.4.2 Metallic and non-metallic materials used to construct internal or external parts of the micro fuel cell power system or unit, in particular those exposed directly or indirectly to moisture, fuel and/or byproducts in either a gas or liquid form as well as all parts and materials used to seal or interconnect the same, e.g. welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable under the normal transportation and normal usage conditions within the manufacturer-defined life span of the product and for all test conditions; in particular, they shall be designed to retain their mechanical stability under normal use;

- they shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation;

- the chemical and physical properties necessary for operational safety shall not be significantly affected within the manufacturer-defined life span of the product; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, ageing resistance, the effects of temperature variations, the effects arising when materials are put together (e.g. galvanic corrosion), and the effects of ultraviolet radiation;
- where conditions of erosion, abrasion, corrosion or other chemical attack may arise, adequate measures shall be taken to
 - minimize that effect by appropriate design, e.g. additional thickness, or by appropriate protection, e.g. use of liners, cladding materials or surface coatings, taking due account of normal use;
 - permit replacement of parts which are most affected;
 - and draw attention, in the manual referred to in Clause 6, to type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement.

4.4.3 Elastomeric materials such as gaskets and tubing in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperatures that they are exposed to during normal use. Compliance shall be determined by the following: ISO 188 and ISO 1817.

4.4.4 Polymeric materials in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperature they are exposed to during normal use. Compliance shall be determined by ISO 175.

4.5 General construction

4.5.1 Micro fuel cell power systems and units shall have a safe construction that is resistant to dropping, vibration, crushing, environmental changes such as temperature, and atmospheric pressure fluctuations during normal use, reasonably foreseeable misuse, and consumer transportation of such items.

4.5.2 Connection mechanisms, including the connection between a detachable fuel cartridge and the micro fuel cell power unit, and the electrical connection between the micro fuel cell power system or unit and the device that it powers, shall be designed such that they cannot be attached at a wrong location or in an incomplete state in such a way that leakage or danger of electrical shock results.

4.5.3 An edge projection or corner of a micro fuel cell power unit and a fuel cartridge shall not be sufficiently sharp to result in a risk of injury to persons during intended use or user maintenance.

4.5.4 The effects of moisture and relative humidity shall be considered during the FMEA process.

4.6 Fuel valves

4.6.1 This subclause applies to all shut-off valves, filling valves, relief valves, refilling valves, including all fuel cartridge types.

4.6.2 Operating and pressure containing parts of the shut-off valve and relief valve assemblies shall last the manufacturer-defined life span of the product under normal conditions.

4.6.3 The valves shall have means to prevent leakage of fuel through normal use, reasonably foreseeable misuse, and storage of the fuel cartridge.

4.6.4 The valves shall not be susceptible to unintended actuation, or manual actuation by a user not using tools, that results in fuel leakage. Compliance shall be checked using test probe 11 of IEC 61032: *Protection of persons and equipment by enclosures – Probes for verification* and a force of 9,8 N.

4.6.5 There shall be no leakage of fuel or fuel vapour loss during storage, connection, disconnection or transferring of fuel from the fuel cartridge to the micro fuel cell power unit.

4.7 Materials and construction – system

4.7.1 The maximum quantity of fuel stored in the micro fuel cell power unit shall not be more than 200 ml.

4.7.2 The micro fuel cell power system or unit shall be designed such that an explosion cannot occur even if fuel leaks from or inside the micro fuel cell power system or unit. The design criteria for such means (for example, required ventilation rate) shall be provided by the micro fuel cell power system or unit manufacturer. The means shall be provided either by the micro fuel cell power system or unit manufacturer or by the manufacturer of the device powered by the micro fuel cell power system or unit.

4.7.3 Components and materials inside the micro fuel cell power system or unit shall be constructed or shall make use of such materials that propagation of fire and ignition is mitigated. The material flammability shall be such that a sustained fire will not be supported after electrical power and the fuel and oxidant supply have been terminated. This may be demonstrated through the selection of materials meeting FV 0, FV 1 or FV 2 in accordance with IEC 60695-1-1 and IEC 60695-11-10.

4.7.4 Micro fuel cell stack membranes are not required to have flammability ratings.

4.7.5 Other materials within the micro fuel cell stack which comprise less than 30 % of the total micro fuel cell stack mass are considered to be of limited quantity and are permissible without flammability ratings.

4.8 Ignition sources

To prevent a fire or explosion hazard within the micro fuel cell power system or unit, the manufacturer shall either eliminate potential unintentional ignition source(s) within areas where fuel is present (or can be potentially released) or shall ensure that immediate and controlled oxidation occurs through the use of a catalytic reactor.

Potential unintentional ignition sources shall be eliminated by one or more of the following.

- The surface temperatures shall not exceed 80 % of the auto-ignition temperature, expressed in degrees Celsius, of the flammable gas or vapour.
- Equipment containing materials or components capable of catalysing the reaction of flammable fluids with air shall be capable of suppressing the propagation of the reaction from the equipment to the surrounding flammable atmosphere.
- Electrical equipment and/or components, if subject to contact with fuel, shall be suitable for the area in which it is installed.
- The potential for static discharge sufficient to cause ignition shall be eliminated by proper material selection and proper bonding and grounding.
- Electrical components like fuses, other over-current protection devices, sensors, electric valves and solenoids, when operating under their intended condition, shall not produce thermal effects, arcs or sparks capable of igniting a flammable release of gas.

Immediate and controlled oxidation shall be ensured by the following:

- Catalytic reactors designed to safely control oxidation are acceptable. The temperature within such reactors may be greater than the auto-ignition temperature of the fluid. If the catalytic reactor deviates from proper operating conditions, as defined by the manufacturer, the micro fuel cell power system or unit shall be automatically transferred into a safe state.

4.9 Enclosures and acceptance strategies

A fire enclosure is required when temperatures of parts under fault conditions could be sufficient for ignition.

4.9.1 Parts requiring a fire enclosure

Except where Method 2 of 4.7.1 of IEC 60950-1:2005 is used exclusively, or as permitted in 4.7.2.2 of IEC 60950-1:2005, the following are considered to have a risk of ignition and, therefore, require a fire enclosure:

- power circuits not meeting the requirements of Table 3 or Table 4 (non-limited power circuits);
- components in circuits supplied by limited power sources as specified in 2.5 of IEC 60950-1:2005, but not mounted on material of flammability class V-1 or V-0 (IEC 60695-11-10) class material;
- components within a power supply unit or assembly having a limited power output as specified in 2.5 of IEC 60950-1:2005, including non-arcing over-current protective devices, limiting impedances, regulating networks and wiring, up to the point where the limited power source output criteria are met.

See Table 1 for material flammability requirements.

Compliance with 4.7.1 of IEC 60950-1:2005 and 4.7.2.2 of IEC 60950-1:2005 is checked by inspection and by evaluation of the data provided by the manufacturer. In the case where no data is provided, compliance is determined by tests.

4.9.2 Parts not requiring a fire enclosure

The following parts do not require a fire enclosure.

- Motors are not required to have fire enclosures if they comply with the applicable requirements outlined in Annex B of IEC 60950-1:2005.
- Electromechanical components complying with 5.3.5 of IEC 60950-1:2005.
- Wiring and cables insulated with PVC, TFE, PTFE, FEP, ETFE, PFA, neoprene, or polyimide.
- Components, including connectors, meeting the requirements of 4.7.3.2 of IEC 60950-1:2005, which fill an opening in a fire enclosure.
- Connectors in circuits supplied by limited power sources complying with 2.5 of IEC 60950-1:2005.
- Other components in circuits supplied by limited power sources complying with 2.5 of IEC 60950-1:2005 and mounted on materials of flammability class V-1 or V-0 (IEC 60695-11-10) class material.
- Other components complying with Method 2 of 4.7.1 of IEC 60950-1:2005.
- Equipment, or a part of the equipment, having a momentary contact switch which the user has to activate continuously, and the release of which removes all power from the equipment or part.
- Fuel cartridges that do not contain electrical circuitry capable of causing ignition under fault conditions do not require a fire enclosure.

- Compliance with 4.7.1 of IEC 60950-1:2005 is checked by inspection and by evaluation of the data provided by the manufacturer. In the case where no data is provided, compliance is determined by tests.

Table 1 – Summary of material flammability requirements

Part		Requirements
Fire enclosure	Enclosure	V-1 (IEC 60695-11-10), or Test A.2 of IEC 60950-1:2005, or Hot wire test of IEC 60695-2-11 (if < 13 mm air from sources of ignition)
	Parts which fill an opening	V-1 (IEC 60695-11-10), or Test A.2 of IEC 60950-1:2005, or Relevant IEC component standards
Outside the fire enclosure	Components and parts including mechanical and electrical enclosures	HB40 (IEC 60695-11-10) for thickness > 3 mm, or HB75 (IEC 60695-11-10) for thickness < 3 mm, or HBF (foamed) (ISO 9772), or 550 °C glow wire test of IEC 60695-2-11, or see 4.9.3 for exceptions
Inside the fire enclosure	Components and parts including mechanical and electrical enclosures	V-2, or HF-2 (foamed) (ISO 9772), or Test A.2 of IEC 60950-1:2005, or Relevant IEC component standards, or see 4.9.4 for exceptions
Any location	Air filter assemblies	V-2 (IEC 60695-11-10), or HF-2 (foamed) (ISO 9772), or Test A.2 of IEC 60950-1:2005, or see 4.7.3.5 of IEC 60950-1:2005

4.9.3 Materials for components and other parts outside fire enclosures

4.9.3.1 Except as otherwise noted below, materials for components and other parts (including mechanical enclosures, electrical enclosures and decorative parts), located outside fire enclosures, shall be of flammability class HB75 if the thinnest significant thickness of this material is < 3 mm, or flammability class HB40 if the thinnest significant thickness of this material is > 3 mm, or flammability class HBF. See Table 1 for material flammability requirements.

NOTE Where a mechanical or an electrical enclosure also serves as a fire enclosure, the requirements for fire enclosures apply.

4.9.3.2 Requirements for materials in air filter assemblies are in 4.7.3.5 of IEC 60950-1:2005. See Table 1 for material flammability requirements.

4.9.3.3 Connectors shall comply with one of the following:

- a) be made of material of flammability class V-2; or
- b) pass the tests of Clause A.2 of IEC 60950-1:2005; or
- c) comply with the flammability requirements of the relevant IEC component standard; or
- d) be mounted on material of flammability class V-1 or V-0 (IEC 60695-11-10) class material and be of a small size.

4.9.3.4 The requirement for materials for components and other parts to be of flammability class HB40, flammability class HB75, or flammability class HBF, does not apply to any of the following.

- a) Electrical components that do not present a fire hazard under abnormal operating conditions when tested according to 5.3.7 of IEC 60950-1:2005.
- b) Materials and components within an enclosure of 0,06 m³ or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas.
- c) Components meeting the flammability requirements of a relevant IEC component standard which includes such requirements.
- d) Electronic components, such as integrated-circuit packages, opto-coupler packages, capacitors and other small parts that are mounted on material of flammability class V-1 or V-0 (IEC 60695-11-10) class material.
- e) Wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP, ETFE, PFA, neoprene, or polyimide.
- f) Individual clamps (not including helical wraps or other continuous forms), lacing tape, twine and cable ties used with wiring harnesses.
- g) Gears, cams, belts, bearings and other small parts which would contribute negligible fuel to a fire, including decorative parts, labels, mounting feet, key caps, knobs and the like.

4.9.3.5 Compliance is checked by inspection of the equipment and material data sheets and, if necessary, by the appropriate test or tests in Annex A of IEC 60950-1:2005.

4.9.4 Materials for components and other parts inside fire enclosures

4.9.4.1 Requirements for materials in air filter assemblies are in 4.7.3.5 of IEC 60950-1:2005. See Table 1 for material flammability requirements.

4.9.4.2 Inside fire enclosures, materials for components and other parts (including mechanical and electrical enclosures located inside fire enclosures) shall comply with one of the following:

- a) be of flammability class V-2, or flammability class HF-2; or
- b) pass the flammability test described in Clause A.2 of IEC 60950-1:2005; or
- c) meet the flammability requirements of a relevant IEC component standard that includes such requirements.
- d) See Table 1 for material flammability requirements.

4.9.4.3 The above requirement does not apply to any of the following:

- electrical components which do not present a fire hazard under abnormal operating conditions when tested according to 5.3.7 of IEC 60950-1:2005;
- materials and components within an enclosure of 0,06 m³ or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas;
- one or more layers of thin insulating material, such as adhesive tape, used directly on any surface within a fire enclosure, including the surface of current-carrying parts, provided that the combination of the thin insulating material and the surface of application complies with the requirements of flammability class V-2, or flammability class HF-2;

NOTE Where the thin insulating material referred to in the above exclusion is on the inner surface of the fire enclosure itself, the requirements in 4.6.2 of IEC 60950-1:2005 continue to apply to the fire enclosure.

- electronic components, such as integrated circuit packages, opto-coupler packages, capacitors and other small parts that are mounted on material of flammability class V-1 or V-0 (IEC 60695-11-10) class material;
- wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP, ETFE, PFA, neoprene, or polyimide;

- individual clamps (not including helical wraps or other continuous forms), lacing tape, twine and cable ties used with wiring harnesses;
- wire which complies with the requirements for VW-1 or FT-1 or better, and which is so marked;
- the following parts, provided that they are separated from electrical parts (other than insulated wires and cables) which under fault conditions are likely to produce a temperature that could cause ignition, by at least 13 mm of air or by a solid barrier of material of flammability class V-1 or V-0 (IEC 60695-11-10) class material;
 - gears, cams, belts, bearings and other small parts which would contribute negligible fuel to a fire, including labels, mounting feet, key caps, knobs and the like;
 - tubing for air or any fluid systems, containers for powders or liquids and foamed plastic parts, provided that they are of flammability class HB75 if the thinnest significant thickness of the material is < 3 mm, or flammability class HB40 if the thinnest significant thickness of the material is > 3 mm, or flammability class HBF.

4.9.4.4 Compliance is checked by inspection of the equipment and material data sheets and, if necessary, by the appropriate test or tests of Annex A of IEC 60950-1:2005.

4.9.5 Mechanical enclosures

4.9.5.1 A mechanical enclosure shall be sufficiently complete to contain or deflect parts which, because of failure or for other reasons, might become loose, separated or thrown from a moving part.

4.9.5.2 Compliance is checked by inspection of the construction and available data and, where necessary, by the relevant tests of 4.2.2, 4.2.3, 4.2.4, and 4.2.7 of IEC 60950-1:2005, and Type Testing in Clause 7 as applicable.

4.9.5.3 After the tests of 4.2.2, 4.2.3, 4.2.4 and 4.2.7 of IEC 60950-1:2005, the sample shall continue to comply with the requirements of 2.1.1 and 4.4.1 of IEC 60950-1:2005. It shall show no signs of interference with the operation of safety features such as thermal cut-outs, over-current protection devices or interlocks.

4.9.5.4 Damage to finish, cracks, dents and chips are disregarded if they do not adversely affect safety.

NOTE If a separate enclosure or part of an enclosure is used for a test, it may be necessary to reassemble such parts on the equipment in order to check compliance.

4.10 Protection against fire, explosion, corrosivity and toxicity hazard

4.10.1 Flammable, toxic and corrosive fluids shall be kept within a closed containment system such as within fuel piping, in a reservoir, a fuel cartridge or similar enclosure. Compliance shall be verified by type testing in accordance with Clause 7.

4.10.2 A micro fuel cell power system or unit may be equipped with a means of detecting concentration levels of fluids in Table 7 and shutting down the micro fuel cell power system or unit prior to exceeding the concentration limit.

4.10.3 Internal wiring and insulation in general shall not be exposed to fuel, oils, grease or similar substances, unless the insulation has been evaluated for contact with these substances.

4.11 Protection against electrical hazards

The voltages within the micro fuel cell power system or unit shall be within the SELV limits. Determinations shall be made in accordance with 2.2 of IEC 60950-1:2005. If internal voltages exceed 60 V d.c., the micro fuel cell power system or unit is to be further investigated in accordance with IEC 60950-1:2005. Circuits that exceed SELV shall meet the criteria for hazardous voltage circuits including electrical spacing, and accessibility criteria as received and after testing that could result in exposed parts in accordance with IEC 60950-1:2005.

Components in hazardous voltage circuits may require additional evaluation as well.

4.12 Fuel supply construction

4.12.1 Fuel cartridge construction

Fuel cartridges shall conform to the following requirements.

4.12.1.1 There shall be no leakage from the fuel cartridge in the temperature range of $-40\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$. Compliance shall be determined by type testing in accordance with 7.3.3 and 7.3.4.

4.12.1.2 There shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at $22\text{ }^{\circ}\text{C}$ or two times the gauge pressure of the fuel cartridge at $55\text{ }^{\circ}\text{C}$, whichever is greater. Compliance shall be determined by type testing in accordance with 7.3.1.

4.12.1.3 Maximum fuel volume in the fuel cartridge shall not exceed 1 l.

4.12.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a micro fuel cell power unit by a consumer, means to prevent fuel leakage prior to, during, and after connection or transfer of fuel to the micro fuel cell power unit shall be provided. Compliance is checked by 7.3.11.

4.12.1.5 A fuel cartridge shall be resistant to corrosion in its usage environment.

4.12.1.6 A fuel cartridge shall be provided with a means to prevent mis-connection that would result in leakage of fuel when it is installed in a micro fuel cell power system. Compliance is checked by the connection cycling test, 7.3.11.

4.12.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel when not attached to a micro fuel cell power unit during normal usage, reasonably foreseeable misuse, and consumer transportation. Compliance is checked by the drop test, 7.3.5, and the connection cycling test, 7.3.11.

4.12.1.8 In the case where a pressure release valve or similar means is provided, such pressure release valve shall satisfy the performance requirement for each type test. This valve shall pass all type tests with no leakage.

4.12.1.9 The structure at the connection to the fuel cartridge shall not allow fuel to leak.

4.12.1.10 A fuel cartridge, including the fuel cartridge interface to the micro fuel cell power unit, including the valve, shall have a construction sufficient to withstand normal use and reasonably foreseeable misuse generated by vibration, heat, pressure, being dropped or otherwise subject to a mechanical shock etc. Compliance is checked by:

- pressure differential tests, 7.3.1;
- vibration test, 7.3.2;

- temperature cycling test, 7.3.3;
- high temperature exposure test, 7.3.4;
- drop test, 7.3.5;
- compressive loading test, 7.3.6;
- long-term storage test, 7.3.9;
- high-temperature connection test, 7.3.10;
- connection cycling tests, 7.3.11.

4.12.1.11 The fuel cartridge valves shall operate as intended without the use of tools and without excessive force needed to connect or disconnect.

4.12.2 Fuel cartridge fill requirement

The fuel cartridge design and fuel fill amount shall allow fuel expansion without leakage to a fuel cartridge temperature of 70 °C in the case of the fuel cartridge alone and when the fuel cartridge is constrained by the micro fuel cell power system or a comparable test fixture.

4.13 Protection against mechanical hazards

4.13.1 Piping and tubing other than fuel lines

Requirements are listed below for the construction of piping, tubing and fittings – other than fuel lines – inside the micro fuel cell power system or unit.

4.13.1.1 Where micro fuel cell power systems or units are designed for internal pressures over 100 kPa gauge, they shall be designed, constructed, and tested in accordance with ISO 15649.

4.13.1.2 Micro fuel cell power systems or units designed for operation below 100 kPa gauge or, in accordance with the applicable regional or national pressure equipment codes and standards not qualifying as pressurized systems, such as low-pressure water hoses, plastic tubing, or other connections to atmospheric or low-pressure tanks and similar containers, shall be constructed of suitable materials, and their related joints and fittings shall be designed and constructed with adequate strength and leakage resistance to prevent unintended releases.

4.13.1.3 Unions shall be designed to be leak tight using sealing methods resistant to the fluid transported and the ambient conditions of use.

4.13.1.4 The piping and tubing construction shall be provided with sufficient capability to resist pressure and other load weight, and there will be no danger of contamination or leakage of the line contents. Compliance is determined by 7.3.1 and 7.3.6.

4.13.1.5 The piping and tubing construction shall be provided with suitable measures to prevent freezing, breakage, corrosion, etc. Compliance for freezing is determined by 7.3.3. Compliance for breakage is shown in 7.3.5.

4.13.2 Exterior surface and component temperature limits

4.13.2.1 General

Micro fuel cell power systems and units shall not attain excessive temperatures during normal operation. Compliance shall be checked by determining the temperature of the various parts while operating at the manufacturer's rated output in the manufacturer's rated maximum ambient operating temperature. The micro fuel cell power system or unit is operated at the manufacturer's rated maximum output until the maximum stabilised temperatures are reached.

During the test, thermal cut-outs and overload devices shall not operate. The temperature shall not exceed the values shown in Table 2.

4.13.2.2 Exterior surfaces

To eliminate any risk of burn injury caused by contact with the micro fuel cell power system or unit, the temperature of the external enclosure shall not exceed the value shown in Table 2.

4.13.2.3 Handles, knobs, grips and similar parts

The user is intended to touch handles, knobs, grips and similar parts in order to operate the micro fuel cell power system or unit. The temperature of handles, knobs, grips and similar parts intended to be touched shall not exceed the values shown in Table 2.

4.13.2.4 Components

4.13.2.4.1 Table 2 shows the maximum normal temperature for various exterior components. The temperature of such components shall not exceed the values shown in Table 2.

4.13.2.4.2 For components and electrical wiring equipped in the micro fuel cell power system or unit that are not shown in Table 2, their temperatures shall not exceed the maximum temperature for which the components and wiring are rated.

Table 2 – Temperature limits

Part	Temperature °C
External enclosure, handles, knobs, grips and the like which, in normal use, are held:	
– metal	50
– porcelain or vitreous material	60
– moulded material, rubber, or wood	70
Parts and materials in direct contact with potentially flammable gas or vapours Exception – Areas that are separately evaluated that utilize a high-temperature process.	80 % of the auto-ignition temperature of the potentially flammable gas or vapour

4.13.3 Motors

4.13.3.1 Whether operating under intended conditions or during an abnormal condition like running overload or locked rotor, the temperature of the motor shall not increase to the point where it acts to ignite a flammable release of gas.

4.13.3.2 Motor parts such as the motor brush, thermal overload device or other make/break component(s), which act to interrupt a circuit even if the interruption is transient in nature, shall not cause a hazard by producing an arc or thermal effect capable of igniting a flammable release of gas.

4.14 Construction of electric device components

4.14.1 Limited power sources

Limited power sources shall meet one of the following:

- the output is inherently limited in compliance with Table 3; or
- an impedance limits the output in compliance with Table 3. If a positive temperature coefficient device is used, it shall pass the tests specified in IEC 60730-1, Clause 15, 17, J.15 and J.17; or
- a non-arcing over-current protective device is used and the output is limited in compliance with Table 4; or
- a regulating network limits the output in compliance with Table 3, both under normal operating conditions and after any single fault (see 1.4.14 of IEC 60950-1:2005,) in the regulating network (open circuit or short circuit); or
- a regulating network limits the output in compliance with Table 3 under normal operating conditions, and a non-arcing over-current protective device limits the output in compliance with Table 4 after any single fault (see 1.4.14 of IEC 60950-1:2005) in the regulating network (open circuit or short circuit). Where a non-arcing over-current protective device is used, it shall be a suitable fuse or a non-adjustable, non-auto-reset, electromechanical device.

Compliance is checked by inspection and measurement and, where appropriate, by examination of the manufacturer's data for batteries. Batteries shall be fully charged when conducting the measurements for V_{OC} and I_{SC} according to Tables 3 and 4.

Table 3 – Limits for inherently limited power sources

Output voltage- d.c. ^a (V_{OC}) V d.c.	Output current ^b (I_{SC}) A	Apparent power ^c (S) VA
≤ 20	$\leq 8,0$	$\leq 5 \times V_{OC}$
$20 < V_{OC} \leq 30$	$\leq 8,0$	≤ 100
$30 < V_{OC} \leq 60$	$\leq 150 / V_{OC}$	≤ 100
^a V_{OC} : Output voltage measured with all load circuits disconnected. Voltages are for ripple-free d.c. ^b I_{SC} : Maximum output current with any non-capacitive load, including short circuit, measured 60 s after the application of the load. ^c S : Maximum output VA with any non-capacitive load measured 60 s after the application of the load.		

**Table 4 – Limits for power sources not inherently limited
(Over-current protection required)**

Output voltage ^a (V_{oc}) V d.c.	Output current ^b (I_{sc}) A	Apparent power ^c (S) VA	Current rating of over-current protection ^d A
≤ 20	$\leq 1\,000 / V_{oc}$	≤ 250	$\leq 5,0$
$20 < V_{oc} \leq 30$			$\leq 100 / V_{oc}$
$30 < V_{oc} \leq 60$			$\leq 100 / V_{oc}$

a V_{oc} : Output voltage measured with all load circuits disconnected. Voltages are for ripple free d.c.

b I_{sc} : Maximum output current with any non-capacitive load, including short circuit, measured 60 s after the application of the load. Current limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protection means are bypassed.

c S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of load. Current-limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protection means are bypassed.

NOTE The reason for making measurements with overcurrent protection means bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protection means. If the overcurrent protection means is a discrete arcing device, further evaluation with respect to its isolation from potentially flammable gas vapours is to be made.

d The current ratings of the overcurrent protection means are based on fuses and circuit breakers that break the circuit within 120 s with a current equal to 210 % of the current rating specified in Table 4.

4.14.2 Devices that use electronic controllers

4.14.2.1 Control systems

System software and electronic circuitry relied upon as the primary safety means as determined by the safety analysis of 4.2, shall comply with Annex H of IEC 60730-1.

Micro fuel cell power systems or units using electronic controllers shall conform to the following.

- During the course of normal usage, in case of any single controller malfunction, safety shall not be compromised.
- During the course of normal usage, safety shall not be compromised in cases where any single portion of the control circuit fails.

4.14.3 Electrical conductors/wiring

4.14.3.1 Electric components and wiring shall be laid out so as to minimize thermal effects.

4.14.3.2 The covering of the wires shall not become damaged during normal carrying, usage, or during periods of non-operation.

4.14.3.3 The conductor used in the wiring shall be as short as possible, and if necessary, locations shall be provided with insulation, protected from heat, immobilized, or provided with other treatment.

4.14.3.4 In the case where exposed lead wires or terminals that connect to the micro fuel cell power system or unit exterior are attached incorrectly, the micro fuel cell power system or unit either will not operate or will operate without any abnormality.

4.14.3.5 Except in the following cases, exposed lead wires or terminals that connect to the exterior of the micro fuel cell power system or unit shall be distinguishable by assigned numbers, letters, symbols, colours, etc.

- a) The wires or terminals have different physical shapes to prevent incorrect connection.
- b) There are only two lead wires or terminals, and interchanging those wires or terminals has no effect on micro fuel cell power system or unit operation.

4.14.3.6 Wireways shall be smooth and free from sharp edges.

4.14.3.7 Wires shall be protected so that they do not come into contact with burrs, or be subjected to pinching during assembly, and the like, which may cause damage to the insulation of conductors.

4.14.3.8 Insulated wires that pass through holes shall be protected to prevent abrasion or cutting damage. Compliance is checked by inspection.

4.14.3.9 With the micro fuel cell power system or unit operating under intended conditions, the temperature of wiring material including printed wiring on circuit boards shall not increase to the point where it acts to ignite a flammable release of gas.

4.14.3.10 In the event of the micro fuel cell power system or unit operating under the abnormal operating condition of an electrical overload, printed wiring on "open" circuit boards shall not produce an arc or thermal effect capable of igniting a flammable release of gas.

4.14.4 Output terminal area

The output terminal area shall be designed to prevent accidental contact with human hands. This restriction does not apply to the following types of output terminal areas.

- a) An output terminal area for which, when in its attached state, there is no risk of accidental human contact.
- b) An output terminal area for which the output voltage and current is inherently limited in compliance with Table 3; or an over-current protection device limits the output in compliance with Table 4.

4.14.5 Electric components and attachments

4.14.5.1 Electric components and attachments shall have sufficient electrical ratings for use within the micro fuel cell power system or unit.

4.14.5.2 Batteries used in the micro fuel cell power system or unit shall comply with the following safety standards, as applicable:

IEC 60086-4, IEC 60086-5, IEC 62133 and IEC 62281.

4.14.6 Protection

4.14.6.1 Objective of protection devices

A micro fuel cell power system or unit shall automatically and safely suspend operation of the micro fuel cell power system or unit when a situation arises that interferes with continued operation. In addition, a protection function shall be provided with the micro fuel cell power system or unit when necessary. Moreover, this protection function shall be able to operate during both start-up and shutdown of the micro fuel cell power system or unit.

4.14.6.2 Protection from short-circuit accidents

A function shall be provided to safely suspend operation or to provide protection in response to a short-circuited load.

4.14.6.3 Protection from electrical overloading

Micro fuel cell power systems and units shall be so designed as to reduce the risk of fire as a result of an abnormal electrical overloading condition.

5 Abnormal operating and fault conditions testing and requirements

5.1 General

- a) Each micro fuel cell power system or unit shall be designed so that the risk of fire, leakage, or other hazard due to mechanical or electrical overload or failure, or due to abnormal operation or careless use, is limited as far as practicable.
- b) After abnormal operation or a single fault, the micro fuel cell power system or unit shall remain in a safe condition.
- c) It is permitted to use fusible links, thermal cut-outs, overcurrent protection devices and the like to provide adequate protection if investigated and found not to become an ignition source.
- d) Compliance is checked by inspection and by the tests of 5.2.

5.2 Compliance testing

- a) Before the start of each test, the micro fuel cell power system or unit shall be operating normally.
- b) If a component or subassembly is so enclosed that short-circuiting or disconnection is not possible, it is permitted to make the tests on sample parts provided with special connecting leads. If this is not possible or not practical, the component or subassembly as a whole shall pass the tests.
- c) The micro fuel cell power system or unit is tested by applying abnormal operation or a single fault condition that may occur in normal use and reasonably foreseeable misuse. Hazard analysis (see 4.2) shall be used for guidance in identifying key faults to test. In addition, the micro fuel cell power system or unit that is provided with a protective covering is tested with the covering in place under normal idling conditions until steady conditions are established.
- d) The micro fuel cell power system or unit, circuit diagrams, FMEA, hazard analysis, and component specifications are to be examined to determine those fault conditions that might occur. Examples include:
 - 1) short circuits and open circuits of semiconductor devices and capacitors;
 - 2) faults causing continuous dissipation in resistors designed for intermittent dissipation;
 - 3) internal faults in integrated circuits causing excessive dissipation.

5.3 Passing criteria

During the tests of simulations of abnormal operating and fault conditions:

- a) No fire or flame at any time. No explosion at any time. No leakage and no fuel vapour loss.
- b) The micro fuel cell power system or unit shall not emit molten metal.
- c) Circuit traces that are designed to intentionally open in a repeatable manner in non-incendive circuits shall be in accordance with IEC 60079-15, or shall be isolated from fuel areas.
- d) Enclosures shall not deform in such a way as to cause access to hazardous parts.
- e) The temperatures of thermal insulation systems of motors, transformers and other coil-wound components shall not exceed 150 °C (302 °F) for Class A, 165 °C (329 °F) for Class E, 175 °C (347 °F) for Class B, 190 °C (374 °F) for Class F and 210 °C (410 °F) for Class H materials. If the failure of the insulation would not result in hazardous energy levels becoming accessible, a maximum temperature of 300 °C (572 °F) is permitted. Higher temperatures are permitted for insulation made of glass or ceramic material.
- f) The temperatures and arcing that may occur shall not be a potential ignition source. If such an occurrence is deemed to become a potential ignition source, other means shall be provided to prevent the arcing or high temperature from occurring.
- g) Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.
- h) Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or unit.

5.4 Simulated faults and abnormal conditions for limited power and SELV circuits

- a) Where it is required to apply simulated faults or abnormal operating conditions, these shall be applied in turn and one at a time.
- b) Faults, that are the direct consequence of a simulated fault or abnormal operating condition, are considered to be part of that simulated fault or abnormal operating condition.
- c) When applying simulated faults or abnormal operating conditions, accessories, supplies and consumable materials shall be in place if they are likely to have an effect on the outcome of the test.
- d) When applying simulated faults or abnormal operating conditions, consideration should be given to the non-arcing overcurrent protection devices provided as part of the protection for the end-product against overcurrents and short circuits.
- e) Consideration shall also be given to arcing parts in the end-product if the application of the micro fuel cell power system or unit may emit potentially flammable vapours during normal or abnormal operation.
- f) Where there is a specific reference to a single fault, the single fault consists of a single failure of any insulation or a single failure of any component.

5.5 Abnormal operation – electromechanical components

Where a hazard is likely to occur, electromechanical components other than motors are checked for compliance by the following fault tests.

- a) Mechanical movement shall be locked in the most disadvantageous position while the component is energized normally.
- b) In the case of a component, which is normally energized intermittently, a fault shall be simulated in the drive circuit to cause continuous energizing of the component.

- c) The duration of each test shall be in accordance with the following.
- 1) For micro fuel cell power system or unit components whose failure to operate is not apparent to the user, the test duration shall be as long as necessary to establish steady conditions or up to the interruption of the circuit due to other consequences of the simulated fault condition, whichever is shorter.
 - 2) For other micro fuel cell power system or unit components, the test duration shall be 5 min or up to the interruption of the circuit due to a failure of the component (for example, burnout).

5.6 Abnormal operation of micro fuel cell power systems or units with integrated batteries

A rechargeable battery, charged in accordance with the manufacturer's design, and integrated with the micro fuel cell power system or unit or recommended by the manufacturer for use with the micro fuel cell power system or unit, shall be used for each of the following tests:

- a) For evaluating the safety of rechargeable battery charging, a battery is charged for a period of 7 h in accordance with each of the following conditions.
 - 1) With the battery-charging circuit adjusted for its maximum charging rate (if such an adjustment exists); followed by any single component failure that is likely to occur in the charging circuit and which would result in overcharging of the battery. The battery is charged for a period of 7 h. The battery is then subjected to rapid discharge by open-circuiting or short-circuiting any current-limiting or voltage-limiting components in the load circuit of the battery under test.
 - 2) With any single component failure that is likely to occur and which would result in reversed charging of the battery. The battery is charged for a period of 7 h. The battery is then subjected to rapid discharge by open-circuiting or short-circuiting any current-limiting or voltage-limiting components in the load circuit of the battery under test.
- b) After completion of the tests above, the micro fuel cell power system or unit shall be subjected to electric strength testing in accordance with guidance provided in IEC 60950-1: 2005.
- c) These battery abnormal tests shall not result in any of the following:
 - 1) chemical or fuel leaks of the battery, micro fuel cell power system, micro fuel cell power unit, or fuel cartridge caused by cracking, rupturing or bursting of a jacket; or
 - 2) explosion of the battery or micro fuel cell power system, micro fuel cell power unit, or fuel cartridge, if such explosion could result in injury to a user;
 - 3) emission of flame or expulsion of molten metal to the outside of the micro fuel cell power system, micro fuel cell power unit, or fuel cartridge;
 - 4) ignition of the micro fuel cell power system, micro fuel cell power unit, or fuel cartridge or fuel contained therein.

5.7 Abnormal operation – simulation of faults based on hazard analysis

The following faults shall be simulated.

- a) Any abnormal conditions deemed necessary, based on Clause 4, to evaluate the protection parameters provided for the micro fuel cell power system or unit, e.g. over-temperature protection, short circuit, stack voltage.
- b) Short circuit, disconnection or overloading of all relevant components and parts unless they are contained within a fire enclosure that complies with all requirements for fire enclosures including materials, see 4.9.1 and 4.9.4.

NOTE An overload condition is any condition between normal load and the maximum current condition up to short circuit.

- c) Temperatures in excess of the over-temperature protection circuitry to ensure the safety of the micro fuel cell power system or unit.

6 Instructions and warnings for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

6.1 General

All micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall be accompanied by appropriate safety information (instructions, warnings, or both) communicating the intended safe transportation, use, storage, maintenance and disposal of the product.

6.2 Minimum markings required on the fuel cartridge

As a minimum, the following shall be marked on the fuel cartridge.

- a) CONTENTS ARE FLAMMABLE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) KEEP AWAY FROM CHILDREN.
- d) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES OR IGNITION SOURCES.
- e) FOLLOW USAGE INSTRUCTIONS.
- f) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- g) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- h) COMPOSITION AND AMOUNT OF FUEL.
- i) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.

6.3 Minimum markings required on the micro fuel cell power system

In addition, as a minimum, the following shall also be marked on the micro fuel cell power system to show:

- a) CONTENTS ARE FLAMMABLE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES OR IGNITION SOURCES.
- d) FOLLOW USAGE INSTRUCTIONS.
- e) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- f) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- g) COMPOSITION OF FUEL.
- h) MAXIMUM CAPACITY OF FUEL IN THE INTERNAL RESERVOIR, IF APPLICABLE.
- i) TEXT OR MARKING THAT INDICATES THAT THE MICRO FUEL CELL POWER SYSTEM COMPLIES WITH IEC 62282-6-100.
- j) ELECTRICAL OUTPUT (VOLTAGE, CURRENT, RATED POWER).

6.4 Additional information required either on the fuel cartridge or on accompanying written information or on the micro fuel cell power system or micro fuel cell power unit

Usage instructions to include:

- a) safety instructions and warnings;
- b) text or markings on the micro fuel cell power system indicating that the micro fuel cell power system complies with IEC 62282-6-100;
- c) all micro fuel cell power systems and micro fuel cell power units shall identify the fuel cartridge(s) which are acceptable for use with the micro fuel cell power systems and micro fuel cell power units;
- d) minimum and maximum operating and storage temperatures.

6.5 Technical documentation

Technical documentation shall include a user information manual which shall include safety instructions and the following:

- a) instructional information that educates the end-user in the proper use, function and disposal of the fuel cartridge, micro fuel cell power unit and/or micro fuel cell power system;
- b) information that identifies the manufacturer of the micro fuel cell power unit and/or micro fuel cell power system, including company name, address, telephone number, and web site;
- c) all warnings and instructions affixed to the micro fuel cell power system, micro fuel cell power unit or fuel cartridge shall be set forth in the manual. Additional information further explaining or enhancing those warnings and instructions may be provided in the manual;
- d) instructions that the micro fuel cell power system or unit shall be used in a well-ventilated area.

Local laws may apply to these requirements. Consult individual country authorities for details.

The manufacturer of the micro fuel cell power system, micro fuel cell power unit and/or fuel cartridges shall specify the type and relevant characteristics of the fuel and, if applicable, the quality and relevant characteristics of the fuel and water to be employed with the micro fuel cell power system. This information shall be provided as part of the documentation provided with the micro fuel cell power system or unit.

The micro fuel cell power systems or units shall specify the fuel cartridge(s) that are intended for use with them. This information shall be provided as part of the documentation provided with the micro fuel cell power unit or micro fuel cell power system.

7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

7.1 General

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table 5 lists the type tests that shall be performed.

Table 5 – List of type tests

Test reference	Test item	Test sample
7.3.1	Pressure differential tests	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.2	Vibration test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.3	Temperature cycling test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.4	High temperature exposure test	Fuel cartridge Partially filled fuel cartridge
7.3.5	Drop test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.6	Compressive loading test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
7.3.9	Long-term storage test	Fuel cartridge Partially filled fuel cartridge
7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Partially filled fuel cartridge and micro fuel cell power unit
7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit
7.3.12	Emission test	Micro fuel cell power system or power unit
Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or partially filled, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test. Test sequence: Tests 7.3.2 and 7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests 7.3.1, 7.3.2 and 7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or units. Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.		

- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table 6.

Table 6 – Laboratory standard conditions

Item	Condition
Laboratory temperature	Laboratory temperature is “room temperature” (standard temperature condition, $22\text{ °C} \pm 5\text{ °C}$)
Laboratory room atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen.

- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of $22\text{ °C} \pm 5\text{ °C}$ for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

7.2 Leakage measurement of methanol and the measuring procedure

The leakage measurement of methanol shall be executed in principle in accordance with the procedure shown in Figures 2 through 7 respectively. Exceptions will be noted in the various subclauses.

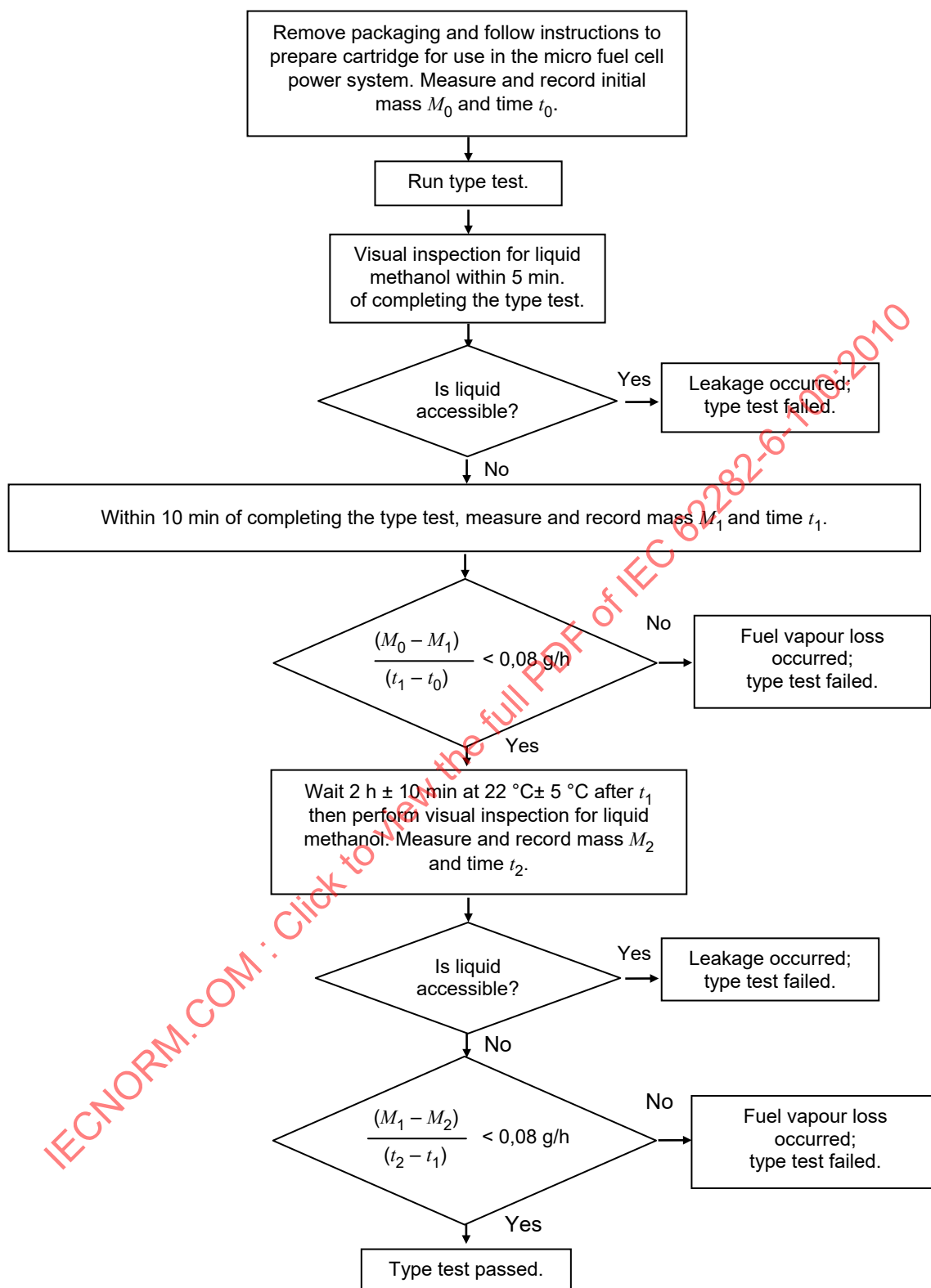


Figure 2 – Fuel cartridge leakage and mass loss test flow chart for pressure differential, vibration, drop, and compressive loading tests

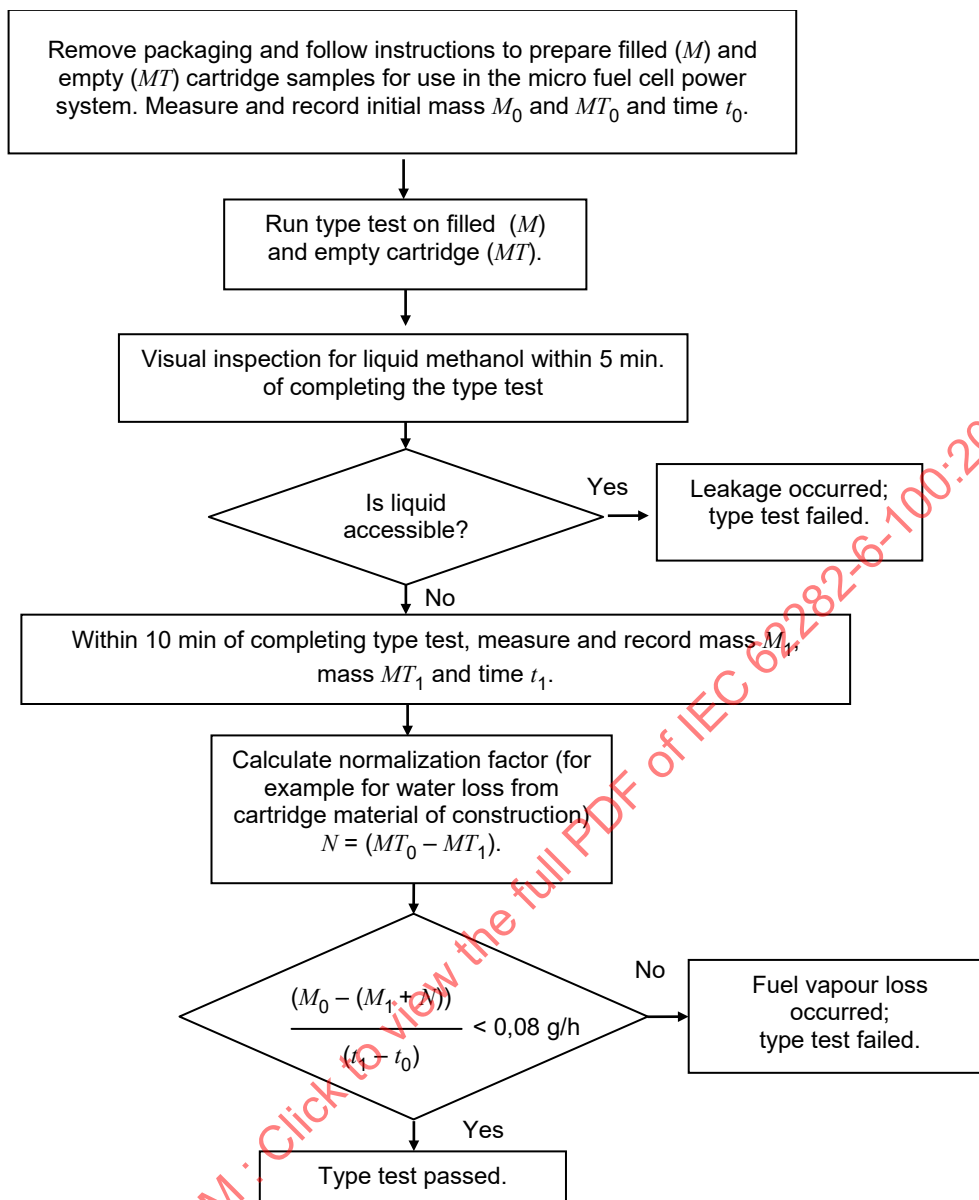


Figure 3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test

The maximum time interval $t_1 - t_0$ shall be set so that no more than half the fuel would be lost if it were escaping at the maximum allowable mass loss rate.

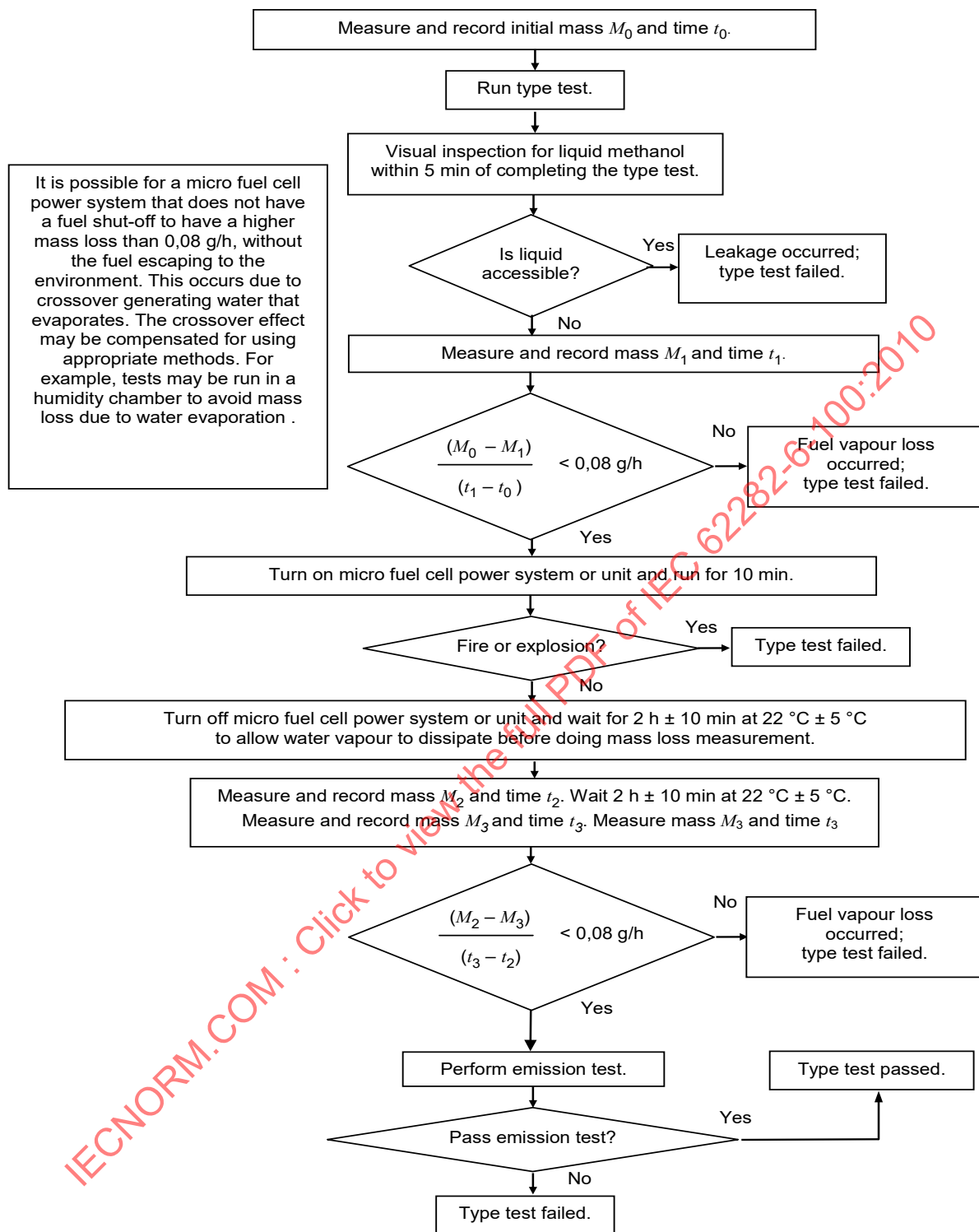


Figure 4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests

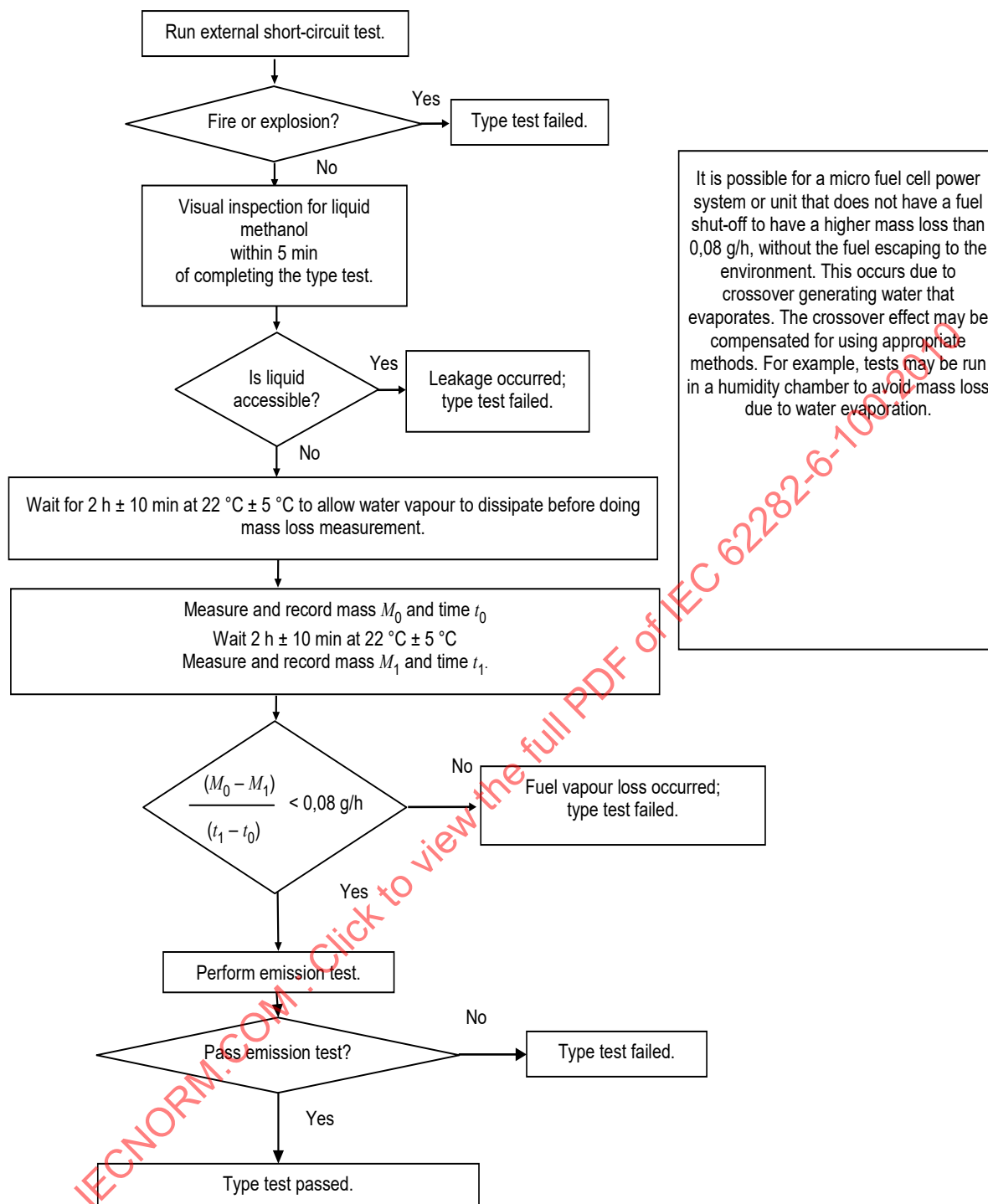


Figure 5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test

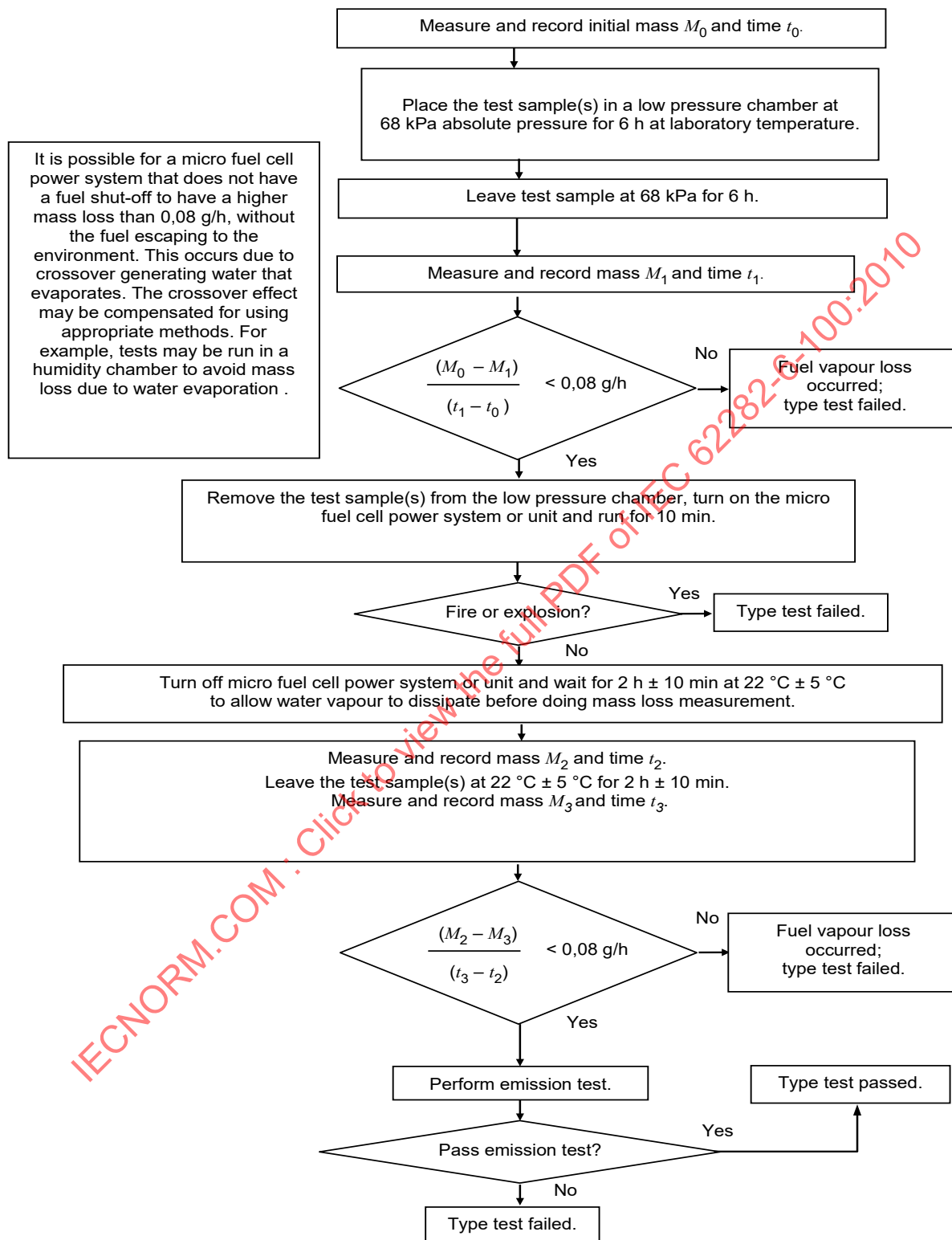


Figure 6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test

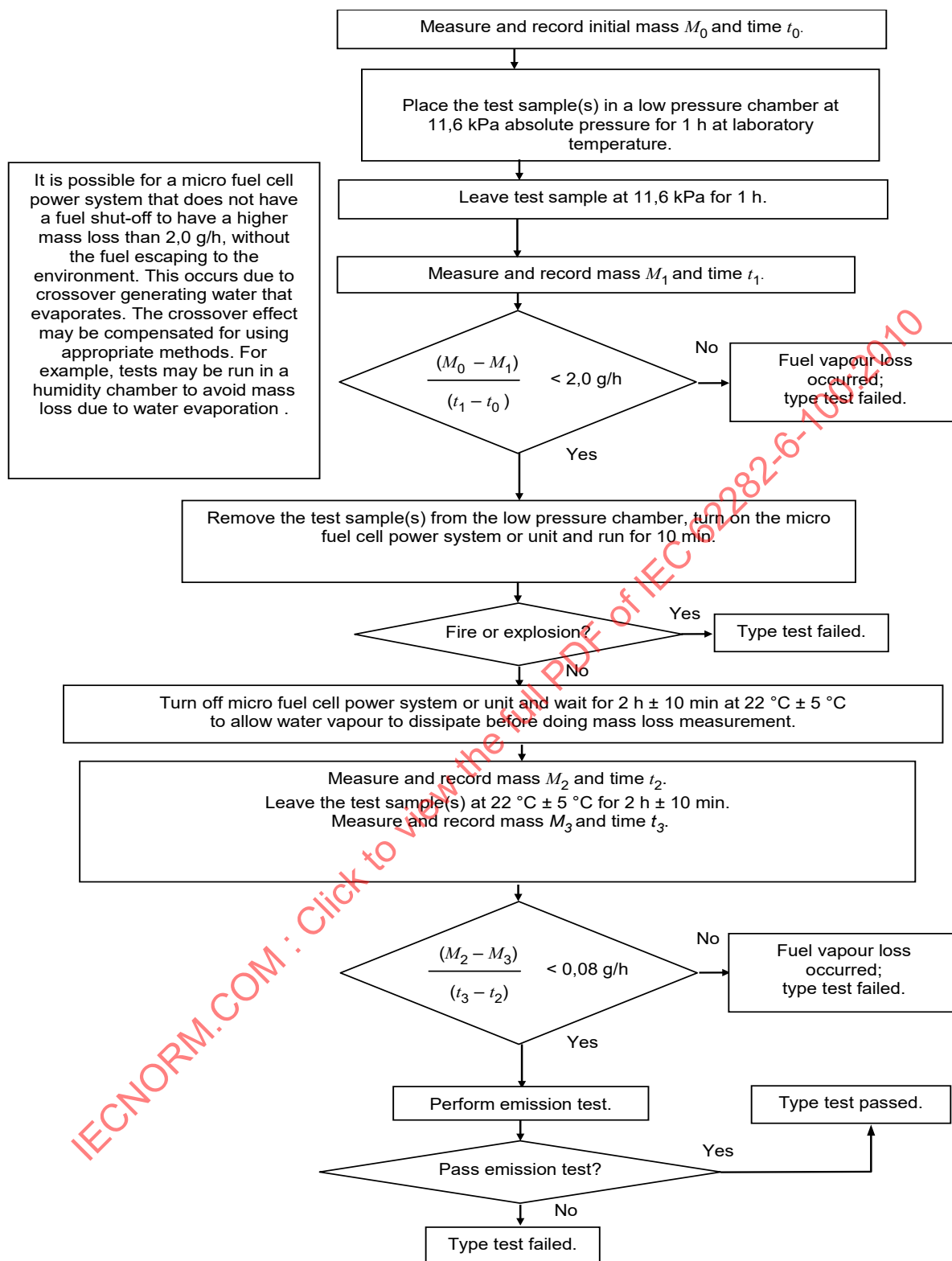


Figure 7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test

7.3 Type tests

7.3.1 Pressure differential tests

7.3.1.1 General

Portions of this test check compliance with Subclause 4.12.1.2 to verify that there shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Depending upon which of the two limiting pressure conditions is greater, two options for testing are provided:

- a) If 95 kPa internal gauge pressure plus normal working pressure of the fuel cartridge at 22 °C is greater than two times the gauge pressure of the fuel cartridge at 55 °C, either Subclause 7.3.1.2 or Subclause 7.3.1.3 may be used to verify compliance with Subclause 4.12.1.2.
- b) If two times the gauge pressure of the fuel cartridge at 55 °C is greater than 95 kPa internal gauge pressure plus normal working pressure at 22 °C, Subclause 7.3.1.2 shall be used to verify compliance with Subclause 4.12.1.2.

7.3.1.2 Fuel cartridge internal pressurization test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**

For the internal pressurization test, the fuel cartridge body and the fuel cartridge valve shall be tested separately.

- 1) Using a suitable fluid medium such as water, pressurize the fuel cartridge body to an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. The pressure rise shall not exceed a rate of 60 kPa/s.
- 2) Maintain the maximum pressure for 30 min at laboratory temperature.
- 3) Using a suitable fluid medium such as water, pressurize the closed fuel cartridge valve to 95 kPa gauge pressure plus the normal working pressure of the cartridge at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. The pressure rise shall not exceed a rate of 60 kPa/s.
- 4) Maintain the maximum pressure for 30 min at laboratory temperature.
- d) **Passing criteria:** No accessible liquid test medium leakage and no sudden drop of pressure during the course of the test. Leakage shall be checked visually. Invert the fuel cartridge and the fuel cartridge valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails.

7.3.1.3 Fuel cartridge low external pressure test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure 2.
 - 2) The sample shall be placed in a vacuum chamber and the pressure in the vacuum chamber shall be reduced to 95 kPa below normal atmospheric pressure.
 - 3) Maintain the vacuum for 30 min.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no fuel vapour loss. See Figure 2. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

7.3.1.4 Micro fuel cell power system or micro fuel cell power unit pressure differential tests

7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
- 1) Perform this test in accordance with Figure 6.
 - 2) Test samples shall be stored at a low external pressure of 68 kPa absolute pressure for 6 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure 6.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no accessible liquid leakage. See Figure 6. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test result is acceptable. During the 6 h test at 68 kPa absolute external pressure, the fuel vapour loss shall be less than 0,08 g/h.

7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
- 1) Perform this test in accordance with Figure 7.
 - 2) Test samples shall be stored at a low external pressure of 11,6 kPa absolute pressure for 1 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure 7, with a fuel vapour loss at 11,6 kPa YES/NO passing criteria of less than 2,0 g/h on the basis of not exceeding 25 % of the lower flammability limit (LFL).
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with 7.3.12.

- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no accessible liquid leakage. See Figure 7. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test result is acceptable. During the 1 h test at 11,6 kPa absolute external pressure, the fuel vapour loss shall be less than 2,0 g/h.

7.3.2 Vibration test

- a) **Test sample:** an unused fuel cartridge, a partially filled fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in 7.3.1 or a micro fuel cell power system used in 7.3.1.
- b) **Purpose:** to simulate the effects of normal transportation vibration and ensure no leakage.
- c) **Test procedure:**
- 1) Perform these tests in accordance with Figure 2 for the fuel cartridge and Figure 4 for the micro fuel cell power system or unit.
 - 2) The test sample shall be firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.
 - 3) The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min.
 - 4) This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions of the test samples.
 - 5) The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g_n is maintained until 18 Hz is reached. The amplitude is then maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of 8 g_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.
 - 6) For the micro fuel cell power system or unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured based upon Figure 2 for the fuel cartridge and Figure 4 for the micro fuel cell power system or unit. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

7.3.3 Temperature cycling test

- a) **Test sample:** a fuel cartridge used in 7.3.2, a partially filled fuel cartridge used in 7.3.2, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in 7.3.2 or a micro fuel cell power system used in 7.3.2.
- b) **Purpose:** to simulate the effects of low temperature and high temperature exposure and the effects of extreme temperature change.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure 3 for the fuel cartridge and Figure 4 for the micro fuel cell power system or unit.
 - 2) For a fuel cartridge, two fuel cartridge orientations shall be tested – valve up and valve down. For a micro fuel cell power system or a micro fuel cell power unit, only one orientation needs to be tested.
 - 3) See Figure 8 for the temperature profile to be used.
 - 4) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from laboratory temperature to $55\text{ °C} \pm 2\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $55\text{ °C} \pm 2\text{ °C}$ for a minimum of 4 h.
 - 5) Decrease the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$ then decrease the chamber temperature to $-40\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $-40\text{ °C} \pm 5\text{ °C}$ for a minimum of 4 h.
 - 6) Increase the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$.
 - 7) The above process is to be done twice.
 - 8) After 1 h at $22\text{ °C} \pm 5\text{ °C}$, leakage and fuel vapour loss shall be measured based upon the procedure described in Figure 3 (for fuel cartridge) and Figure 4 (for micro fuel cell power system or unit).
 - 9) For the micro fuel cell power system or micro fuel cell power unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured based upon Figure 3 for the fuel cartridge and Figure 4 for the micro fuel cell power system or unit. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

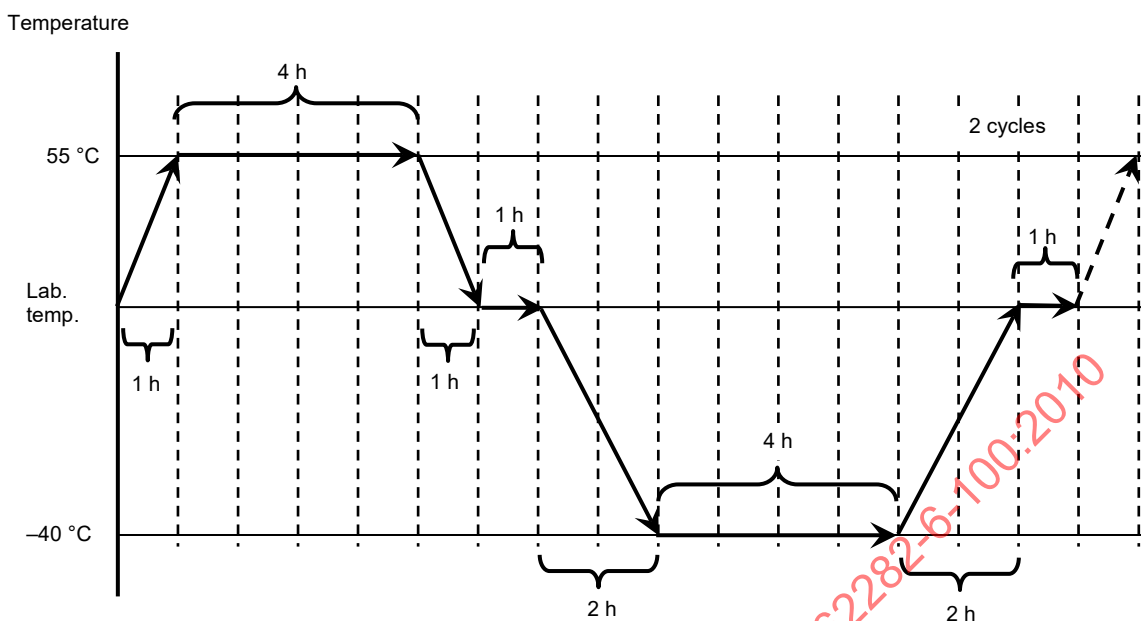


Figure 8 – Temperature cycling

7.3.4 High temperature exposure test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of a fuel cartridge left in high temperature environments.
- c) **Test procedure:**
 - 1) Two orientations shall be tested – valve up and valve down.
 - 2) Place the test sample in a temperature controlled test chamber that is at a temperature of $70\text{ °C} \pm 2\text{ °C}$ and allow chamber temperature to recover to $70\text{ °C} \pm 2\text{ °C}$ and maintain that temperature for at least 4 h with the sample in the chamber.
 - 3) Remove the test sample to laboratory temperature.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure 3 for a fuel cartridge. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

7.3.5 Drop test

- a) **Test sample:** an unused fuel cartridge, a partially filled fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an inadvertent drop and ensure no leakage.
- c) **Test procedure:**
 - 1) The test sample shall be dropped on a horizontal surface that consists of hardwood at least 13 mm thick, mounted on two layers of plywood each 18 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor from a predetermined height.
 - 2) The height of the drop shall be:
 - i) $1\,200\text{ mm} \pm 10\text{ mm}$: in the case of a micro fuel cell power unit and/or a micro fuel cell power system;

- ii) 1 500 mm $\pm$ 10 mm: in the case of a fuel cartridge of more than 200 ml;
 - iii) 1 800 mm $\pm$ 10 mm: in the case of a fuel cartridge of up to 200 ml.
- 3) For the fuel cartridge tests, the drop test shall be carried out in four drop orientations with the same sample.
 - 4) For the micro fuel cell power unit or the micro fuel cell power system, one micro fuel cell power system or unit may be used for all four drop orientations, or more than one micro fuel cell power system or unit may be used in subsequent drops, at the discretion of the manufacturer.
 - 5) For all tests, drop orientations shall be:
 - i) valve up;
 - ii) valve down;
 - iii) two other mutually perpendicular orientations.
 - 6) For micro fuel cell power system or micro fuel cell power unit tests, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured based upon Figure 2 for the fuel cartridge and Figure 4 for the micro fuel cell power system or unit. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

7.3.6 Compressive loading test

7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the micro fuel cell power unit, or micro fuel cell power system.
- c) **Test procedure:**
 - 1) The micro fuel cell power system or unit test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of 245 N $\pm$ 9,8 N.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of 245 N $\pm$ 9,8 N shall be applied to the stationary sample for 5 s.
 - 4) The test shall be carried out in three mutually perpendicular orientations as a rule. If the sample would not stand on its own, it does not need to be tested in that orientation.
 - 5) Perform emission testing in accordance with 7.3.12 following the compressive loading test.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure 4. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of

leakage. If any accessible liquid leakage is found, the test fails. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions from micro fuel cell power system or unit shall meet the passing criteria in 7.3.12. If the micro fuel cell power system or unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

7.3.6.2 Fuel cartridge

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the fuel cartridge.
- c) **Test procedure:**
 - 1) The fuel cartridge test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $981 \text{ N} \pm 9,8 \text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $981 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) Fuel cartridge orientations shall be selected on the basis of likely stable resting positions when accidentally dropped (e.g. those orientations having the lowest centres of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic fuel cartridge that is sufficiently cubic and the curved surface of a cylindrical fuel cartridge with a longitudinal axis length longer than twice the diameter.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure 2. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

7.3.7 External short-circuit test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an external short-circuit.
- c) **Test procedure:**
 - 1) External short-circuit testing shall be done separately on both operating [DEVICE ON] and non-operating [DEVICE OFF] micro fuel cell power systems or micro fuel cell power units respectively.
 - 2) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power system or unit with wire having a maximum resistance load of $0,1 \Omega$ for at least 5 min.
 - 3) Perform emission testing in accordance with 7.3.12 after each external short-circuit test.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure 5. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valves point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed temperatures in Table 2 during or after external short-circuit testing.

Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system or unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

NOTE The external short-circuit test can be done sequentially with the surface, component and exhaust gas temperature test using the same sample.

7.3.8 Surface, component and exhaust gas temperature test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to eliminate any risk of burn injury caused by contact with the enclosure of a micro fuel cell power system or unit and to eliminate any risk of burn injury caused by blown exhaust gas from vents and to verify compliance with component temperature ratings.
- c) **Test procedure:**
 - 1) Temperatures shall be measured until temperatures stabilise within ± 2 °C for 5 min.
 - 2) This test shall be conducted at the manufacturer's rated ambient operating temperature.
 - 3) Temperature of the bare surface of micro fuel cell power units or micro fuel cell power systems operating at rated output shall be measured using infrared camera(s), thermocouples, or other suitable means.
 - 4) The micro fuel cell power system or unit shall be positioned for normal operation so that the exhaust gases are unimpeded.
 - 5) The temperature of exhaust gases shall be measured at a distance of 1 cm from the exhaust vent of the micro fuel cell power system or unit operating at rated output.
- d) **Passing criteria:** The surface temperature of the micro fuel cell power system or micro fuel cell power unit parts where persons can touch easily shall not exceed the value shown in Table 2 depending upon the material. The temperature at 1 cm from the exhaust vent of the operating micro fuel cell power system or unit shall be less than 70 °C. During the test, thermal cut-outs and overload devices shall not operate.

For components and electrical wiring in the micro fuel cell power system or unit that are not shown in Table 2, their temperatures shall not exceed the maximum temperature for which the components and wiring are rated. Safety related components shall be identified by the FMEA.

NOTE This test can be done sequentially with the external short-circuit test using the same sample.

7.3.9 Long-term storage test

7.3.9.1 General

Either 7.3.9.2 (Option 1), 7.3.9.3 (Option 2) or 7.3.9.4 (Option 3) may be used.

7.3.9.2 Option 1 – continuous weight measurement

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure 9):
 - 1) Use a load cell (continuous electronic weight sensing device) designed and calibrated for use at 50 °C $\pm$ 2 °C inside the temperature chamber.

- 2) Place the load cell in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Place the fuel cartridge on top of the load cell so that all the weight is being applied to the load cell. A fixture may be used to control the position of the fuel cartridge, to ensure all the weight is applied to the load cell.
- 3) Connect a digital readout to the load cell and collect the data either manually or automatically. The data should be collected with a high degree of confidence to assure that the fuel vapour loss does not exceed 0,08 g/h.
- 4) Measure and record initial mass M_{initial} and time t_i .
- 5) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
- 6) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{initial} and record time t_i . If the average mass loss rate is less than 0,08 g/h, then the test sample passes the test for fuel vapour loss.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{final}} = \text{the final mass of the fuel cartridge.}$$

- 7) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,08 g/h.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$$

$$\text{ii) } \Delta t_{\text{last}} = \text{the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{last}} = \text{the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss and no liquid leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure 9. If the fuel cartridge fuel vapour loss is less than the 0,08 g/h fuel vapour loss criteria, then the test sample passes the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

7.3.9.3 Option 2 – periodic weight measurements

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.

c) **Test procedure** (See Figure 9):

- 1) Measure and record initial mass M_{initial} and time t_i .
- 2) Place the fuel cartridge in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Weight measurements should be collected with a high degree of confidence to determine if the fuel vapour loss is less than 0,08 g/h with a minimum of once every three days.
- 3) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
- 4) The time in which the test samples are removed from the chamber for measurement shall not be included in the time the test sample is to be tested (28 days). Additional time should be added to get the test sample to the test temperature ($50\text{ °C} \pm 2\text{ °C}$) each time the test sample is removed from the chamber. The test samples should only be stabilised at laboratory temperature if the mass loss will be affected.
- 5) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,08 g/h, then the test sample passes the test for fuel vapour loss.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{final}} = \text{the final mass of the fuel cartridge.}$$

- 6) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,08 g/h.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$$

$$\text{ii) } \Delta t_{\text{last}} = \text{the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{last}} = \text{the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss and no liquid leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure 9. If the fuel cartridge fuel vapour loss is less than the 0,08 g/h fuel vapour loss criteria, then the test sample passes the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

7.3.9.4 Option 3 – one weight measurement

This option is intended for fuel cartridges with very small leak rates.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure 9):
 - 1) Measure and record initial mass M_{initial} and time t_i .
 - 2) Place the fuel cartridges in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. After 28 days, the fuel cartridges are removed from the chamber for measurement. The test samples should be stabilised at laboratory temperature if the mass loss will be affected. Then weight measurement is executed.
 - 3) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,08 g/h, then the test sample passes the test for fuel vapour loss.
 - i) Fuel vapour loss $= \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$
 - ii) $\Delta t = t_f - t_i = 28\text{ days} \times 24\text{ h/day} = 672\text{ h}$.
 - iii) M_{initial} = the initial mass of the fuel cartridge.
 - iv) M_{final} = the final mass of the fuel cartridge.
 - 4) If the fuel cartridge is empty after 28 days, then the type test according to 7.3.9.2 Option 1 or 7.3.9.3 Option 2 shall be done.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss and no liquid leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure 9. If the fuel cartridge fuel vapour loss is less than the 0,08 g/h fuel vapour loss criteria, then the test sample passes the test for fuel vapour loss. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

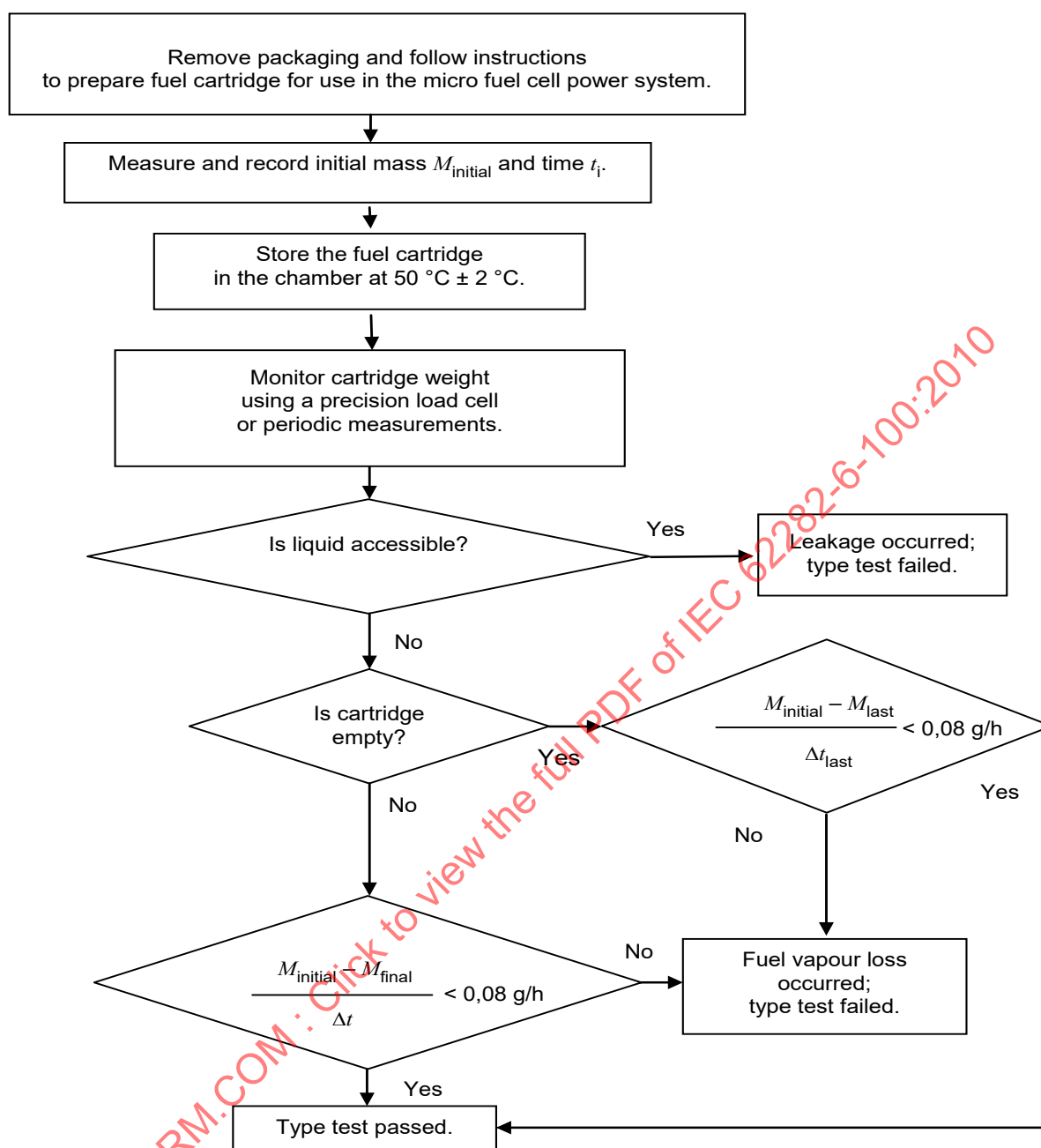


Figure 9 – Fuel cartridge leakage and mass loss test flow chart for long-term storage test

7.3.10 High temperature connection test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge and a micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage, no fire, no explosion.
- c) **Test procedure:**
 - 1) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of $50\text{ °C} \pm 2\text{ °C}$ for at least 4 h.
 - 2) The micro fuel cell power unit or test fixture with micro fuel cell power unit valve is kept at laboratory temperature.
 - 3) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or test fixture with micro fuel cell power unit valve within 5 min of removal from the chamber.
 - 4) Check for leakage upon connection.
 - 5) Disconnect the fuel cartridge and check for leakage.
- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, this is acceptable. Leakage shall be checked visually. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power unit valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit.

7.3.11 Connection cycling tests

7.3.11.1 Fuel cartridge

7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

- a) **Test sample:** an unused insert cartridge, exterior cartridge or attached cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve and fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection.
 - 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 4) Disconnect the fuel cartridge and check for leakage.
 - 5) Repeat this twice more for a total of three connections and disconnections.
 - 6) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.

- 8) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 10) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper such that the valve points downward toward the indicating paper and look for signs of leakage.
 - 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 13) Disconnect the fuel cartridge and check for leakage.
- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. Leakage shall be checked visually. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power unit valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit.

7.3.11.1.2 Satellite cartridge

- a) **Test sample:** an unused satellite fuel cartridge and an unused micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection and initiate or simulate fuel flow.
 - 2) Disconnect the fuel cartridge and check for leakage.
 - 3) Repeat this twice more for a total of three connections and disconnections.
 - 4) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 5) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
 - 6) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 7) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 8) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 9) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and initiate or simulate fuel flow.
 - 10) Disconnect the fuel cartridge and check for leakage.
 - 11) Repeat steps 1 through 10 four more times for a total of 55 cycles, waiting 1 h between each set of 11 cycles.

- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. Leakage shall be checked visually. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power unit valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit.

7.3.11.2 Micro fuel cell power unit

- a) **Test sample:** a minimum of two unused fuel cartridges and an additional 98 fuel cartridges or suitable test fixtures with fuel cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the fuel cartridge valve geometry and material and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage both at initial use and after suitable ageing of the micro fuel cell power unit connection.

First fuel cartridge (#1) and final fuel cartridge (#100) are inspected; the other 980 cycles are only to age the micro fuel cell power unit.

In the case of a micro fuel cell power unit using satellite cartridge, it shall be tested according to the following procedure by simulating fuel flow between the satellite cartridge and the micro fuel cell power unit.

c) **Test procedure:**

- 1) Connect the first fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the fuel cartridge and check for leakage.
- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 7) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 9) Connect and disconnect the first fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 11) Connect the first fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
- 12) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 13) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 14) Disconnect the first fuel cartridge and check for leakage.

- 15) In order to age the micro fuel cell power unit fuel cartridge connection, perform the following steps.
 - i) Using either fuel cartridges or a suitable test fixture with fuel cartridge valves, cycle the micro fuel cell power unit fuel cartridge connection for a total of 980 connections and disconnections.
 - ii) Simulate fuel flow after each set of 50 connection-disconnection cycles.
 - iii) Inversion of the micro fuel cell power unit or the fuel cartridges is not necessary, but, if leakage is found, the test fails.
 - iv) Following this ageing, a final unused fuel cartridge will be tested.
- 16) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
- 17) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 18) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 19) Disconnect the fuel cartridge and check for leakage.
- 20) Repeat this twice more for a total of three connections and disconnections.
- 21) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 22) Connect and disconnect the final fuel cartridge four more times for a total of seven connections and disconnections.
- 23) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 24) Connect and disconnect the final fuel cartridge three more times for a total of ten connections and disconnections.
- 25) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 26) Connect the fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
- 27) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 28) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 29) Disconnect the fuel cartridge and check for leakage.
- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. Leakage shall be checked visually. Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit.

7.3.12 Emission test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or micro fuel cell power unit – that is fuelled with methanol – emissions of carbon monoxide (CO), carbon dioxide (CO₂) and organic compounds such as methanol, formaldehyde, formic acid and methyl formate shall be maintained at less than the specified values. Maintaining these limits not only prevents inadvisable exposure but also ensures that an adequate supply of oxygen is maintained in the operating environment.

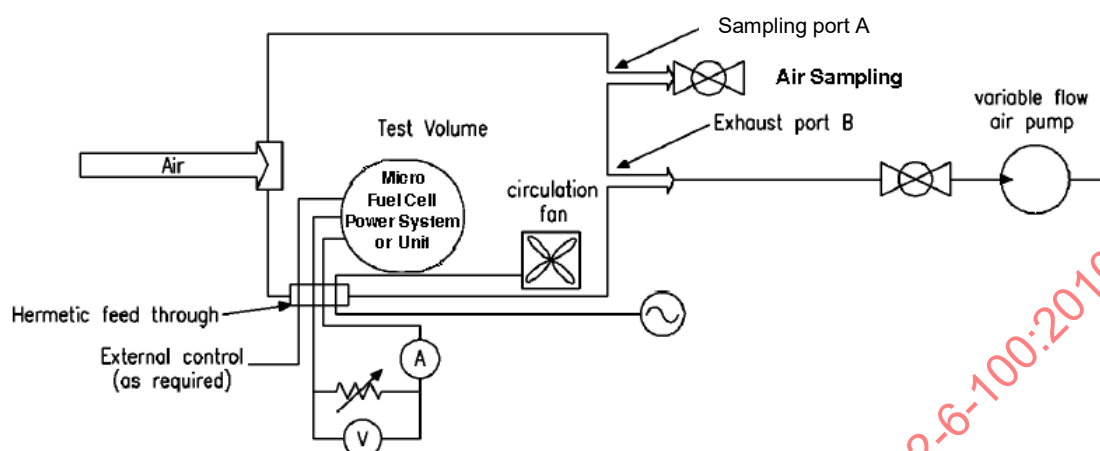


Figure 10 – Operational emission rate testing apparatus

- c) **Test apparatus:** An example of the operational emission rate testing apparatus is shown in Figure 10. The configuration shown in Figure 10 is for emission rate testing of all micro fuel cell power systems or units. Emission rate testing in accordance with 7.3.12 d) 1) is required for all types of micro fuel cell power systems and micro fuel cell power units.

For micro fuel cell power systems or units that are intended to be used in close proximity to a consumer's mouth or nose (such as micro fuel cell power systems or units used to power cell phones, handheld games, etc.) additional testing in accordance with 7.3.12 d) 2) is required to verify that emission concentrations in the vicinity of a user's mouth or nose are kept within appropriate limits. This emission concentration testing shall be done in a large open room using a different emission concentration testing apparatus. An example of the operational emission concentration testing apparatus is shown in Figure 11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell power system or unit to a consumer's mouth or nose when in use) for emissions concentration limit testing.

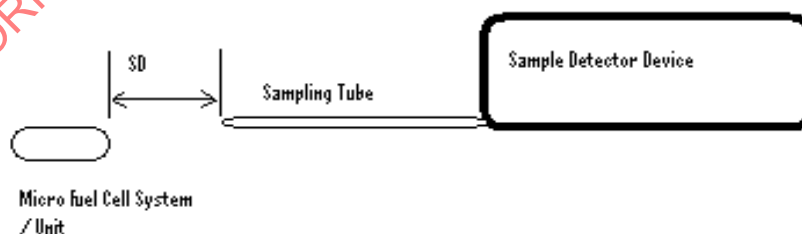


Figure 11 – Operational emission concentration testing apparatus

Emission gases might be composed of toxic organic materials such as methanol, formaldehyde, formic acid and methyl formate, which are potentially exhausted from a micro fuel cell power system or a micro fuel cell power unit.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) or a high-performance liquid chromatography (HPLC) system shall be used by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyzer through

sampling port A in Figure 10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

The concentration of CO and CO₂ gas can be measured by a non-dispersive infrared absorption analyzer. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) **Test procedure:**

- 1) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed.
 - i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure 10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "DEVICE ON" position.
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure 10.
 - iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure 10, while simultaneously measuring and recording the flow through the test chamber. The flow through the test chamber can be computed from the sum of the variable flow air pump flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber.
 - vi) Record the concentrations of the chemical compounds of interest. See Table 7.
 - vii) Calculate the emission rate of chemical compounds of interest being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- viii) Compare the maximum measured emission rate to Table 7. If the emission rate is not less than the emission rate limit in Table 7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria 7.3.12 e) 1) i) and 7.3.12 e) 2) i).
 - ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 2) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emissions concentration sampling test shall be performed.
- i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling system do not contribute emissions (that is, contaminants) to the test. Prior to testing, a system check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results.
 - ii) Operate the micro fuel cell power system or micro fuel cell power unit at rated power in the large open room while sampling the emission concentrations using the operational emission concentration testing apparatus shown in Figure 11. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission concentration test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "ON" position.
 - iii) Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - iv) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the operational emission concentration testing apparatus shown in Figure 11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - v) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - vi) Allow the sample flow rate to stabilise.
 - vii) Sample and record the micro fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - viii) Record the concentrations of the chemical compounds of interest. See Table 7.
 - ix) Compare the maximum measured concentrations to Table 7. If the emission concentrations are not less than the emission concentration limits in Table 7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria 7.3.12 e) 2) ii).

- x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- e) **Passing criteria:**
- 1) For micro fuel cell power systems and micro fuel cell power units not intended to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table 7 shall be less than the emission rate limit value in Table 7 when tested in accordance with 7.3.12 d) 1). If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
 - 2) For micro fuel cell power systems and micro fuel cell power units to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table 7 shall be less than the emission rate limit value in Table 7 when tested in accordance with 7.3.12 d) 1). If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
 - ii) For micro fuel cell power systems and micro fuel cell power units intended to be used in close proximity to a consumer's mouth or nose; in addition to meeting the emission rate limit above, the maximum emission concentration for each of the constituents of interest shall be less than the emission concentration limit in Table 7 when tested in accordance with 7.3.12 d) 2). If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.

Table 7 – Emission limits

	Concentration limit	Emission rate limit ^a
Water	Unlimited	No limit
Methanol	0,26 g/m ³	2,6 g/h
Formaldehyde	0,000 1 g/m ³ ^b	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Formic acid	0,009 g/m ³	0,09 g/h
Methyl formate	0,245 g/m ³	2,45 g/h

^a The emission rate limit was based on 10 m³ ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is over 20 m³, so a product of 10 is conservative.

^b WHO guideline limit is 0,000 1 g/m³. Background levels are 0,000 03 g/m³. The emission limit cannot push the background level above the guideline limit.

^c A seated human adult has a CO₂ emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO₂ concentration does not reach the WHO eight-hour concentration limit of 9 g/m³. In an environment with 10 m³ ACH, this limits the contribution from the fuel cell to 60 g/h.

Annex A (normative)

Formic acid micro fuel cell power systems

A.1 Scope

A.1.2 Fuels and technologies covered by this annex

Annex A covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use formic acid in water solutions - that are comprised of less than 85 % formic acid by weight - as fuel. These systems and units use direct formic acid fuel cell technologies.

Figure A.1 replaces Figure 1 showing a formic acid micro fuel cell power system block diagram for use with this annex.

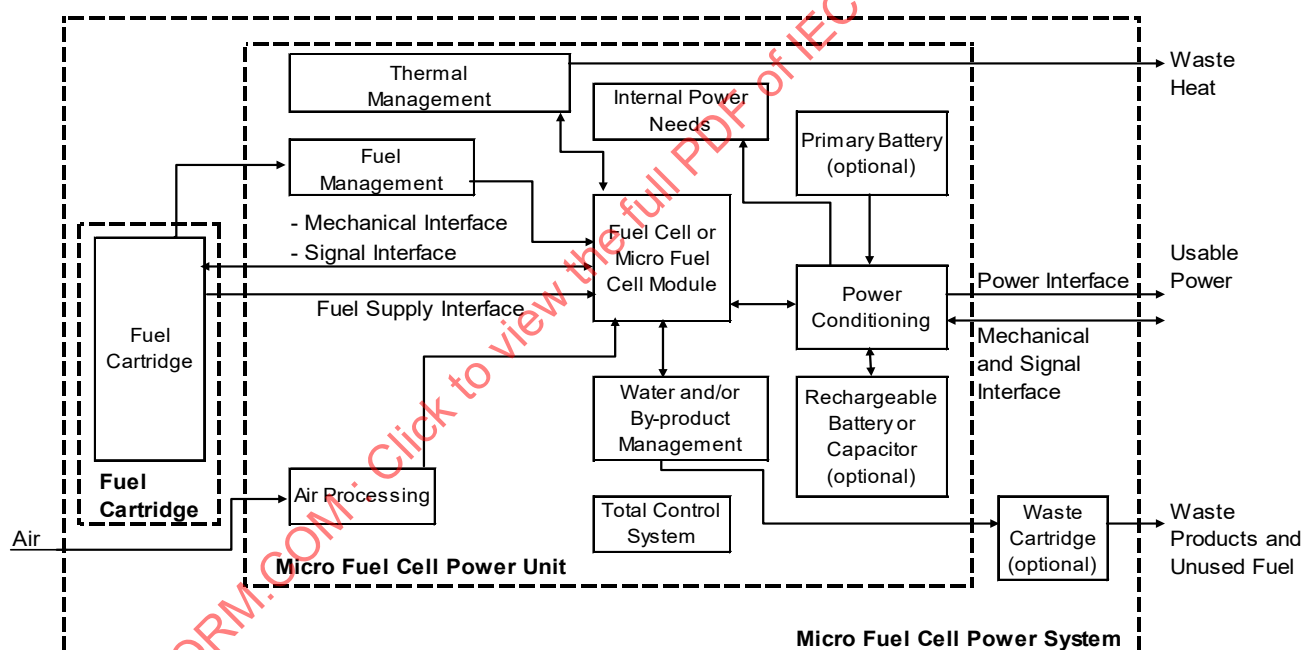


Figure A.1 – Formic acid micro fuel cell power system block diagram –
Replaces Figure 1

A.1.3 Equivalent level of safety

This subclause replaces Subclause 1.3.

- The requirements of this standard are not intended to constrain innovation. The manufacturer may consider fuels, materials, designs or constructions not specifically dealt with in this standard. These alternatives should be evaluated as to their ability to yield levels of safety equivalent to those prescribed by this standard.
- It is understood that all micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall comply with applicable country and local requirements including, but not limited to, those concerning transportation, child-resistance, and storage, where required.

- c) The following similarities between methanol and formic acid micro fuel cell power systems are provided to enhance understanding of why the formic acid requirements mimic methanol requirements with minimal changes.
- 1) The similarity in micro fuel cell power system components (see Figure 1 and Figure A.1).
 - 2) Both types of micro fuel cell power systems use liquid fuels and both micro fuel cell power systems have the “no accessible liquid” criteria for no leakage (see definitions in Clause A.3).
 - 3) Both types of micro fuel cell power systems may have similar gaseous emissions components and thus shall have similar criteria for measurement and analysis of the emissions, and the same considerations shall be made for emission risk levels.
 - 4) Formaldehyde and methyl formate emissions seen in methanol micro fuel cell power systems are not present in formic acid micro fuel cell power systems. Theoretical reactions with formic acid and hydrogen can produce methanol, methyl formate and formaldehyde but these reactions have very high activation energies which can only be achieved with combinations of high temperatures – typically greater than 200 °C – with high pressures – typically greater than 10 MPa – and in the presence of hydrogenation catalysts such as transition metal oxides. These conditions are not expected to be seen in the formic acid micro fuel cell power system, thus the existence of these three emission products, as a result of a reduction reaction forming them, do not have to be considered in formic acid micro fuel cell power systems. Due to the extremely low permissible human exposure levels to formaldehyde, formaldehyde is being measured in the emission test for purposes of validation.
 - 5) Hydrogen and carbon dioxide emissions are only possible when formic acid is exposed to temperatures greater than 150 °C or when it is in contact with decomposition catalysts with no load on the fuel cell. Formic acid fuel cartridges and micro fuel cell power units are not expected to be subjected to such high temperatures. Properly functioning non-operating micro fuel cell power systems shall have fail-safe mechanisms to prevent fuel flow to the catalysts. Failure modes and effects analysis and related testing shall ensure protection against such failure modes and ensure existence of relevant design mitigations.
 - 6) Since even with the micro fuel cell power system off, carbon monoxide and formic acid vapour may be produced from a formic acid fuel cartridge and a micro fuel cell power system, the emission test shall be performed with the micro fuel cell power system off “DEVICE – OFF” as an additional test.
 - 7) Carbon dioxide, carbon monoxide, formic acid vapour, hydrogen and water vapour are all possible emissions from an operational “DEVICE – ON” micro fuel cell power system.
 - 8) Formic acid fuel below 85 % concentration by weight is non-flammable; thus warning statements for the product related to fuel flammability do not apply to formic acid micro fuel cell power system products.

A.3 Terms and definitions

The terms and definitions below replace those corresponding terms and definitions in Clause 3 for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex A. All terms and definitions in Clause 3 not specifically mentioned here also apply.

A.3.5

fuel

formic acid and water solution less than 85 % formic acid concentration by weight

A.3.8

hazardous (corrosive) liquid fuel

formic acid fuel that has a pH less than 3,0 (pH of 3,0 is approximately 0,35 % formic acid by weight in water)

A.3.10

internal reservoir

not applicable to this Annex A

A.3.11

leakage

accessible hazardous liquid fuel outside the micro fuel cell power system or fuel cartridge or a positive pH indication of liquid formic acid (see A.3.37)

A.3.19

no fuel vapour loss

vaporous fuel emission from fuel cartridge, or micro fuel cell power system or unit limited to 0,018 g/h

The additional terms and their definitions below are needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex A in addition to those given in Clause A.3 and in Clause 3.

A.3.37

positive pH indication of liquid formic acid

positive indication of the presence of acid (pH less than 3,0) on pH paper (acid base indicator paper) attached to the possible leak areas of the micro fuel cell power system during the type test.

A.3.38

device

either the micro fuel cell power system (see Figure A.1) or an end use product that incorporates a micro fuel cell power system as its power supply

A.3.39

"DEVICE – ON"

device with its power switch turned on and operating to produce power or unable to produce power due to a failure or other reasons

A.3.40

"DEVICE – OFF"

device with its power switch turned off and not producing power

A.4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges

A.4.12.1.3 *This requirement applies to formic acid fuel cartridges and replaces the corresponding requirement in Subclause 4.12.1.3. All other requirements of Clause 4 apply.*

The maximum formic acid fuel volume in the fuel cartridge shall not exceed 1 l.

A.6 Instructions and warnings for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

A.6.2 Minimum markings required on the fuel cartridge

These markings replace the markings required by Subclause 6.2.

As a minimum, the following shall be marked on the fuel cartridge.

- a) CONTENTS ARE CORROSIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) KEEP AWAY FROM CHILDREN.

- d) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- e) FOLLOW USAGE INSTRUCTIONS.
- f) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- g) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- h) COMPOSITION AND AMOUNT OF FUEL.
- i) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.

A.6.3 Minimum markings required on the micro fuel cell power system

These markings replace the markings required by Subclause 6.3.

In addition, as a minimum, the following shall also be marked on the micro fuel cell power system to show:

- a) CONTENTS ARE CORROSIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) DO NOT EXPOSE TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- d) FOLLOW USAGE INSTRUCTIONS.
- e) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- f) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- g) COMPOSITION AND AMOUNT OF FUEL.
- h) MAXIMUM CAPACITY OF FUEL IN THE INTERNAL RESERVOIR, IF APPLICABLE.
- i) TEXT OR MARKING THAT INDICATES THAT THE MICRO FUEL CELL POWER SYSTEM COMPLIES WITH IEC 62282-6-100.
- j) ELECTRICAL OUT PUT (VOLTAGE, CURRENT, RATED POWER).

A.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

A.7.1 General

This Subclause A.7.1 replaces Subclause 7.1 for this annex when testing formic acid micro fuel cell power systems, formic acid micro fuel cell power units and formic acid fuel cartridges.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table A.5 lists the type tests that shall be performed. *Table A.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table A.6. *Table A.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of 22 °C ± 5 °C for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table A.5 – List of type tests – Replaces Table 5

Test reference	Test item	Test sample
A.7.3.1	Pressure differential tests	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.2	Vibration test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.3	Temperature cycling test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.4	High temperature exposure test	Fuel cartridge Partially filled fuel cartridge
7.3.5	Drop test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.6	Compressive loading test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
A.7.3.9	Long-term storage test	Fuel cartridge Partially filled fuel cartridge
7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Partially filled fuel cartridge and micro fuel cell power unit
7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit
A.7.3.12	Emission test	Micro fuel cell power system or power unit

Table A.5 replaces Table 5.

Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or partially filled, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test.

Test sequence: Tests 7.3.2 and 7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests A.7.3.1, 7.3.2, and 7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or power units.

Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.

Table A.6 – Laboratory standard conditions – Replaces Table 6

Item	Condition
Laboratory temperature	Laboratory temperature is "room temperature" (standard temperature condition, 22 °C ± 5 °C)
Laboratory room atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen.
Table A.6 replaces Table 6.	

A.7.2 Leakage measurement of formic acid and the measuring procedure

This Subclause A.7.2 replaces Subclause 7.2 for this annex when testing formic acid micro fuel cell power systems, formic acid micro fuel cell power units and formic acid fuel cartridges.

- a) *The leakage measurement of formic acid shall be executed in principle in accordance with the procedures shown in Figures A.2 through A.7. These figures and their procedures replace the corresponding figures in Subclause 7.2.*
- b) As an additional tool for finding formic acid leaks, pH paper, attached to the possible leak areas of the micro fuel cell power system, shall be used to aid in the visual check for liquid formic acid leaks (see definition of "positive pH indication of liquid formic acid"). This is an additional requirement in Annex A for formic acid fuel cells. For operational tests, reactant air passages into the micro fuel cell power system and exhaust ports should not be blocked with pH paper.

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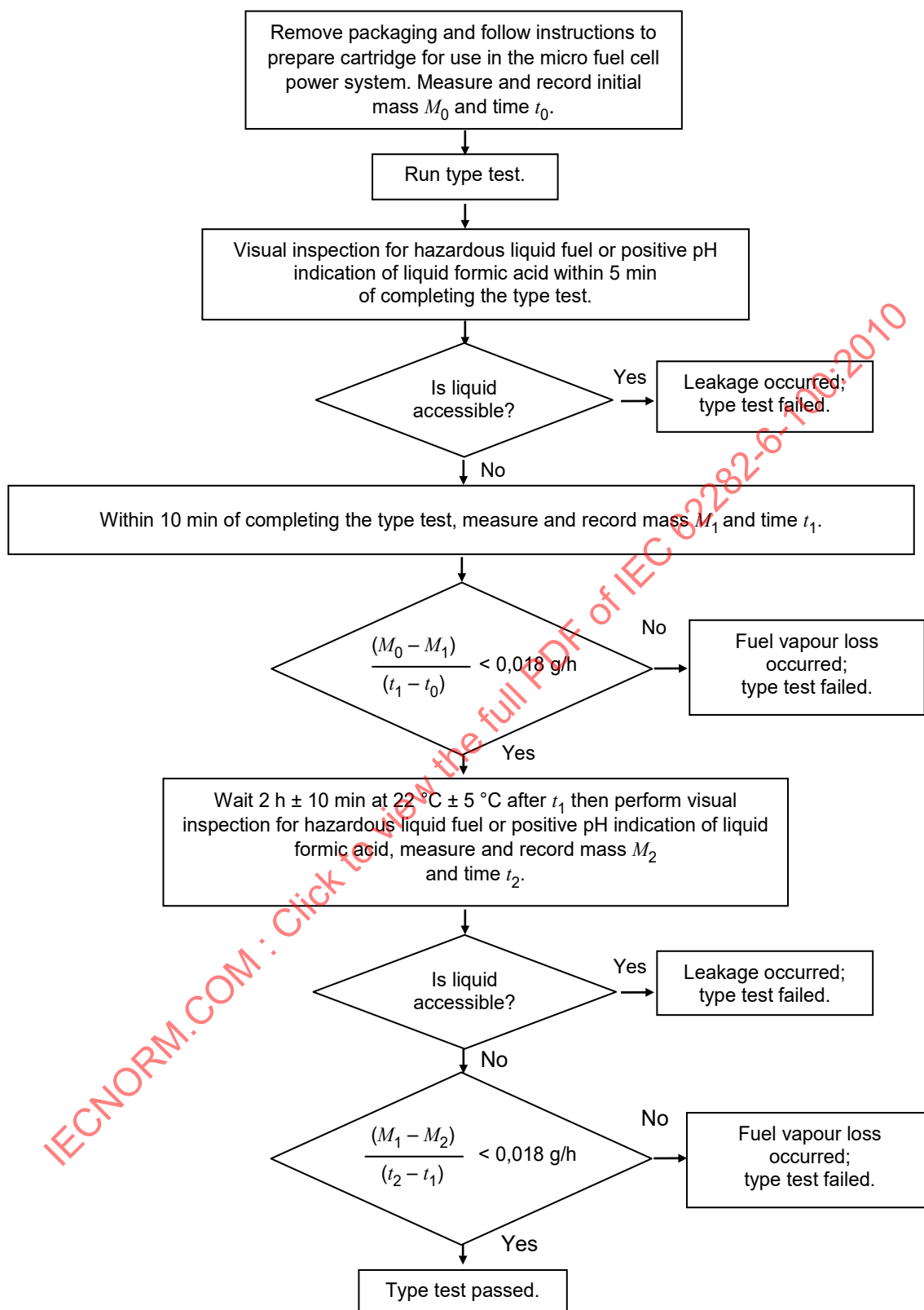


Figure A.2 – Fuel cartridge leakage and mass loss test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

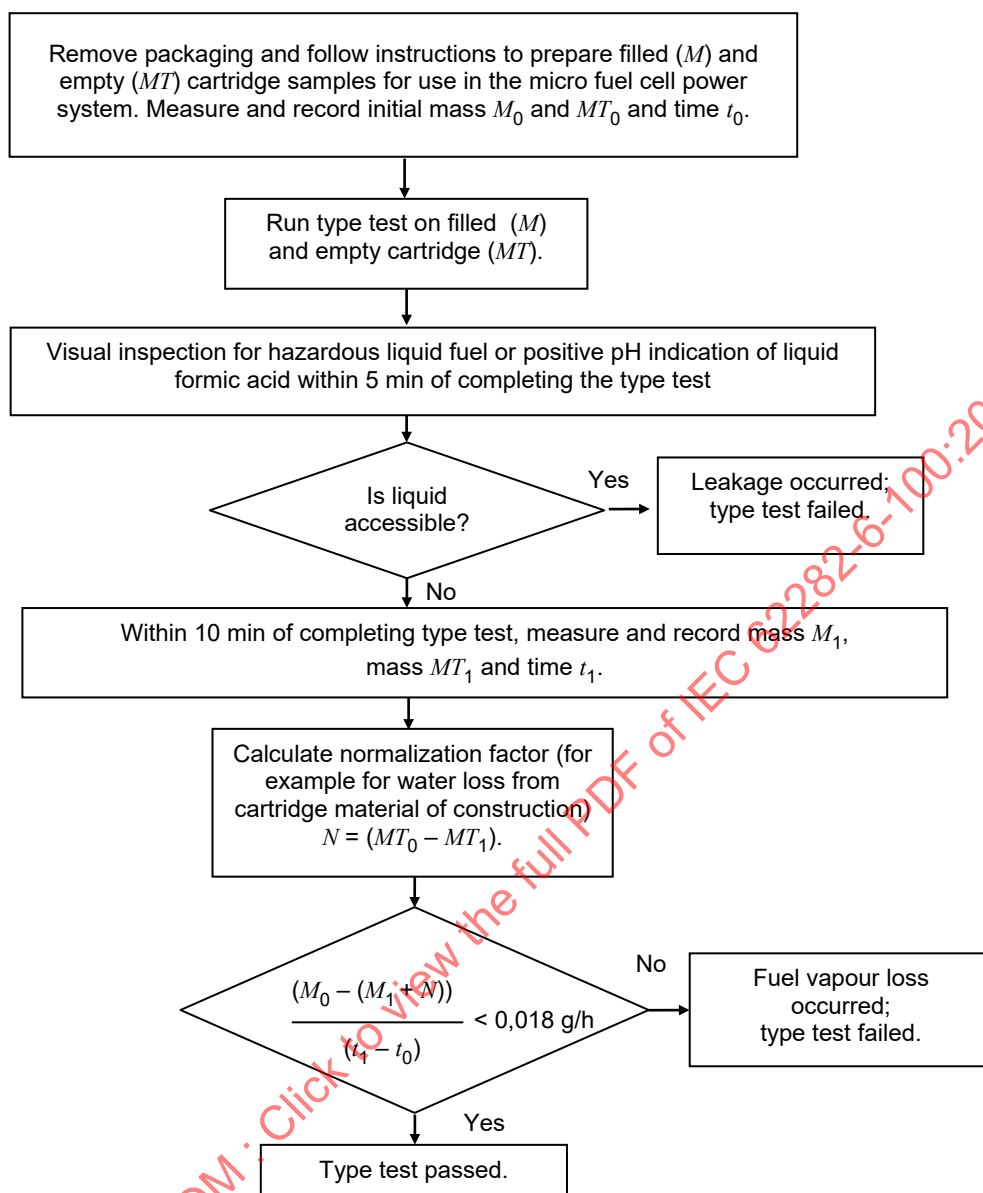


Figure A.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

The maximum time interval $t_1 - t_0$ shall be set so that no more than half the fuel would be lost if it were escaping at the maximum allowable mass loss rate.

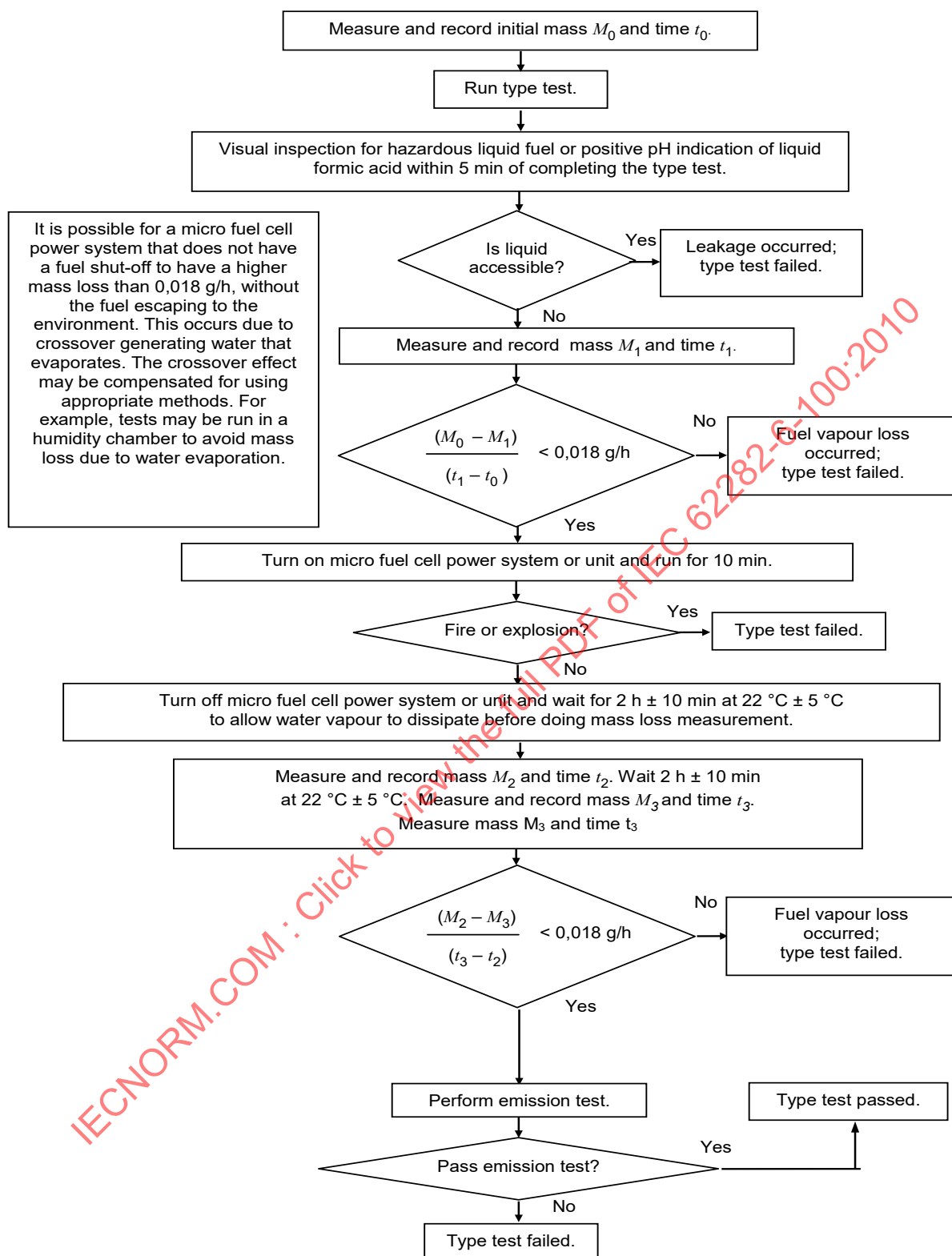


Figure A.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss flow chart for pressure differential, vibration, temperature cycling test, drop, and compressive loading tests – Replaces Figure 4

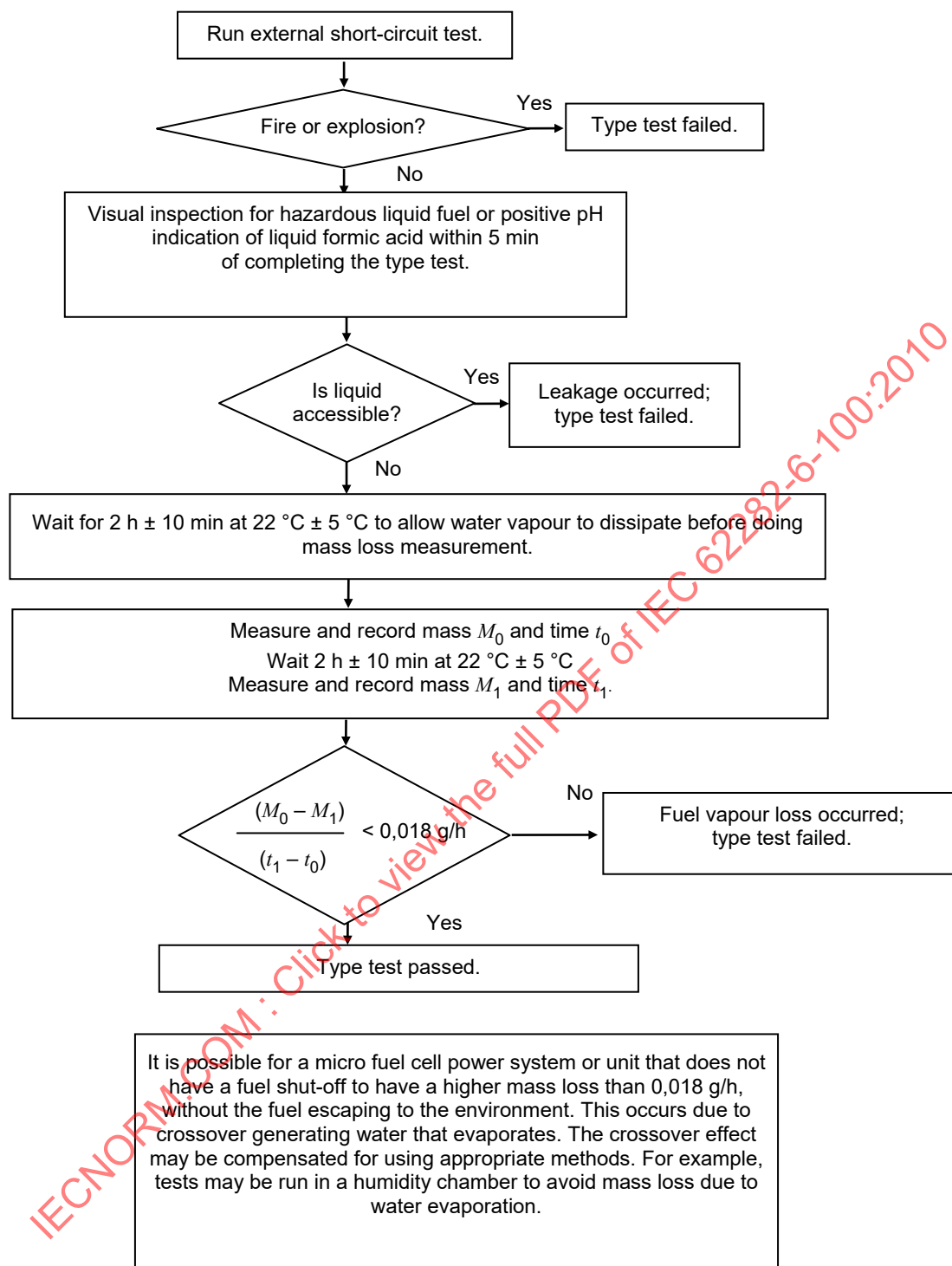


Figure A.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

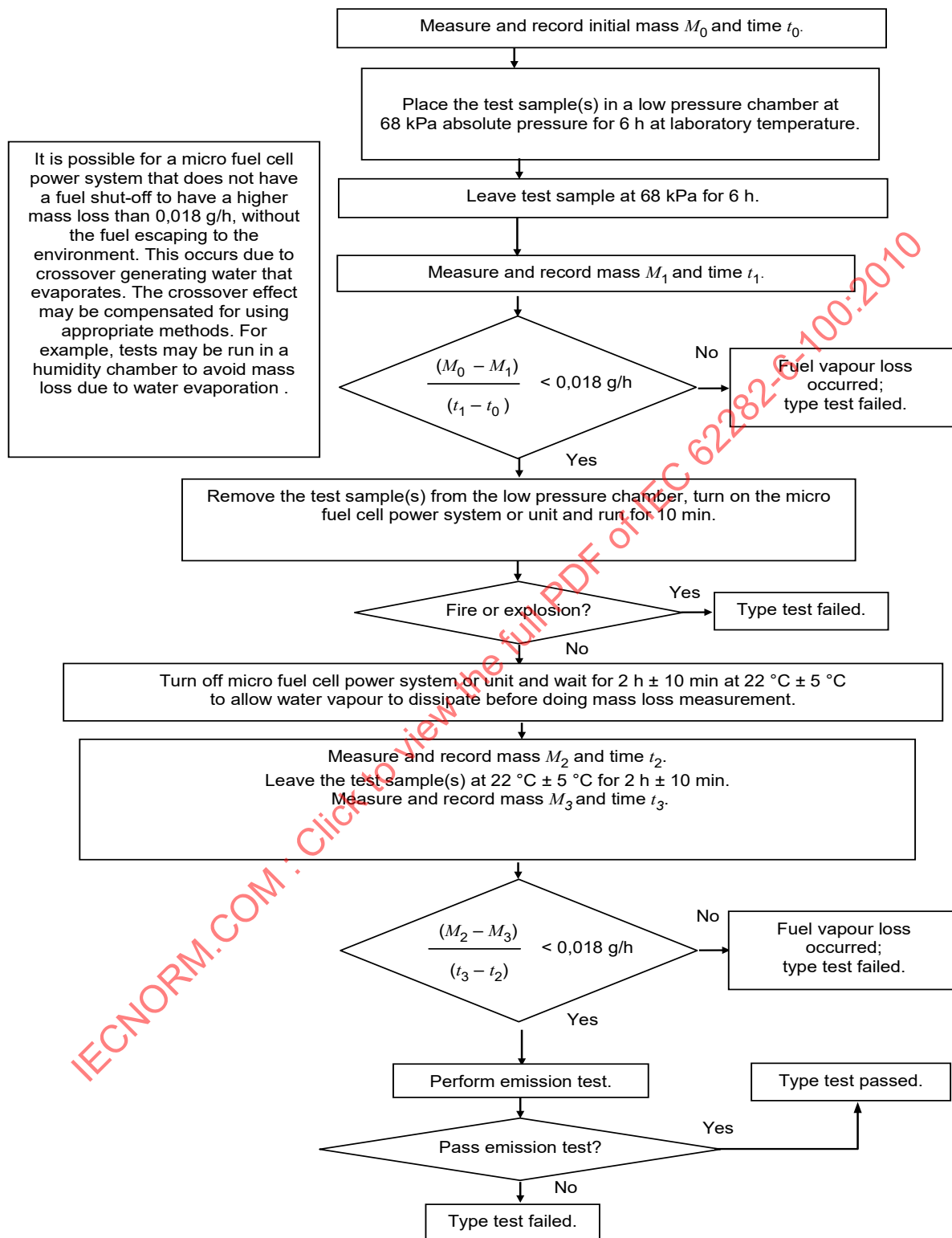


Figure A.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

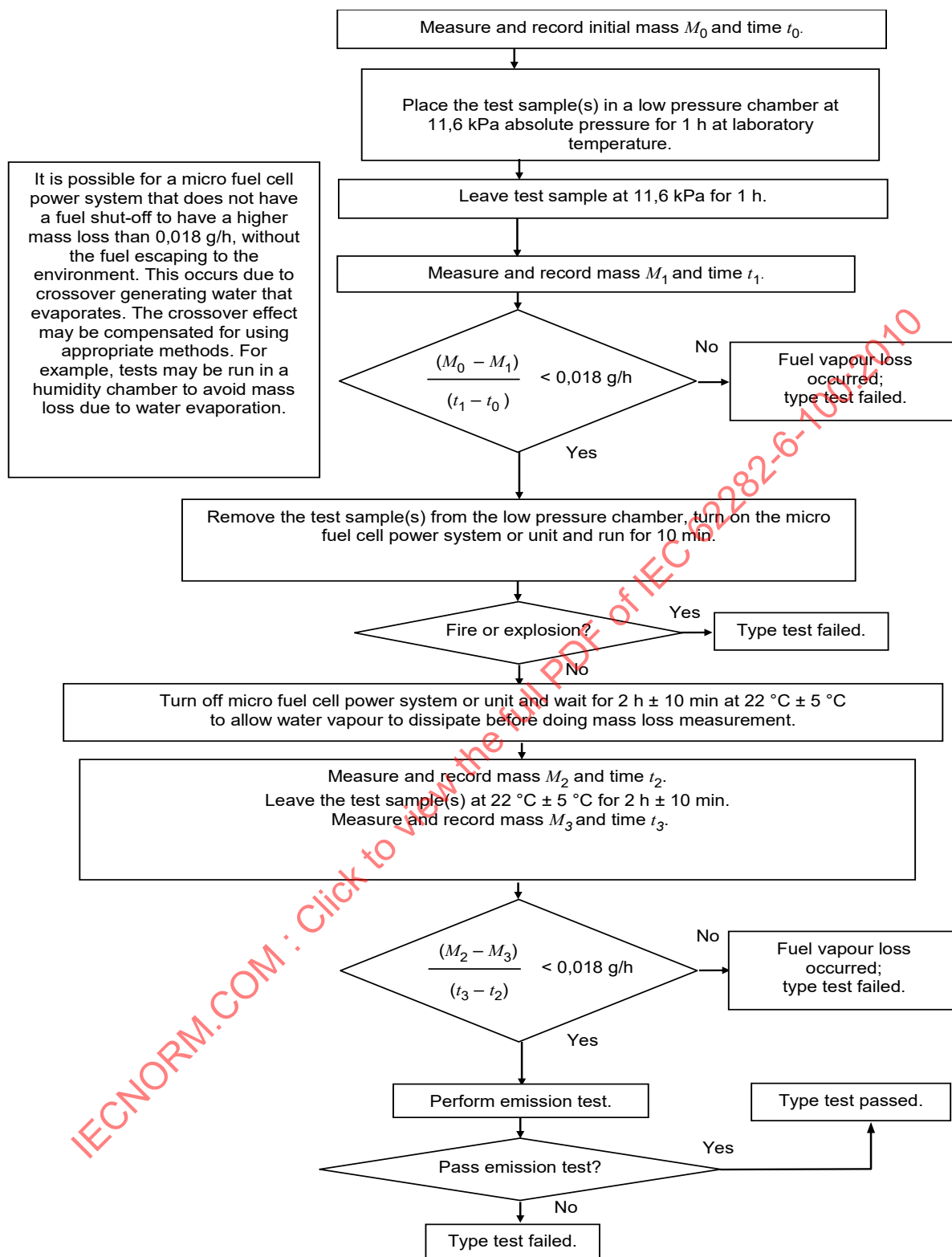


Figure A.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

A.7.3 Type tests

A.7.3.1 Pressure differential tests

A.7.3.1.1 General

Subclause A.7.3.1 replaces Subclause 7.3.1.

Portions of this test check compliance with Subclause 4.12.1.2 to verify that there shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Depending upon which of the two limiting pressure conditions is greater, two options for testing are provided:

- a) If 95 kPa internal gauge pressure plus normal working pressure of the fuel cartridge at 22 °C is greater than two times the gauge pressure of the fuel cartridge at 55 °C, either Subclause A.7.3.1.2 or Subclause A.7.3.1.3 may be used to verify compliance with Subclause 4.12.1.2.
- b) If two times the gauge pressure of the fuel cartridge at 55 °C is greater than 95 kPa internal gauge pressure plus normal working pressure at 22 °C, Subclause A.7.3.1.2 shall be used to verify compliance with Subclause 4.12.1.2.

A.7.3.1.2 Fuel cartridge internal pressurization test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**

For the internal pressurization test, the fuel cartridge body and the fuel cartridge valve shall be tested separately.

- 1) Using a suitable fluid medium such as water, pressurize the fuel cartridge body to an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater.
- 2) The pressure rise shall not exceed a rate of 60 kPa/s.
- 3) Maintain the maximum pressure for 30 min at laboratory temperature.
- 4) Using a suitable fluid medium such as water, pressurize the closed fuel cartridge valve to 95 kPa gauge pressure plus the normal working pressure of the cartridge at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater.
- 5) The pressure rise shall not exceed a rate of 60 kPa/s.
- 6) Maintain the maximum pressure for 30 min at laboratory temperature.
- d) **Passing criteria:** No accessible liquid test medium leakage and no sudden drop of pressure during the course of the test. Leakage shall be checked visually. Invert the fuel cartridge and the fuel cartridge valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails.

A.7.3.1.3 Fuel cartridge low external pressure test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure A.2.
 - 2) The sample shall be placed in a vacuum chamber and the pressure in the vacuum chamber shall be reduced to 95 kPa below normal atmospheric pressure.
 - 3) Maintain the vacuum for 30 min.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no fuel vapour loss. See Figure A.2. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

A.7.3.1.4 Micro fuel cell power system or micro fuel cell power unit pressure differential tests**A.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test**

This test is required for all formic acid micro fuel cell power systems and formic acid micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure A.6.
 - 2) Test samples shall be stored at a low external pressure of 68 kPa absolute pressure for 6 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure A.6.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with A.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no fuel vapour loss. See Figure A.6. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of A.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test result is acceptable. During the 6 h test at 68 kPa absolute external pressure, the fuel vapour loss shall be less than 0,018 g/h.

A.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

This test is required for all formic acid micro fuel cell power systems and formic acid micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure A.7.
 - 2) Test samples shall then be stored at a low external pressure of 11,6 kPa absolute pressure for 1 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure A.7, with a fuel vapour loss at 11,6 kPa YES/NO passing criteria of less than 0,018 g/h on the basis of not exceeding 25 % of the lower flammability limit (LFL).
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with A.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no fuel vapour loss. See Figure A.7. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of A.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of A.7.3.12, the emission test result is acceptable. During the 1 h test at 11,6 kPa absolute external pressure, the fuel vapour loss shall be less than 0,018 g/h.

A.7.3.9 Long-term storage test

A.7.3.9.1 General

Subclause A.7.3.9 replaces Subclause 7.3.9 for formic acid fuel cartridges testing in this Annex A. Figure A.9, included herein, replaces Figure 9 for this Annex A.

- a) Either A.7.3.9.2 Option 1 – Continuous weight measurement, A.7.3.9.3 Option 2 – Periodic measurements or A.7.3.9.4 Option 3 – One weight measurement, may be used.
- b) If the results of this test do not pass the 0,018 g/h limit for fuel vapour loss, then a full emission test (A.7.3.12) shall be performed for the fuel cartridge only situation at 50 °C in the 1 m³ ACH volume with all emission components measured. "DEVICE – OFF" limits of Table A.7 shall be met.

A.7.3.9.2 Option 1 – Continuous weight measurement

Option 1 is not preferred for formic acid fuel cartridges due to the very low anticipated fuel vapour loss.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure A.9):
 - 1) Use a load cell (continuous electronic weight sensing device) designed and calibrated for use at 50 °C inside the temperature chamber.

- 2) Place the load cell in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Place the fuel cartridge on top of the load cell so that all the weight is being applied to the load cell. A fixture may be used to control the position of the fuel cartridge, to ensure all the weight is applied to the load cell.
- 3) Connect a digital readout to the load cell and collect the data either manually or automatically. The data should be collected with a high degree of confidence to assure that the fuel vapour loss does not exceed 0,018 g/h.
- 4) Measure and record initial mass M_{initial} and time t_i .
- 5) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
- 6) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,018 g/h, then the test sample passes the test for fuel vapour loss.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{final}} = \text{the final mass of the fuel cartridge.}$$

- 7) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,018 g/h.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$$

$$\text{ii) } \Delta t_{\text{last}} = \text{the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{last}} = \text{the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss and no liquid leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure A.9. If the fuel cartridge fuel vapour loss is not less than 0,018 g/h, then the test sample fails the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

If the results of this test do not pass the 0,018 g/h limit for fuel vapour loss, then a full emission test (A.7.3.12) shall be performed for the fuel cartridge only situation at 50 °C in the 1 m^3 ACH volume with all emission components measured. "DEVICE – OFF" limits of Table A.7 shall be met.

A.7.3.9.3 Option 2 – Periodic weight measurements

Option 2 is preferred for formic acid fuel cell cartridges.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure A.9):
 - 1) Place the fuel cartridge in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Weight measurements should be collected with a high degree of confidence to determine if the fuel vapour loss does not exceed 0,018 g/h with a minimum of once every three days.
 - 2) Measure and record initial mass M_{initial} and time t_i .
 - 3) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
 - 4) The time in which the test samples are removed from the chamber for measurement shall not be included in the time the test sample is to be tested (28 days). Additional time should be added to get the test sample to the test temperature ($50\text{ °C} \pm 2\text{ °C}$) each time the test sample is removed from the chamber. The test samples should only be stabilised at laboratory temperature if the mass loss will be affected.
 - 5) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,018 g/h, then the test sample passes the test for fuel vapour loss.
 - i) Fuel vapour loss $= \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$
 - ii) $\Delta t = t_f - t_i = 28\text{ days} \times 24\text{ h/day} = 672\text{ h}$.
 - iii) M_{initial} = the initial mass of the fuel cartridge.
 - iv) M_{final} = the final mass of the fuel cartridge.
 - 6) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,018 g/h.
 - i) Fuel vapour loss $= \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$
 - ii) Δt_{last} = the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.
 - iii) M_{initial} = the initial mass of the fuel cartridge.
 - iv) M_{last} = the last weight measurement taken when liquid fuel still remained in the fuel cartridge.
- d) **Passing criteria:** No fire at any time, no explosion at any time, no fuel vapour loss and no liquid leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure A.9. If the fuel cartridge fuel vapour loss is not less than the 0,018 g/h fuel vapour loss criteria, then the test sample fails the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

If the results of this test do not pass the 0,018 g/h limit for fuel vapour loss, then a full emission test (A.7.3.12) shall be performed for the fuel cartridge only situation at 50 °C in the 1 m³ ACH volume and all emission components measured. "DEVICE – OFF" limits of Table A.7 shall be met.

A.7.3.9.4 Option 3 – One weight measurement

This option is intended for fuel cartridges with very small leak rates. Option 3 may also be used for formic acid fuel cartridges with very small leak rates.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure A.9):
 - 1) Measure and record initial mass M_{initial} and time t_i .
 - 2) Place the fuel cartridges in a temperature chamber at 50 °C ± 2 °C. After 28 days, the fuel cartridges are removed from the chamber for measurement. The test samples should be stabilised at laboratory temperature if the mass loss will be affected. Then the weight measurement is executed.
 - 3) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,018 g/h, then the test sample passes the test for fuel vapour loss.
 - i) Fuel vapour loss $= \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$
 - ii) $\Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h}$.
 - iii) M_{initial} = the initial mass of the fuel cartridge.
 - iv) M_{final} = the final mass of the fuel cartridge.
 - 4) If the fuel cartridge is empty after 28 days, then the type test according to A.7.3.9.2 Option 1 or A.7.3.9.3 Option 2 shall be done.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss and no liquid leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure A.9. If the fuel cartridge fuel vapour loss is less than the 0,018 g/h fuel vapour loss criteria, then the test sample passes the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

If the results of this test are not less than the 0,018 g/h limit for fuel vapour loss, then a full emission test (A.7.3.12) shall be performed for the fuel cartridge only situation at 50 °C in the 1 m³ ACH volume with all emission components measured. "DEVICE – OFF" limits of Table A.7 shall be met.

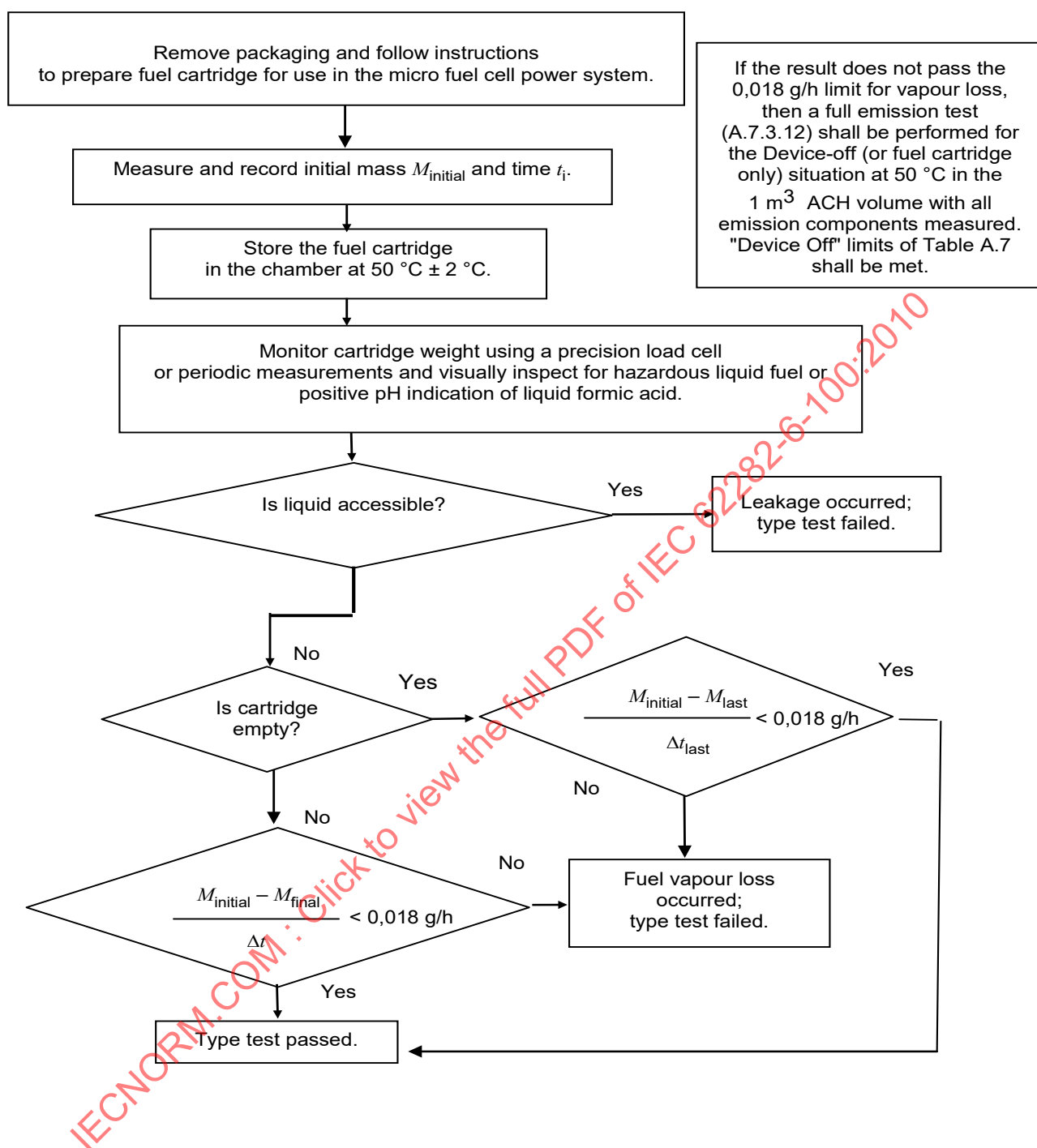


Figure A.9 – Fuel cartridge leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

NOTE The eight-hour time weighted average (TWA) limit for carbon monoxide is 25 ppmv²⁾. The fifteen-minute short term exposure limit (STEL) for carbon monoxide is 200 ppmv. Due to the extremely low formic acid to carbon monoxide decomposition rate at 50 °C and the human exposure limit to carbon monoxide being higher than formic acid (TWA = 5 ppmv and STEL = 10 ppmv), the assumption that all mass loss in this test is formic acid makes this evaluation more conservative. If result does not pass the 0,018 g/h limit for fuel vapour loss, a full emission test (A.7.3.12) is allowed.

2) ppmv = parts per million by volume.

A.7.3.12 Emission test

This Subclause A.7.3.12 shall replace Subclause 7.3.12 for formic acid micro fuel cell power systems or units tested in accordance with Annex A. The included Table A.7, Emission limits, replaces Table 7 in Subclause 7.3.12. The new additional Table A.8, Occupational exposure limits, is provided to inform the user regarding exposure limits. Figure A.10 replaces Figure 10 and is identical to Figure 10. Hydrogen emissions are evaluated separately. The procedure for hydrogen emission testing is detailed in Figure A.12, which is to be used as an additional figure when testing is done in accordance with Annex A.

- a) **Test sample:** A micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or a micro fuel cell power unit – that is fuelled with formic acid – emissions of formic acid vapours, carbon dioxide, carbon monoxide, formaldehyde, hydrogen, and water vapour shall be maintained at less than the specified values. Maintaining these limits not only prevents inadvisable exposure but also ensures an adequate supply of oxygen is maintained in the operating environment.

Since even with the micro fuel cell power system off, carbon monoxide and formic acid vapour may be produced from a formic acid fuel cartridge and a micro fuel cell power system, the emission test shall also be performed with the micro fuel cell power system off ("DEVICE – OFF") as an additional test. Carbon monoxide and formic acid vapour shall be kept below the "DEVICE – OFF" limits given to avoid harmful exposures.

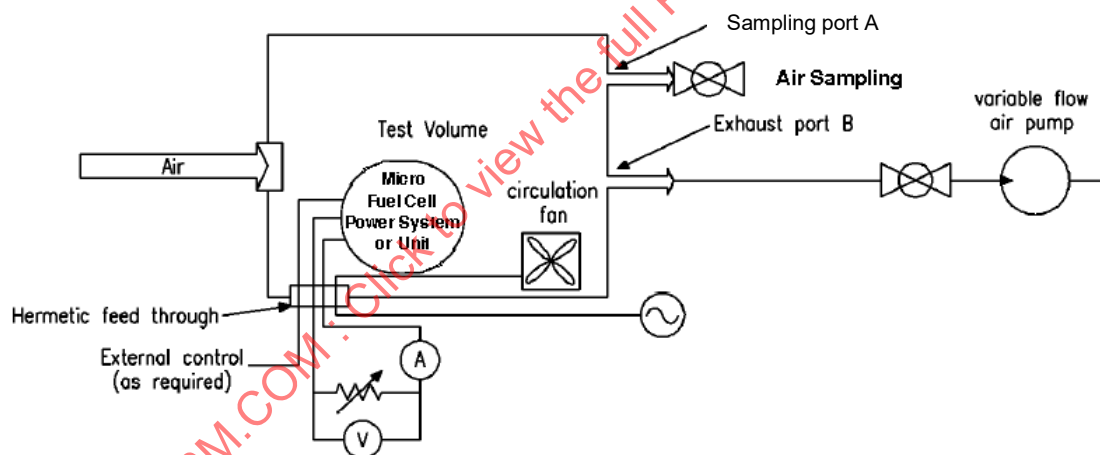


Figure A.10 – Operational emission rate testing apparatus – Replaces Figure 10

- c) **Test apparatus:** An example of the operational emission test apparatus is shown in Figure A.10. The configuration shown in Figure A.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex A. Emission rate testing in accordance with A.7.3.12 d) 1) is required for all types of micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex A.

For micro fuel cell power systems or units that are intended to be used in close proximity to a consumer's mouth or nose (such as micro fuel cell power systems or units used to power cell phones, handheld games, etc.), additional testing in accordance with A.7.3.12 d) 3) and A.7.3.12 d) 4) is required to verify that emission concentrations in the vicinity of a user's mouth or nose are kept within appropriate limits. This emission concentration testing shall be done in a large open room using a different emission concentration testing apparatus. An example of the operational emission concentration testing apparatus is shown in Figure A.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance

from the micro fuel cell power system or unit to a consumer's mouth or nose when in use) for emissions concentration limit testing.

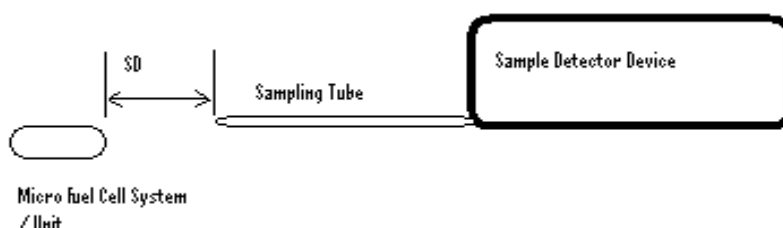


**Figure A.11 – Operational emission concentration testing apparatus –
Replaces Figure 11**

Emission gases might be composed of toxic organic materials such as formic acid vapours, carbon dioxide, carbon monoxide and formaldehyde, which are potentially exhausted from a micro fuel cell power system or a micro fuel cell power unit.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) shall be used by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyzer through sampling port A in Figure A.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

A hydrogen detector calibrated for the zero-to-one-percent mass concentration hydrogen range can be used to measure the hydrogen concentration.

The concentration of CO and CO₂ gas can be measured by a non-dispersive infrared absorption analyzer. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) Test procedure:

Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure A.12, which is to be used as an additional figure when testing is done in accordance with Annex A.*

Emission rate sampling tests shall be performed both with the micro fuel cell power system or unit on ("DEVICE – ON") and with the micro fuel cell power system or unit off ("DEVICE – OFF") as follows:

- 1) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed with the micro fuel cell power system or unit on ("DEVICE – ON") as follows.
 - i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure A.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.

- iii) Gaseous emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure A.10.
- iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure A.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vi) Record the concentrations of chemical compounds of interest. See Table A.7.
- vii) Calculate the emission rate of chemical compounds of interest being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- viii) Compare the maximum measured "DEVICE – ON" emission rate to Table A.7. If the emission rate is not less than the emission rate limit in Table A.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria A.7.3.12 e) 1) i) and A.7.3.12 e) 2) i).
 - ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 2) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed with the micro fuel cell power system or unit off ("DEVICE – OFF") as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure A.10 for 10 min or until 10 % of the fuel capacity of a full fuel cartridge is used up, whichever is less.

- ii) Turn the micro fuel cell power system or unit off ("DEVICE – OFF") and measure the emission rates with the micro fuel cell power system or unit off ("DEVICE – OFF") inside the small test chamber shown in Figure A.10.
- iii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- iv) Gaseous emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown on Figure 10.
- v) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- vi) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure A.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vii) Record the concentrations of chemical compounds of interest. See Table A.7.
- viii) Calculate the emission rate of chemical compounds being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- ix) Compare the maximum measured "DEVICE – OFF" emission rate to Table A.7. If the emission rate is not less than the emission rate limit in Table A.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria A.7.3.12 e) 1) i) and A.7.3.12 e) 2) i).
 - x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 3) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emissions concentration sampling test shall be performed with the micro fuel cell power system or unit on "DEVICE – ON" as follows.

- i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling system do not contribute emissions (that is, contaminants) to the test. Prior to testing, a system check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results. Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - ii) Operate the micro fuel cell power system or micro fuel cell power unit at rated power in the large open room while sampling the emission concentrations using the operational emission concentration testing apparatus shown in Figure A.11. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission concentration test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "ON" position.
 - iii) Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - iv) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the operational emission concentration testing apparatus shown in Figure A.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - v) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - vi) Allow the sample flow rate to stabilise.
 - vii) Sample and record the fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - viii) Record the concentrations of the chemical compounds of interest. See Table A.7.
 - ix) Compare the maximum stabilized concentrations to Table A.7. If the emission concentrations are not less than the emission concentration limits in Table A.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria A.7.3.12 e) 2) ii).
 - x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 4) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emissions concentration and emission rate sampling test shall be performed with the micro fuel cell power system or unit off "DEVICE – OFF" as follows.
- i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling system do not contribute emissions (that is, contaminants) to

the test. Prior to testing, a system check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results. Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.

- ii) Operate the micro fuel cell power system or micro fuel cell power unit at rated power for 10 min or until 10 % of the fuel capacity of a full fuel cartridge is used up, whichever is less.
 - iii) Turn the micro fuel cell power system or unit off ("DEVICE – OFF") while sampling the emission concentrations using the operational emission concentration testing apparatus shown in Figure A.11.
 - iv) Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - v) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the emission concentration testing apparatus shown in Figure A.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - vi) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - vii) Allow the sample flow rate to stabilise.
 - viii) Sample and record the fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - ix) Record the concentrations of the chemical compounds of interest. See Table A.7.
 - x) Compare the maximum stabilized concentrations to Table A.7. If the emission concentrations are not less than the emission concentration limits in Table A.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria A.7.3.12 e) 2) ii).
 - xi) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 5) Upon completion of the emissions measurements with both "DEVICE – ON" and "DEVICE – OFF" in accordance with Table A.7, "DEVICE – ON" hydrogen emissions are evaluated as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure A.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure A.10.

- iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure A.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vi) Record the hydrogen concentration.
- vii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- viii) Compare the maximum measured "DEVICE – ON" hydrogen emission rate to Table A.7.

NOTE This is a stabilised concentration measurement.

- ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 6) Upon completion of the hydrogen emissions measurements with "DEVICE – ON", hydrogen emissions with ("DEVICE – OFF") are evaluated as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure A.10 for 10 min or until 10 % of the fuel capacity of a full fuel cartridge is used up, whichever is less.
 - ii) Turn the micro fuel cell power system or unit off ("DEVICE – OFF") and measure the emission rates with the micro fuel cell power system or unit off ("DEVICE – OFF") inside the small test chamber shown in Figure A.10.
 - iii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.

- iv) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown on Figure A.10.
- v) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- vi) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure A.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vii) Record the hydrogen concentration.
- viii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- ix) Compare the maximum measured "DEVICE – OFF" hydrogen emission rate to Table A.7.

NOTE This is a stabilised concentration measurement.

- x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

7) Evaluate the hydrogen emission rate as follows.

- i) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and below the allowable 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or unit passes the test and no further testing is necessary.
- ii) If the hydrogen emission rate measurement is not below the allowable 0,0032 g/h with the "DEVICE – OFF" and not below the total allowable 0,8 g/h with the "DEVICE – ON", the system or unit fails the test and no further testing is necessary.
- iii) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and is below the total allowable 0,8 g/h with the "DEVICE –

ON" but is not below 0,016 g/h with the "DEVICE – ON", then proceed with A.7.3.13, hydrogen point source gas loss detection test to verify that no single source of hydrogen exceeds 0,016 g/h.

e) **Passing criteria:**

- 1) For micro fuel cell power systems and micro fuel cell power units not intended to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table A.7 shall be less than the emission rate limit value in Table 7 when tested in accordance with A.7.3.12 d) 1) for "DEVICE – ON" and A.7.3.12 d) 2) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 2) For micro fuel cell power systems and micro fuel cell power units to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table A.7 shall be less than the emission rate limit value in Table A.7 when tested in accordance with A.7.3.12 d) 1) for "DEVICE – ON" and A.7.3.12 d) 2) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
 - ii) For micro fuel cell power systems and micro fuel cell power units intended to be used in close proximity to a consumer's mouth or nose; in addition to meeting the emission rate limit above, the maximum emission concentration for each of the constituents of interest shall be less than the emission concentration limit in Table A.7 when tested in accordance with A.7.3.12 d) 3) "DEVICE – ON" and A.7.3.12 d) 4) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 3) Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure A.12, which is to be used as an additional figure when testing is done in accordance with Annex A.* Upon completion of the hydrogen emissions measurements with both "DEVICE – ON" and "DEVICE – OFF" in accordance with Table A.7, hydrogen emissions are evaluated as follows.
 - i) **Passing criteria for non-operating systems:** The hydrogen emission rate shall be less than 0,0032 g/h with the "DEVICE – OFF".
 - ii) **Passing criteria for operational systems:** If the total hydrogen emission rate is less than 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or micro fuel cell power unit passes the emission test and no further testing is required. If the total hydrogen emission rate is not less than 0,8 g/h with the "DEVICE – ON", the micro fuel cell power system or unit fails the emission test and no further testing is required. If the hydrogen emission rate is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON", A.7.3.13, hydrogen point source gas loss detection test shall be performed with acceptable results to show no more than 0,016 g/h hydrogen leakage from any single point leak.

NOTE 1 The allowable flammable hydrogen emission level that will not support a standing flame is 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). The non-flammable hydrogen emissions limit is based on the criteria that hydrogen emission does not build up to more than 25 % of LFL in the reference volume.

NOTE 2 Hydrogen is defined as a simple asphyxiant but for this risk to exist, oxygen levels have to fall less than 18 % at normal atmospheric pressure. Hydrogen related flammability risk arises at hydrogen-in-air concentrations greater than 4 %, while the asphyxiant risk arises at hydrogen-in-air concentrations greater than 12 %. Therefore, the flammability limits are used in defining the limits for hydrogen emissions.

NOTE 3 Carbon dioxide, carbon monoxide and formic acid vapour emission level limits are based on toxicity and corrosivity (formic acid only) effects on humans while the hydrogen emissions level limit is based on the risk of creating a flammable atmosphere in confined spaces and the risk of a potential standing hydrogen flame.

NOTE 4 The formic acid flammability risk, based on the criteria of maintaining the concentration-in-air below 25 % of LFL, is orders of magnitude lower than the toxicity risk (flammability limit = 42 500 ppmv to toxicity limit = 5 ppmv). Thus, the formic acid toxicity level is used to set the limits of its emissions.

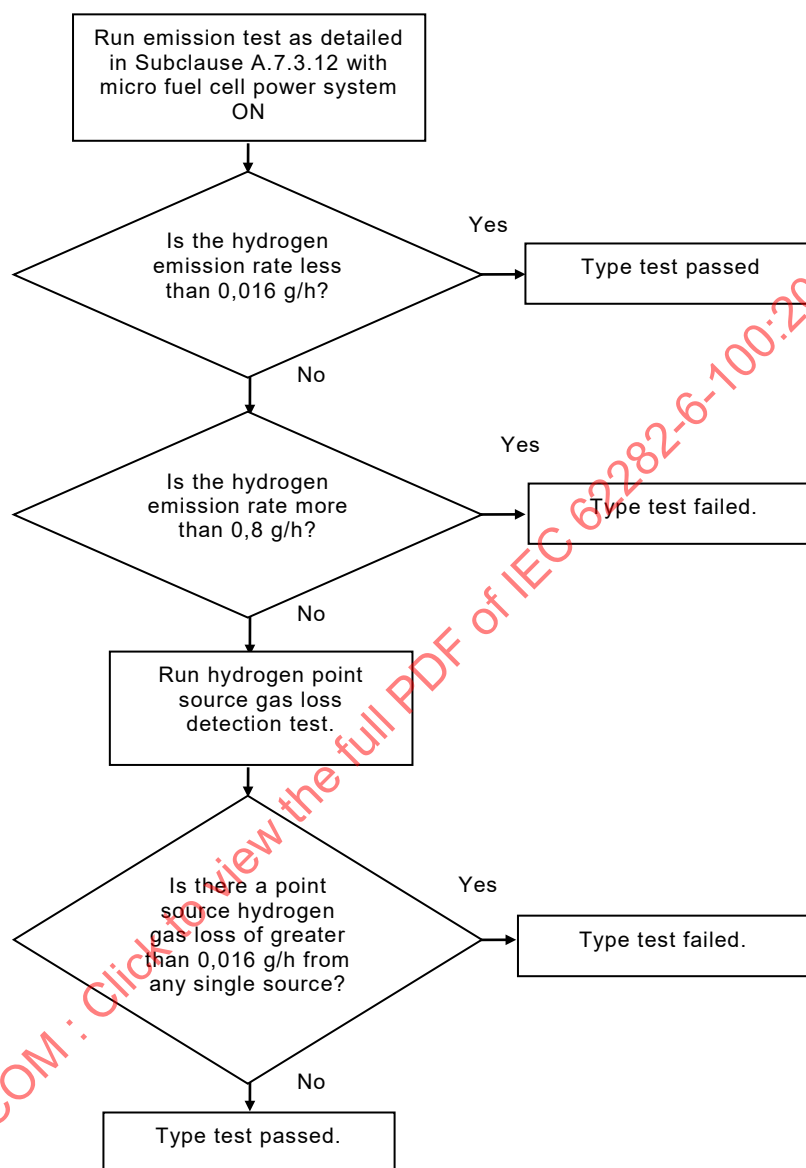


Figure A.12 – Hydrogen emission test procedure for operating micro fuel cell power system

Table A.7 – Emission limits – Replaces Table 7

Emissions	"DEVICE – OFF" Concentration limit ^a based on STEL values for "DEVICE – OFF" test condition	"DEVICE – ON" Concentration limit ^a based on TWA values for "DEVICE – ON" test condition	"DEVICE – OFF" Permissible emissions rate in 1 m ³ ACH volume ^c	"DEVICE – ON" Permissible emissions rate in 10 m ³ ACH volume ^b
Water	Unlimited	Unlimited		
CO	0,232 g/m ³	0,029 g/m ³	0,232 g/h	0,290 g/h
CO ₂	54 g/m ³	9 g/m ³	Not applicable (see A.1.3.C.5)	60 g/h ^d
Formic acid	0,018 g/m ³	0,009 g/m ³	0,018 g/h	0,09 g/h
Formaldehyde ^e	0,000 1 g/m ³	0,000 1 g/m ³	0,000 06 g/h	0,000 6 g/h
Hydrogen ^f	See footnote f	0,8 g/m ³	0,0032 g/h	0,8 g/h total 0,016 g/h from single point leak

^a The concentration limits for CO, CO₂ and formic acid in this table are the mg/m³ equivalent of the TWA and STEL exposure limits, quoted in ppmv, in Table A.8.

^b The "DEVICE – ON" emission rate limit was based on 10 m³ ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is over 20 m³, so a product of 10 is conservative.

^c The "DEVICE – OFF" emission rate is based on 1 m³ ACH because it covers the reasonably foreseeable environments where micro fuel cell power systems may be stored. The limits are based on STEL values because it is reasonable to expect human exposure to such conditions being for short (equivalent to STEL parameters) durations.

^d A seated human adult has a CO₂ emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO₂ concentration does not reach the WHO eight-hour concentration limit of 9 g/m³. In an environment with 10 m³ ACH, this limits the contribution from the fuel cell to 60 g/h.

^e WHO guideline limit is 0,000 1 g/m³. Background levels are 0,000 03 g/m³. The emission limit cannot push the background level above the guideline limit.

^f The hydrogen emission rate for the "DEVICE – OFF" state is based on a 0,283 m³ volume, 0 ACH and 24-h duration for the emission environment. The emission rate for the "DEVICE – ON" state is as per note b but with an additional safety factor of 10.

Table A.8 – Occupational exposure limits

Emissions	TWA exposure limit (TWA – time weighted average over 8 h of operation)	STEL value (15 min exposures to a maximum of 4 times a day)
CO ₂	< 5 000 ppmv	<30 000 ppmv
Formic acid	< 5 ppmv	<10 ppmv
CO	< 25 ppmv	<200 ppmv

A.7.3.13 Hydrogen point source gas loss detection test

The procedure for hydrogen emission testing is detailed in Figure A.12, which is to be used as an additional figure when testing is done in accordance with Annex A. This subclause shall be used if required by Subclause A.7.3.12 d) 7) ii) to show compliance with Table A.7, for formic acid micro fuel cell power systems and formic acid micro fuel cell power units. This subclause is required to be performed to meet the passing criteria of Subclause A.7.3.12 e) 3) ii) if the total hydrogen emission rate from an operational formic acid micro fuel cell power system or unit is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON". This subclause is additional to the requirements in Clause 7.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or a micro fuel cell power unit – that is fuelled with formic acid – emission of hydrogen shall be maintained at less than the specified values in Table A.7. The hydrogen point source gas loss detection test shall be performed to determine that no single source on the micro fuel cell power system or unit can support a flame in all cases where such compliance cannot be definitively determined by the hydrogen emission test. Maintaining these limits ensures that, in addition to not permitting a flammable concentration to build up in the reference volume, there is no gas loss of hydrogen from the specimen that could support a flame and along with the other emissions testing ensures an adequate supply of oxygen is maintained in the operating environment.
- c) **Test apparatus:** The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, a hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL. The response of the aforementioned hydrogen detectors is commonly slow, with a response time of many seconds, thus high sweep speeds may cause underestimation of the hydrogen concentration. It is important that the sweep speed shall be slow enough to accurately measure the hydrogen concentration.
- d) **Test procedure:**
 - 1) The micro fuel cell power system or micro fuel cell power unit shall remain turned on ("DEVICE – ON") throughout the duration of the hydrogen point source gas loss detection test.
 - 2) The testing shall be conducted in a space with no substantial air movement. The measured wind speed 10 cm above the micro fuel cell power system or unit shall not exceed 0,02 m/s. The local concentration of hydrogen diffusion measured in this test is very susceptible to the effect of wind. It is desirable that wind speed anywhere in the test space is as close to zero as possible. Testing in a closed space, such as a glove box or equivalent chamber, is one available method to achieve this requirement.
 - 3) The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL.
 - 4) The sensor of the hydrogen detector shall sweep the micro fuel cell power system or unit at a distance no more than 3 mm normal to the surface of the micro fuel cell power system or unit. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the micro fuel cell power system or unit. The entire surface of the micro fuel cell power system or unit shall be swept in this manner.

- 5) An effective method for completing these sweeps would be to attach a stand off to the sensor that ensures that a spacing of 3 mm from the micro fuel cell power system or unit is maintained at all times. A pen or other marking utensil attached to the stand off could be used to identify swept areas and ensure that the distance between sweeps does not exceed 8 mm.
 - 6) The sensor should always face directly downward, and the micro fuel cell power system or unit should be moved beneath it such that the surface directly below the sensor is always horizontal.
 - 7) If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the micro fuel cell power system or unit shall be considered to have passed.
 - 8) When some point source sweeps show a large region of 25 % LFL or greater in the initial linear sweeps, recording the measured concentration values will assist in determining the starting point of secondary spiral sweeps. Point sources are supposed to be where local maximum values exist in the distribution of measured concentration values.
 - 9) If any points are detected to have a hydrogen concentration of 25 % LFL or greater, a second test shall be conducted to ensure that the emission does not exceed 0,016 g/h of pure hydrogen from any single source.
 - 10) The second test shall be performed with the sensor height adjusted to 6,5 mm above the micro fuel cell power system or unit.
 - 11) A spiral sweep shall then be made, originating from the point where the detection of 25 % LFL or greater of hydrogen occurred during the initial linear sweep. The spiral sweep shall have a spacing of 1 mm or less between sweeps, and shall spiral out to a radial distance of at least 4 mm and far enough to detect the maximum hydrogen level from the particular hydrogen source.
 - 12) If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the micro fuel cell power system or unit passes the test.
- e) **Passing criteria:** No gas loss of hydrogen from any single source at greater than 0,016 g/h as indicated by sweep testing. No indications of hydrogen that is 25 % of LFL during the primary sweep testing or no indications of hydrogen that is 25 % of LFL during the secondary sweep testing at 6,5 mm above the micro fuel cell power system or unit. If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. See Table A.7.

Annex B (normative)

Hydrogen stored in hydrogen absorbing metal alloy and micro fuel cell power systems

B.1 Scope

B.1.2 Fuels and technologies covered by this annex

Annex B covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use hydrogen gas – that has been stored in a hydrogen absorbing metal alloy – as fuel. These systems and units use proton exchange membrane fuel cell technologies.

NOTE Fuel cartridges for this technology are referred to by ISO 16111:2008 as “metal hydride assemblies”.

B.1.3 Equivalent level of safety

This subclause replaces Subclause 1.3 for this Annex B.

- a) The requirements of this standard are not intended to constrain innovation. The manufacturer may consider fuels, materials, designs or constructions not specifically dealt with in this standard. These alternatives should be evaluated as to their ability to yield levels of safety equivalent to those prescribed by this standard.
- b) It is understood that all micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall comply with applicable country and local requirements including, but not limited to, those concerning transportation, child-resistance, and storage, where required.
- c) The following differences between methanol and hydrogen micro fuel cell power systems are provided to enhance understanding of why the hydrogen requirements contained in Annex B differ from the methanol requirements in the main body.
 - i) Hydrogen is not toxic; therefore, many of the subclauses in the main body containing requirements, procedures, and tests in the main body dealing with toxicity are modified in this Annex B. In addition, the labelling requirements concerning toxicity are not required (refer to Clause B.6).
 - ii) Hydrogen is defined as a simple asphyxiant but for this risk to exist, oxygen levels have to fall less than 18 % at normal atmospheric pressure. Hydrogen related flammability risk arises at hydrogen-in-air concentrations greater than 4 %, while the asphyxiant risk arises at hydrogen-in-air concentrations greater than 12 %. Therefore, the flammability limits are used in defining the limits for hydrogen emissions.
 - iii) The primary hazard of hydrogen gas is its flammability: the flammability range of hydrogen gas is about 4 % to 75 % concentration by volume in air at atmospheric pressure. Consequently, the “impermissible hydrogen gas loss” (refer to B.3.38) and hydrogen emission limits found in Annex B are based on not exceeding 25 % of the lower flammability limit (LFL) of hydrogen in a given reference volume. In addition, the hydrogen emission limits for operating micro fuel cell power systems or units are further monitored to ensure that no flame can be supported by any single point source hydrogen emission.
 - iv) This Annex B considers hydrogen gas, stored in a (solid) hydrogen-absorbing metal alloy, as fuel. The systems do not contain any liquid fuel, which is why the definitions for “hazardous liquid fuel” and “no accessible liquid” are not applicable to this annex. This annex also defines and uses “impermissible hydrogen gas loss” instead of “no fuel vapour loss” as the criterion for non-operating micro fuel cell power systems or units. Furthermore, fuel cartridges are checked for hydrogen leakage using a liquid leak detector or equivalent method (see B.7.2.1) and visually inspected to ensure no “hydrogen absorbing metal alloy leakage” instead of being inspected for accessible liquid following type tests.

- v) The possible by-products of operation of a hydrogen-powered PEM fuel cell are heat and water. Since the fuel does not contain any hydrocarbons (and therefore will not produce any derivative hydrocarbons on operation), the hydrocarbon emissions tested for in the main body are not tested for in this Annex B. Instead, only hydrogen emissions are tested for.
- vi) Special considerations need to be taken into account when designing a fuel cartridge or internal reservoir containing a hydrogen absorbing metal alloy. To ensure safety of these devices, this Annex B requires that they are also designed, tested and certified to ISO 16111:2008 (refer to B.2, B.7.3.14 and B.7.3.15).

B.2 Normative references

In addition to the normative references specified in Clause 2, 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 16111:2008, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

B.3 Terms and definitions

The terms and definitions below replace those corresponding terms and definitions in Clause 3 for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex B. All terms and conditions in Clause 3 not specifically mentioned here also apply.

B.3.5

fuel

hydrogen gas, stored in a hydrogen-absorbing metal alloy

B.3.8

hazardous liquid fuel

not applicable to this Annex B

B.3.11

leakage

not applicable to this Annex B

B.3.18

no accessible liquid

not applicable to this Annex B

B.3.19

no fuel vapour loss

not applicable to this Annex B

The additional terms and their definitions below are needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex B in addition to those given in Clause B.3 and in Clause 3.

B.3.37

hydrogen leakage

hydrogen gas outside fuel containment system, including fuel cartridge and internal reservoir (see B.7.2.1)

B.3.38

impermissible hydrogen gas loss

hydrogen gas escaping non-operating micro fuel cell power system or micro fuel cell power unit greater than or equal to 0,0032 g/h

B.3.39

no hydrogen absorbing metal alloy leakage

no hydrogen absorbing metal alloy outside the micro fuel cell power system or micro fuel cell power unit or fuel cartridge

B.4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges

B.4.1 General

These requirements apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.1.

- a) Compliance with the requirements of Clause B.4 shall be verified during the review of the safety FMEA and/or during type testing specified in Clause B.7.
- b) The micro fuel cell power unit, when coupled to the fuel cartridge, shall be designed and constructed to avoid any credible risk of leakage, fire or explosion posed by the micro fuel cell power system itself or hydrogen or metal hydrides or other substances produced or used by the micro fuel cell power system.
- c) To prevent a fire or explosion hazard within the micro fuel cell power system, the manufacturer shall eliminate potential ignition source(s) within areas where fuel is present (or can be potentially released).
- d) Flammable, toxic or corrosive materials shall be kept within a closed containment system such as within fuel piping, in a reservoir, a fuel cartridge or similar enclosure.

B.4.3 General materials

These requirements apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.3.

- a) The materials and coating shall be resistant to degradation under the normal transportation and normal usage conditions over the manufacturer-defined life span of the product.
- b) Fuel cartridges shall comply with materials and construction requirements of ISO 16144:2008.

B.4.4 Selection of materials

- a) These requirements of Subclause B.4.4 below apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex B.
- b) *These requirements replace the corresponding requirements of Subclause 4.4.*

B.4.4.1 Micro fuel cell power systems and units are expected to be exposed to a number of environmental conditions over the manufacturer-defined life span of the product such as vibration, shock, varying humidity levels and corrosive environments. Materials employed in the micro fuel cell power system or unit shall be resistant to these environmental conditions. If a micro fuel cell power system or unit is to be used in service where specific environmental conditions are beyond those accounted for in the required tests of this standard, then additional testing shall be performed to verify safety under those environmental conditions.

B.4.4.2 Metallic and non-metallic materials used to construct internal or external parts of the micro fuel cell power system or unit, in particular those exposed directly or indirectly to moisture, fuel and/or byproducts in either a gas or liquid form as well as all parts and materials used to seal or interconnect the same, e.g. welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable under the normal transportation and normal usage conditions within the manufacturer-defined life span of the product and for all test conditions; in particular, they shall be designed to retain their mechanical stability under normal use:

- they shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation;
- the chemical and physical properties necessary for operational safety shall not be significantly affected within the manufacturer-defined life span of the product; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, ageing resistance, the effects of temperature variations, the effects arising when materials are put together (e.g. galvanic corrosion), and the effects of ultraviolet radiation;
- where conditions of erosion, abrasion, corrosion or other chemical attack may arise, adequate measures shall be taken to
 - minimize that effect by appropriate design, e.g. additional thickness, or by appropriate protection, e.g. use of liners, cladding materials or surface coatings, taking due account of normal use;
 - permit replacement of parts which are most affected;
 - and draw attention, in the manual referred to in Clause 6, to type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement;
- fuel containing parts, such as piping systems, shall employ materials suitable for exposure to hydrogen, as defined in the material selection requirements of ISO 16111:2008, 5.2. In addition, Annex A of ISO 16111:2008 details material compatibility for hydrogen service.

B.4.4.3 Elastomeric materials such as gaskets and tubing in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperatures that they are exposed to during normal use. Compliance shall be determined by the following: ISO 188.

B.4.4.4 *Subclause 4.4.4 does not apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex B.*

B.4.6 Fuel valves

These requirements of Subclause B.4.6 apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.6. This subclause applies to all shut-off valves, filling valves, relief valves, refilling valves, including all fuel cartridge types.

B.4.6.1 Operating and pressure containing parts of the shut-off valve and relief valve assemblies shall last the manufacturer-defined life span of the product under normal conditions.

B.4.6.2 The valves shall have means to prevent leakage of fuel through normal use, reasonably foreseeable misuse, and storage of the fuel cartridge.

B.4.6.3 The valves shall not be susceptible to unintended actuation, or manual actuation by a user not using tools, that results in fuel leakage. Compliance shall be checked using test probe 11 of IEC 61032 and a force of 9,8 N.

B.4.6.4 There shall be no leakage of fuel or metal hydride material during storage, connection, disconnection or transferring of fuel from the fuel cartridge to the micro fuel cell power unit.

B.4.7 Materials and construction – system

These requirements of Subclause B.4.7 apply to micro fuel cell power systems and units covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.7.

B.4.7.1 The maximum quantity of hydrogen stored in the micro fuel cell power unit shall not be more than 25 g. The hydrogen stored in the micro fuel cell power unit internal reservoir may be stored in a hydrogen absorbing metal alloy.

B.4.7.2 The micro fuel cell power system or unit shall be designed such that an explosion cannot occur even if fuel leaks from or inside the micro fuel cell power system or unit. The design criteria for such means (for example, required ventilation rate) shall be provided by the micro fuel cell power system or unit manufacturer. The means shall be provided either by the micro fuel cell power system or unit manufacturer or by the manufacturer of the device powered by the micro fuel cell power system or unit.

B.4.7.3 Components and materials inside the micro fuel cell power system or unit shall be constructed or shall make use of such materials that propagation of fire and ignition is mitigated. The material flammability shall be such that a sustained fire will not be supported after electrical power and the fuel and oxidant supply have been terminated. This may be demonstrated through the selection of materials meeting FV 0, FV 1 or FV 2 in accordance with IEC 60695-1-1 and IEC 60695-11-10.

B.4.7.4 Exemptions

B.4.7.4.1 Micro fuel cell stack membranes are not required to have flammability ratings.

B.4.7.4.2 Other materials within the micro fuel cell stack which comprise less than 30 % of the total micro fuel cell stack mass are considered to be of limited quantity and are permissible without flammability ratings.

B.4.8 Ignition sources

These requirements of Subclause B.4.8 apply to micro fuel cell power systems and units covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.8.

To prevent a fire or explosion hazard within the micro fuel cell power system or unit, the manufacturer shall either eliminate potential unintentional ignition source(s) within areas where fuel is present (or can be potentially released) or shall ensure that immediate and controlled oxidation occurs through the use of a catalytic reactor.

Potential unintentional ignition sources shall be eliminated by one or more of the following.

- The surface temperatures shall not exceed 80 % of the auto-ignition temperature, expressed in degrees Celsius, of the flammable gas.
- Equipment containing materials or components capable of catalysing the reaction of flammable fluids with air shall be capable of suppressing the propagation of the reaction from the equipment to the surrounding flammable atmosphere.
- Electrical equipment and/or components, if subject to contact with fuel, shall be suitable for the area in which it is installed.
- The potential for static discharge sufficient to cause ignition shall be eliminated by proper material selection and proper bonding and grounding.

- Electrical components like fuses, other over-current protection devices, sensors, electric valves and solenoids when operating under their intended condition shall not produce thermal effects, arcs or sparks capable of igniting a flammable release of gas.

Immediate and controlled oxidation shall be ensured by the following.

- Catalytic reactors designed to safely control oxidation are acceptable. The temperature within such reactors may be greater than the auto-ignition temperature of the fluid. If the catalytic reactor deviates from proper operating conditions, as defined by the manufacturer, the micro fuel cell power system or unit shall be automatically transferred into a safe state.

B.4.10 Protection against fire, explosion, corrosivity and toxicity hazard

These requirements apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.10.

B.4.10.1 Flammable fluids, hydrogen gas in particular, shall be kept within a closed containment system, such as within fuel piping, in a reservoir, a fuel cartridge, or similar enclosure. Testing in accordance with B.7.2 verifies this requirement.

B.4.10.2 A micro fuel cell power system or unit may be equipped with a means of detecting concentration levels of fluids in Table B.7 and shutting down the micro fuel cell power system or unit prior to exceeding the concentration limit.

B.4.10.3 Internal wiring and insulation in general shall not be exposed to fuel, oils, grease or similar substances, unless the insulation has been evaluated for contact with these substances.

B.4.12 Fuel supply construction

B.4.12.1 Fuel cartridge construction

These requirements apply to the fuel cartridge covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.12.1. Fuel cartridges shall conform to the following requirements:

B.4.12.1.1 There shall be no hydrogen leakage and no hydrogen absorbing metal alloy leakage from the fuel cartridge in the temperature range of $-40\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$. Compliance shall be determined by type testing in accordance with B.7.3.3 and B.7.3.4.

B.4.12.1.2 There shall be no hydrogen leakage and no hydrogen absorbing metal alloy leakage from the fuel cartridge after being subjected to a vacuum of 95 kPa below normal atmospheric pressure at $22\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$. Compliance shall be determined by type testing in accordance with B.7.3.1.2. Cartridges shall comply with shell design requirements of ISO 16111:2008, 5.3 and with the no hydrogen leakage requirements of the leak test of ISO 16111:2008, 6.2.5.

B.4.12.1.3 The maximum quantity of hydrogen gas absorbed in a hydrogen absorbing metal alloy permitted in the fuel cartridge is 100 g.

B.4.12.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a micro fuel cell power unit by a consumer, means to prevent fuel or hydrogen absorbing metal alloy leakage prior to, during, and after connection or transfer of fuel to the micro fuel cell power unit shall be provided. Compliance shall be determined by the connection cycling test, B.7.3.11.

B.4.12.1.5 A fuel cartridge shall be resistant to corrosion in its usage environment.

B.4.12.1.6 A fuel cartridge shall be provided with a means to prevent mis-connection that would result in leakage of fuel or hydrogen absorbing metal alloy when it is installed in a micro fuel cell power system. Compliance shall be determined by the connection cycling test, B.7.3.11.

B.4.12.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel or hydrogen absorbing metal alloy when not attached to a micro fuel cell power unit during normal usage, reasonably foreseeable misuse, and consumer transportation. Compliance shall be determined by the drop test, B.7.3.5, and the connection cycling test, B.7.3.11.

B.4.12.1.8 In the case where a pressure release valve or similar means is provided, such pressure release valve shall satisfy the performance requirement for each type test. This valve shall pass all type tests with no leakage.

B.4.12.1.9 The structure at the connection to the fuel cartridge shall not allow fuel or hydrogen absorbing metal alloy to leak.

B.4.12.1.10 A fuel cartridge, including the fuel cartridge interface to the micro fuel cell power unit, including the valve, shall have a construction sufficient to withstand normal use and reasonably foreseeable misuse generated by vibration, heat, pressure, being dropped or otherwise subject to a mechanical shock etc. Compliance shall be determined by:

- Pressure differential tests, B.7.3.1;
- Vibration test, B.7.3.2;
- Temperature cycling test, B.7.3.3;
- High temperature exposure test, B.7.3.4;
- Drop test, B.7.3.5;
- Compressive loading test, B.7.3.6;
- Long-term storage test, B.7.3.9;
- High-temperature connection test, B.7.3.10;
- Connection cycling tests, B.7.3.11;
- Fuel cartridge integrity test B.7.3.14;
- Internal reservoir integrity test B.7.3.15.

B.4.12.1.11 The fuel cartridge valves shall operate as intended without the use of tools and without excessive force needed to connect or disconnect.

B.4.12.1.12 Fuel cartridges shall comply with ISO 16111:2008.

B.4.12.1.13 The maximum volumetric capacity of the fuel cartridge shall not exceed 1 l.

B.4.12.2 Fuel cartridge fill requirement

These requirements apply to micro fuel cell power systems and units covered by this Annex B. *These requirements replace the corresponding requirements of Subclause 4.12.2. Fuel cartridges shall conform to the following requirements:*

- a) The fuel cartridge shall not be filled beyond its rated capacity, as defined in ISO 16111: 2008.
- b) The pressure in the fuel cartridge or in the internal reservoir shall not exceed 5 MPa internal gauge pressure at 55 °C when the fuel cartridge or internal reservoir is filled to its rated capacity.

B.4.13 Protection against mechanical hazards

B.4.13.1 Piping and tubing other than fuel lines

These requirements apply to micro fuel cell power systems and units covered by this Annex B. These requirements replace the corresponding requirements of Subclause 4.13.1. Requirements are listed below for the construction of piping, tubing and fittings – other than fuel lines – inside the micro fuel cell power system or unit.

B.4.13.1.1 Where micro fuel cell power systems or units are designed for internal pressures over 100 kPa gauge, they shall be designed, constructed, and tested in accordance with ISO 15649.

B.4.13.1.2 Micro fuel cell power systems or units designed for operation below 100 kPa gauge or in accordance with the applicable regional or national pressure equipment codes and standards not qualifying as pressurized systems, such as low-pressure water hoses, plastic tubing, or other connections to atmospheric or low-pressure tanks and similar containers, shall be constructed of suitable materials, and their related joints and fittings shall be designed and constructed with adequate strength and leakage resistance to prevent unintended releases.

B.4.13.1.3 Unions shall be designed to be leak tight using sealing methods resistant to the fluid transported and the ambient conditions of use.

B.4.13.1.4 The piping and tubing construction shall be provided with sufficient capability to resist pressure and other load weight, and there will be no danger of contamination or leakage of the line contents. Compliance is determined by B.7.3.1 and B.7.3.6.

B.4.13.1.5 The piping and tubing construction shall be provided with suitable measures to prevent freezing, breakage, corrosion, etc. Compliance for freezing is determined by B.7.3.3. Compliance for breakage is shown in B.7.3.5.

B.6 Instructions and warnings for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

B.6.2 Minimum markings required on the fuel cartridge

These markings replace the markings required by Subclause 6.2.

As a minimum, the following shall be marked on the fuel cartridge.

- a) CONTENTS ARE FLAMMABLE, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) KEEP AWAY FROM CHILDREN.
- d) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- e) FOLLOW USAGE INSTRUCTIONS.
- f) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- g) COMPOSITION AND AMOUNT OF FUEL.
- h) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.
- i) MARKINGS REQUIRED BY ISO 16111:2008.

B.6.3 Minimum markings required on the micro fuel cell power system

These markings replace the markings required by Subclause 6.3.

In addition, as a minimum, the following shall also be marked on the micro fuel cell power system to show:

- a) CONTENTS ARE FLAMMABLE, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- d) FOLLOW USAGE INSTRUCTIONS.
- e) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- f) COMPOSITION AND AMOUNT OF FUEL.
- g) MAXIMUM CAPACITY OF FUEL IN THE INTERNAL RESERVOIR, IF APPLICABLE.
- h) TEXT OR MARKING THAT INDICATES THAT THE MICRO FUEL CELL POWER SYSTEM COMPLIES WITH IEC 62282-6-100.
- i) ELECTRICAL OUTPUT (VOLTAGE, CURRENT, RATED POWER).
- j) IF HYDROGEN ABSORBING METAL ALLOY IS PRESENT IN THE INTERNAL RESERVOIR, MARKINGS REQUIRED BY ISO 16111:2008 SHALL BE MARKED ON THE MICRO FUEL CELL POWER UNIT.

B.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

B.7.1 General

This Subclause B.7.1 replaces Subclause 7.1 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use hydrogen gas, stored in a hydrogen-absorbing metal alloy, as fuel.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table B.5 lists the type tests that shall be performed. *Table B.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table B.6. *Table B.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of 22 °C ± 5 °C for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table B.5 – List of type tests – Replaces Table 5

Test reference	Test item	Test sample
B.7.3.1	Pressure differential tests	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
B.7.3.2	Vibration test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit used in B.7.3.1.3
B.7.3.3	Temperature cycling test	Fuel cartridge used in B.7.3.2 Partially filled fuel cartridge used in B.7.3.2 Micro fuel cell power system or power unit used in B.7.3.2
B.7.3.4	High temperature exposure test	Fuel cartridge Partially filled fuel cartridge
B.7.3.5	Drop test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
B.7.3.6	Compressive loading test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
B.7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
B.7.3.9	Long-term storage test	Fuel cartridge Partially filled fuel cartridge
B.7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Partially filled fuel cartridge and micro fuel cell power unit
B.7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit
B.7.3.12	Emission test	Micro fuel cell power system or power unit
B.7.3.14	Fuel cartridge integrity	Fuel cartridge (ISO 16111)
B.7.3.15	Internal reservoir integrity	Micro fuel cell power unit internal reservoir (ISO 16111)

Table B.5 replaces Table 5.

Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or partially filled, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test. The quantity of the samples for B.7.3.14 and B.7.3.15 shall be in accordance with ISO 16111:2008.

Test sequence: Tests B.7.3.2 and B.7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests B.7.3.1, B.7.3.2, and B.7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or power units.

Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.

Table B.6 – Laboratory standard conditions – Replaces Table 6

Item	Condition
Laboratory temperature	Laboratory temperature is "room temperature" (standard temperature condition, 22 °C ± 5 °C)
Laboratory atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen. The laboratory atmosphere contains not more than 0,008 % hydrogen
Table B.6 replaces Table 6.	

B.7.2 Leakage measurement of hydrogen and the measuring procedure

This Subclause B.7.2 replaces Subclause 7.2 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use hydrogen gas, stored in a hydrogen-absorbing metal alloy, as fuel.

- The leakage measurement of hydrogen shall be executed in principle in accordance with the procedures shown in Figures B.2 through B.5, B.9 and B.12, as applicable. These figures and their procedures, replace the corresponding figures in Subclause 7.2.*
- Compliance with the no "hydrogen leakage" and no "impermissible hydrogen gas loss" requirement for all type tests specified in Subclause B.7.3 shall be determined by the hydrogen leakage measurement procedure of Subclause B.7.2.1 and the hydrogen gas loss measurement procedure of B.7.2.2 in conjunction with the definition of "hydrogen leakage" in Subclause B.3.37 and the definition of "impermissible hydrogen gas loss" in Subclause B.3.38, unless otherwise specified.

B.7.2.1 Hydrogen leakage measurement from fuel cartridges and/or internal reservoirs and measuring procedures

- For fuel cartridges containing hydrogen stored in hydrogen absorbing metal alloy, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the fuel cartridge. See Figure B.2 and Figure B.3.
- If the fuel cartridge is of the type that is refillable by the manufacturer (automated or by trained technicians), it shall be charged with hydrogen to its rated capacity at rated charging pressure prior to testing. If the fuel cartridge is not refillable, it shall be tested in the condition in which it completed the type test in question. The fuel cartridge shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel cartridge.
- For micro fuel cell power systems or micro fuel cell power units with an internal reservoir that contains hydrogen gas above ambient pressure, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the internal reservoir. The internal reservoir shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the internal reservoir.
- Both for fuel cartridges containing hydrogen stored in hydrogen absorbing metal alloy, and for internal reservoirs containing hydrogen, no hydrogen leakage is allowed. Testing for hydrogen leakage with a liquid leak detector (bubble forming) solution is acceptable only if no bubbles are found.

NOTE The "no leakage" criteria for fuel cartridges containing hydrogen stored in a metal hydride has been chosen to be consistent with the 15th Edition of the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations; Special Provision 339 for UN 3479, Fuel Cell Cartridges *containing hydrogen in metal hydride*.

B.7.2.2 Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures

- a) For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure B.4 or B.5, as applicable, as follows.
- 1) Perform hydrogen emission testing in accordance with B.7.3.12.2 with the micro fuel cell power system or unit turned off ("DEVICE – OFF"). Hydrogen gas loss shall be less than 0,0032 g/h.
 - 2) Perform hydrogen emission testing in accordance with B.7.3.12.1 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h.
 - 3) As required by B.7.3.12.1, if hydrogen emissions in accordance with B.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") in step B.7.2.2 a) 2) were greater than 0,016 g/h, perform the hydrogen point source gas loss detection test in accordance with B.7.3.13. If the micro fuel cell power system or unit fails the hydrogen point source gas loss detection test in accordance with B.7.3.13, the micro fuel cell power system or unit fails the type test and no further testing is necessary.
 - 4) Total hydrogen emissions from an operational system shall be less than 0,8 g/h and hydrogen gas loss from any single point leak shall be less than 0,016 g/h. See Table B.7.
 - 5) Total hydrogen gas loss from a non-operating system shall be less than 0,0032 g/h. See Table B.7.

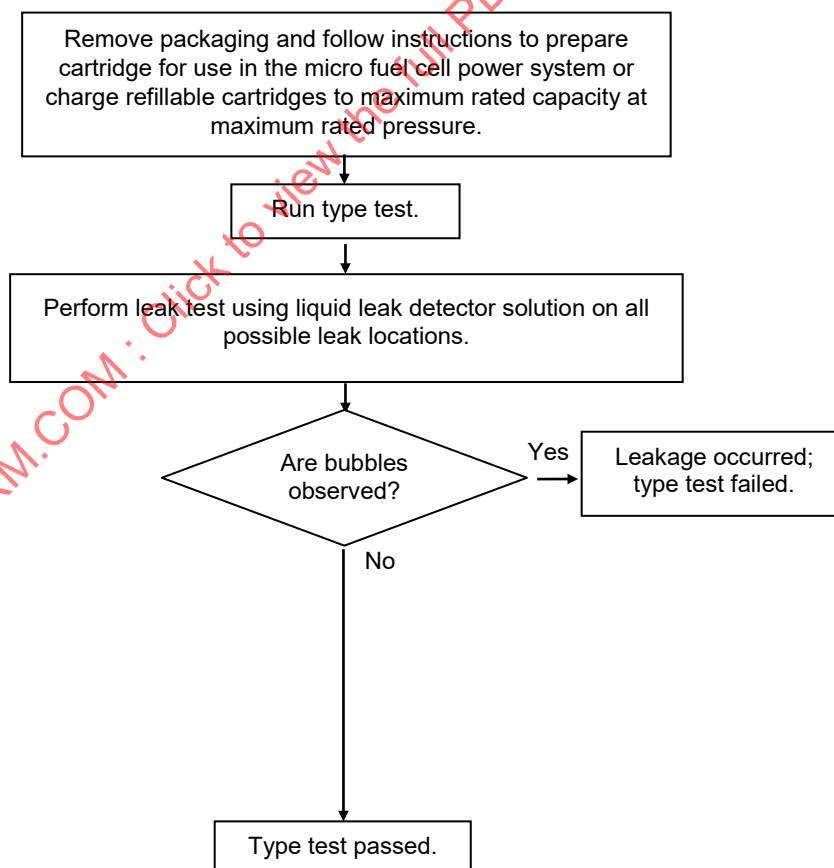


Figure B.2 – Fuel cartridge leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

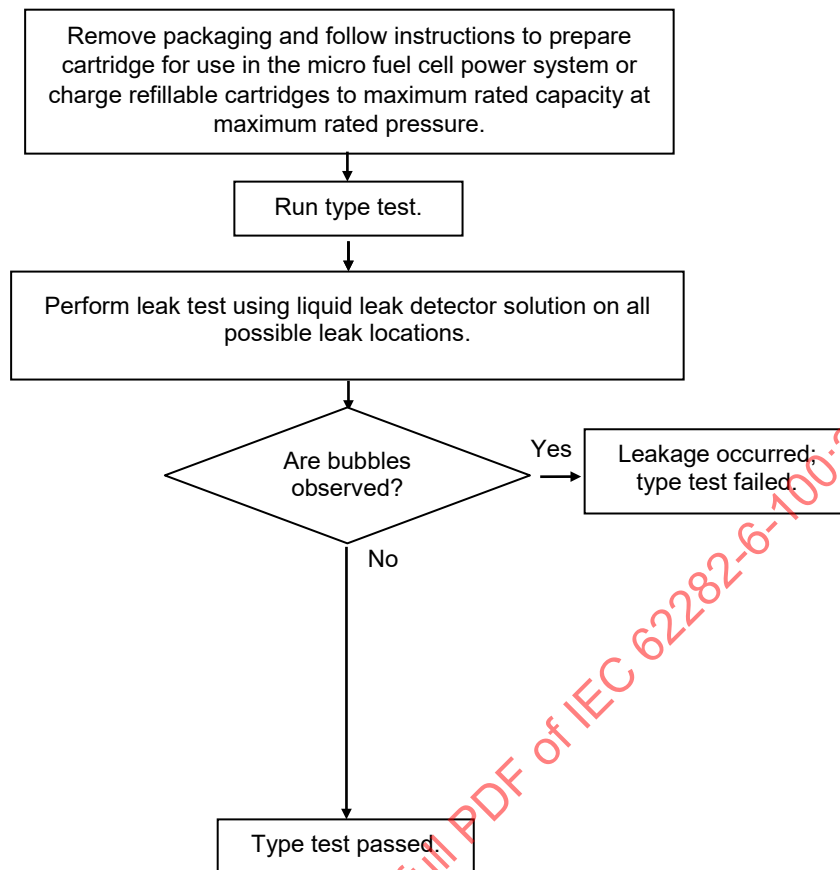


Figure B.3 – Fuel cartridge leakage test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

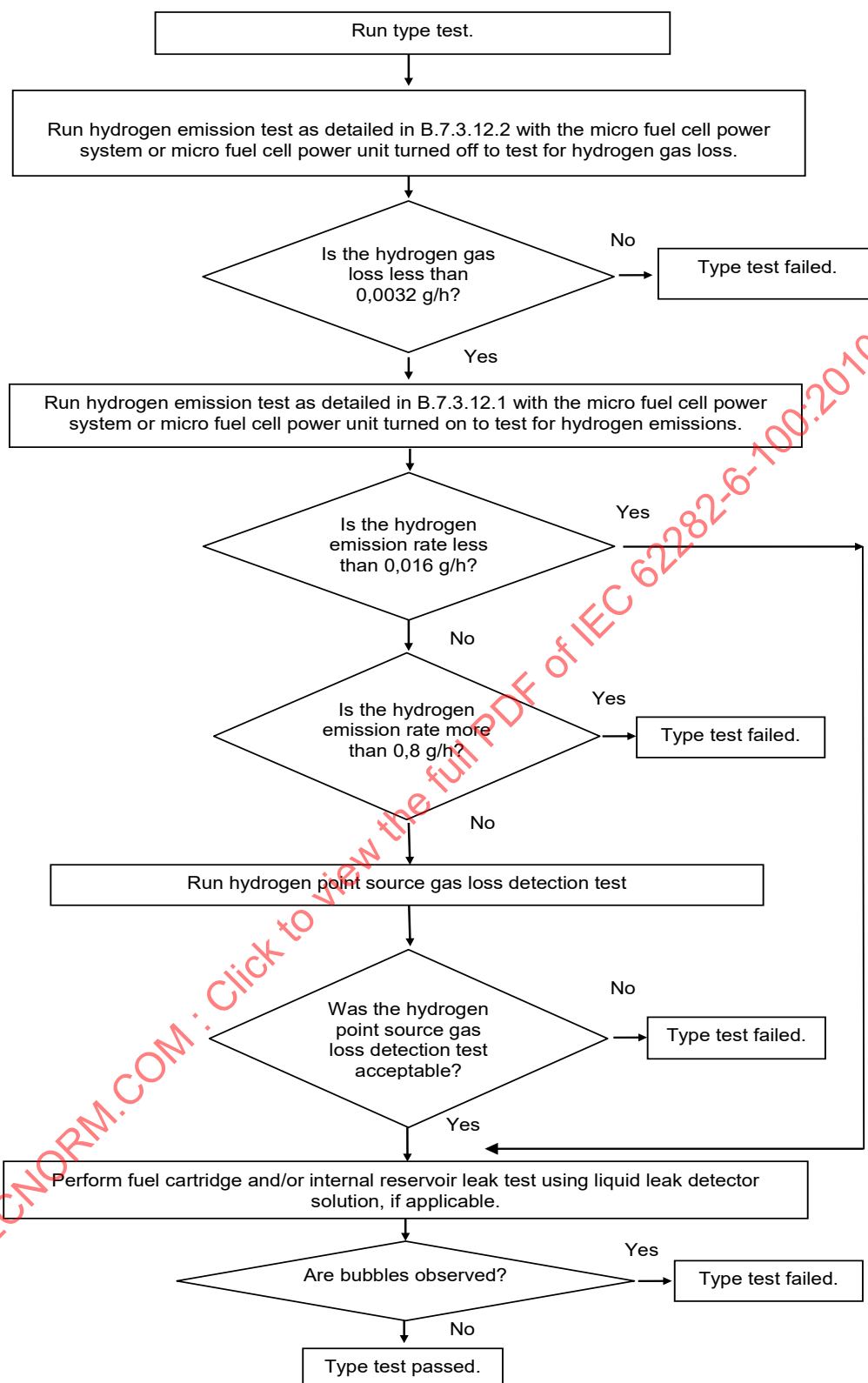


Figure B.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop, and compressive loading tests – Replaces Figure 4

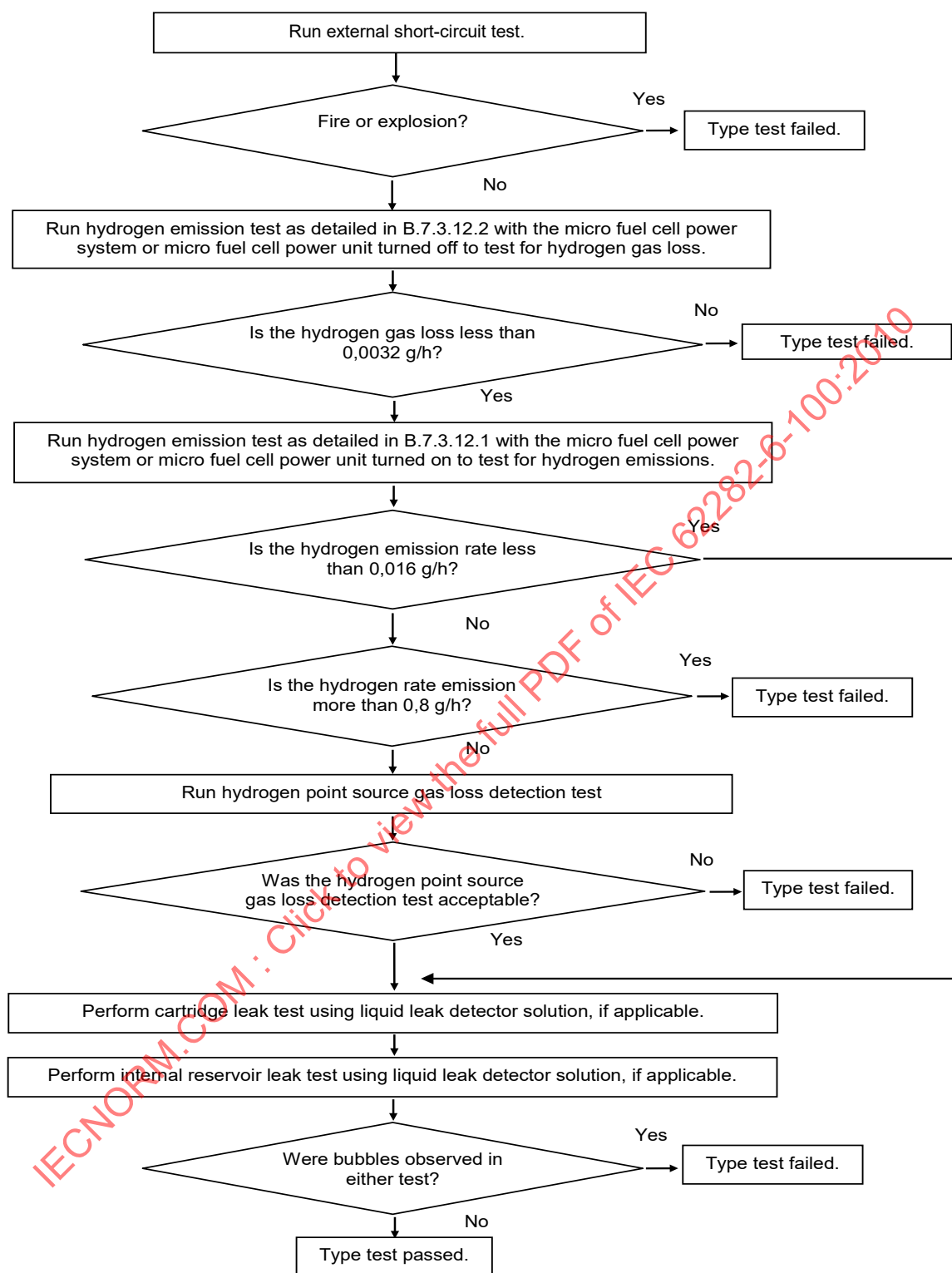


Figure B.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

B.7.3 Type tests

B.7.3.1 Pressure differential tests

B.7.3.1.1 General

Subclause B.7.3.1 replaces Subclause 7.3.1.

Portions of this test check compliance with Subclause B.4.12.1.2 to verify that there shall be no hydrogen leakage and no hydrogen absorbing metal alloy leakage from the fuel cartridge after being subjected to a vacuum of 95 kPa below normal atmospheric pressure at $22\text{ °C} \pm 5\text{ °C}$.

B.7.3.1.2 Fuel cartridge low external pressure test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge
- b) **Purpose:** to simulate the effects of low external pressure on a fuel cartridge and ensure no leakage.
- c) **Test procedure:**
Perform this test in accordance with Figure B.2.
 - 1) The sample shall be placed in a vacuum chamber and the pressure in the vacuum chamber shall be reduced to 95 kPa below normal atmospheric pressure.
 - 2) Maintain the vacuum for 30 min.
 - 3) Remove the sample from the vacuum chamber and check for leakage using the procedure given in B.7.2.1 using a liquid leak detector (bubble forming) solution and visually inspect the sample for hydrogen absorbing metal alloy leakage.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage and no hydrogen absorbing metal alloy leakage. See Figure B.2. Hydrogen leakage shall be checked using the hydrogen leakage measurement procedure in B.7.2.1. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.1.3 Micro fuel cell power system or micro fuel cell power unit 33,3 kPa pressure differential test

B.7.3.1.3.1 General

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex B. The test may be conducted using either of two test methods. Both test methods test the samples with at least a 33,3 kPa pressure differential using either low external pressure or internal pressurization to achieve the 33,3 kPa pressure differential.

Either B.7.3.1.3.2, Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test;

or alternatively;

B.7.3.1.3.3, Micro fuel cell power system or micro fuel cell power unit 33,3 kPa internal pressurization test, may be used.

B.7.3.1.3.2 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with the manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test apparatus:** Test samples shall be stored in a sealed vacuum chamber at a low external pressure of 68 kPa absolute pressure for 6 h. It is recommended that the size of the vacuum chamber provide more than 0,022 m³ free air space and less than 0,28 m³ free air space. The size of the chamber will affect the hydrogen concentration measurements, and should be selected to ensure safety throughout the test. Care should be taken to ensure that a flammable concentration of hydrogen will not accumulate in the sealed chamber. Suitable sampling equipment shall be used to sample for hydrogen concentration at the end of the test period.
- d) **Test procedure:**

- 1) Calculate the hydrogen concentration in the test chamber that would result from the impermissible hydrogen gas loss rate of 0,0032 g/h of hydrogen during the six-hour test as follows:

$$C_{pv} = \frac{\frac{HLR \times t}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{\frac{0,0032 \frac{g}{h} \times 6h}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{0,213l}{V} \times 100$$

where

C_{pv} is the hydrogen concentration in % by volume that would result from a hydrogen gas loss rate of 0,0032 g/h of hydrogen in the vacuum chamber in 6 h;

V is the volume of the free space in the vacuum chamber, in standard litres;

HLR is the impermissible hydrogen gas loss rate of 0,0032 g/h;

t is the duration of the test, in this case, 6 h;

or simplified to:

$$C_{pv} = \frac{0,213l}{V} \times 100$$

where

C_{pv} is the hydrogen concentration in % by volume that would result from a hydrogen gas loss rate of 0,0032 g/h of hydrogen in the vacuum chamber in 6 h;

V is the volume of the free space in the vacuum chamber, in standard litres.

For example, in a vacuum chamber having 0,28 m³ of free air space, a hydrogen concentration of 0,08 % indicates 0,0032 g/h hydrogen gas loss and fails the test.

- 2) Test samples shall be stored in the sealed vacuum chamber at a low external pressure of 68 kPa absolute pressure for at least 6 h at laboratory temperature.
- 3) At the end of the six-hour test period, re-pressurize the vacuum chamber to 101,3 kPa with known purity or bottled air meeting the requirements for laboratory atmosphere given in Table B.6. Allow the atmosphere in the vacuum chamber to stabilise or provide suitable mixing. The atmosphere in the vacuum chamber shall then be checked for hydrogen concentration.
- 4) Compare the measured hydrogen concentration in the vacuum chamber to the hydrogen concentration that would result from a hydrogen gas loss rate of 0,0032 g/h calculated in 1) above.

- 5) The hydrogen gas loss rate shall be less than the impermissible hydrogen gas loss limit of 0,0032 g/h in accordance with B.3.38 and shall be determined by ensuring that the hydrogen concentration in the vacuum chamber is less than the calculated hydrogen concentration that would result from a hydrogen gas loss rate of 0,0032 g/h. If the hydrogen concentration in the vacuum chamber is less than the hydrogen concentration C_{pv} calculated in 1) above, then the test sample passes the test for hydrogen gas loss.
- 6) Following the pressure differential test, remove the test sample from the vacuum chamber, and perform the hydrogen gas loss measurement in accordance with B.7.2.2.
- 7) If the test sample contains a fuel cartridge, perform the hydrogen leakage measurement in accordance with B.7.2.1 on the fuel cartridge. No hydrogen leakage is allowed.
- 8) If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, hydrogen leakage shall be checked in B.7.3.3. See B.7.3.3 c) 7) iii).

e) **Passing criteria:**

- 1) No fire or flame at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss during the test shall be less than the impermissible hydrogen gas loss limit of 0,0032 g/h in accordance with B.3.38. The hydrogen concentration in the vacuum chamber shall be less than the calculated hydrogen concentration [C_{pv}] that would result from a hydrogen gas loss rate of 0,0032 g/h. Hydrogen leakage shall meet the no "hydrogen leakage" requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Hydrogen absorbing metal alloy leakage shall be checked visually.
- 2) Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit following the type test. If the micro fuel cell power system or unit is not operational following the type test, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable

B.7.3.1.3.3 Micro fuel cell power system or micro fuel cell power unit 33,3 kPa internal pressurization test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with the manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test apparatus:** A sampling test chamber shall be equipped with ventilation, sampling and measuring instruments capable of accurately measuring air flow through the test chamber and the hydrogen concentration in the test chamber. The test chamber may be similar to the emission test apparatus shown in Figure B.10. The test chamber shall be supplied with clean air from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- d) **Test procedure:**
 - 1) Place the samples in the sampling test chamber at laboratory temperature.
 - 2) Using suitable adapters, connect the micro fuel cell power system or micro fuel cell power unit to a pressure regulated source of pure hydrogen external to the sampling chamber.
 - 3) Pressurize the micro fuel cell power system or micro fuel cell power unit to 33,3 kPa gauge pressure with the pressure regulated source of pure hydrogen sufficient to maintain 33,3 kPa gauge pressure internal to the micro fuel cell power unit throughout the six-hour test.

- 4) The samples shall remain pressurized at 33,3 kPa gauge pressure in the sampling test chamber for at least 6 h at laboratory temperature.
- 5) Hydrogen gas loss from the micro fuel cell power system or unit shall be sampled continuously at the outlet of the test chamber, at an air sampling port similar to port A shown in Figure B.10.
- 6) Sample and record the gaseous contents of the test chamber through an air sampling port similar to port A shown in Figure B.10, while simultaneously measuring and recording the total air flow through the test chamber. The total air flow through the test chamber can be computed from the sum of the outlet air flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber. The flow rate through the test chamber and the hydrogen concentration in the test chamber shall be monitored continuously.
- 7) Calculate the hydrogen gas loss rate by multiplying the concentration of hydrogen in the test chamber by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state outlet air flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the hydrogen gas loss rate.

See below:

$$HLR = (F_o + F_s) \times C$$

or

$$HLR = (F_i) \times C$$

where

HLR is the hydrogen gas loss rate in grams per hour;

F_o is the outlet air flow rate in standard litres per hour;

F_s is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration of hydrogen in grams per standard litre.

- 8) Compare the maximum calculated hydrogen gas loss rate to the impermissible hydrogen gas loss limit of 0,0032 g/h. If the maximum calculated hydrogen gas loss rate is less than the impermissible hydrogen gas loss limit of 0,0032 g/h, the system passes the test for hydrogen gas loss.
- 9) Following the pressure differential test, remove the test sample from the chamber, return the sample to normal operating pressure, and perform the hydrogen gas loss measurement in accordance with B.7.2.2.
- 10) If the test sample contains a fuel cartridge, perform hydrogen leakage measurement in accordance with B.7.2.1 on the fuel cartridge. No hydrogen leakage is allowed.
- 11) If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, hydrogen leakage shall be checked in B.7.3.3. See B.7.3.3 c) 7) iii).

e) Passing criteria:

- 1) No fire or flame at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss during the test shall be less than the impermissible hydrogen gas loss limit of 0,0032 g/h in accordance with B.3.38. Hydrogen leakage shall meet the no “hydrogen leakage” requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Hydrogen absorbing metal alloy leakage shall be checked visually.
- 2) Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit following the type test. If the micro fuel cell power system or unit is not operational following the type test, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable

B.7.3.1.4 Micro fuel cell power system or micro fuel cell power unit 89,7 kPa pressure differential test**B.7.3.1.4.1 General**

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex B. The test may be conducted using either of two test methods. Both test methods test the samples with at least a 89,7 kPa pressure differential using either low external pressure or internal pressurization to achieve the 89,7 kPa pressure differential.

Either B.7.3.1.4.2, Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test;

or alternatively;

B.7.3.1.4.3, Micro fuel cell power system or micro fuel cell power unit 89,7 kPa internal pressurization test, may be used.

B.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with the manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage. Hydrogen gas loss shall be less than 0,08 g/h on the basis of not exceeding 25 % of the lower flammability limit in a one-hour period.
- c) **Test apparatus:** Test samples shall be stored in a sealed vacuum chamber at a low external pressure of 11,6 kPa absolute pressure for 1 h. It is recommended that the size of the vacuum chamber provide more than 0,09 m³ free air space and less than 0,28 m³ free air space. The size of the chamber will affect the hydrogen concentration measurements, and should be selected to ensure safety throughout the test. Care should be taken to ensure that a flammable concentration of hydrogen will not accumulate in the sealed chamber. Suitable sampling equipment shall be used to sample for hydrogen concentration at the end of the test period.

d) **Test procedure:**

- 1) Calculate the hydrogen concentration in the test chamber that would result from the maximum allowable hydrogen gas loss rate of 0,08 g/h of hydrogen during the one-hour test as follows:

$$C_{pv} = \frac{\frac{HLR \times t}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{\frac{0,08 \frac{g}{h} \times 1h}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{0,9l}{V} \times 100$$

where

C_{pv} is the hydrogen concentration in % by volume that would result from a hydrogen gas loss rate of 0,08 g/h of hydrogen in the vacuum chamber in 1 h;

V is the volume of the free space in the vacuum chamber, in standard litres;

HLR is the maximum allowable hydrogen gas loss rate of 0,08 g/h;

t is the duration of the test, in this case, 1 h;

or simplified to:

$$C_{pv} = \frac{0,9l}{V} \times 100$$

where

C_{pv} is the hydrogen concentration in % by volume that would result from a hydrogen gas loss rate of 0,08 g/h of hydrogen in the vacuum chamber in 1 h;

V is the volume of the free space in the vacuum chamber, in standard litres.

For example, in a vacuum chamber having 0,28 m³ of free air space, a hydrogen concentration of 0,32 % indicates 0,08 g/h hydrogen gas loss and fails the test.

- 2) Test samples shall be stored in the sealed vacuum chamber at a low external pressure of 11,6 kPa absolute pressure for at least 1 h at laboratory temperature.
- 3) At the end of the one-hour test period, re-pressurize the vacuum chamber to 101,3 kPa with known purity or bottled air meeting the requirements for laboratory atmosphere given in Table B.6. Allow the atmosphere in the vacuum chamber to stabilise or provide suitable mixing. The atmosphere in the vacuum chamber shall then be checked for hydrogen concentration.
- 4) Compare the measured hydrogen concentration in the vacuum chamber to the hydrogen concentration that would result from a hydrogen gas loss rate of 0,08 g/h calculated in 1) above.
- 5) Hydrogen gas loss shall be less than 0,08 g/h on the basis of not exceeding 25 % of the lower flammability limit in a one-hour period and shall be determined by ensuring that the hydrogen concentration in the vacuum chamber is less than the calculated hydrogen concentration that would result from a hydrogen gas loss rate of less than the calculated hydrogen concentration that would result from a hydrogen gas loss rate of 0,08 g/h. If the hydrogen concentration in the vacuum chamber is less than the hydrogen concentration C_{pv} calculated in 1) above, then the test sample passes the test for hydrogen gas loss.
- 6) Following the pressure differential test, remove the test sample from the vacuum chamber, and perform hydrogen gas loss measurement in accordance with B.7.2.2.
- 7) If the test sample contains a fuel cartridge, perform the hydrogen leakage measurement in accordance with B.7.2.1 on the fuel cartridge. No hydrogen leakage is allowed.
- 8) If the test sample contains an internal reservoir that contains hydrogen gas above ambient pressure, perform the hydrogen leakage measurement in accordance with B.7.2.1 on the internal reservoir. No hydrogen leakage is allowed.

e) Passing criteria:

- 1) No fire or flame at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss during the test shall be less than 0,08 g/h on the basis of not exceeding 25 % of the lower flammability limit in a one-hour period. The hydrogen concentration in the vacuum chamber shall be less than the calculated hydrogen concentration C_{pv} that would result from a hydrogen gas loss rate of 0,08 g/h. Hydrogen leakage shall meet the no “hydrogen leakage” requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Hydrogen absorbing metal alloy leakage shall be checked visually.
- 2) Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit following the type test. If the micro fuel cell power system or unit is not operational following the type test, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable

B.7.3.1.4.3 Micro fuel cell power system or micro fuel cell power unit 89,7 kPa internal pressurization test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with the manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test apparatus:** A sampling test chamber shall be equipped with ventilation, sampling and measuring instruments capable of accurately measuring air flow through the test chamber and the hydrogen concentration in the test chamber. The test chamber may be similar to the emission test apparatus shown in Figure B.10. The test chamber shall be supplied with clean air from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- d) **Test procedure:**
 - 1) Place the samples in the sampling test chamber at laboratory temperature.
 - 2) Using suitable adapters, connect the micro fuel cell power system or micro fuel cell power unit to a pressure regulated source of pure hydrogen external to the sampling chamber.
 - 3) Pressurize the micro fuel cell power system or micro fuel cell power unit to 89,7 kPa gauge pressure with the pressure regulated source of pure hydrogen sufficient to maintain 89,7 kPa gauge pressure internal to the micro fuel cell power unit throughout the one-hour test.
 - 4) The samples shall remain pressurized at 89,7 kPa gauge pressure in the sampling test chamber for at least 1 h at laboratory temperature.
 - 5) Hydrogen gas loss from the micro fuel cell power system or unit shall be sampled continuously at the outlet of the test chamber, at an air sampling port similar to port A shown in Figure B.10.
 - 6) Sample and record the gaseous contents of the test chamber through an air sampling port similar to port A shown in Figure B.10, while simultaneously measuring and recording the total air flow through the test chamber. The total air flow through the test chamber can be computed from the sum of the outlet air flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber. The flow rate through the test chamber and the hydrogen concentration in the test chamber shall be monitored continuously.
 - 7) Calculate the hydrogen gas loss rate by multiplying the concentration of hydrogen in the test chamber by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state outlet air flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the hydrogen gas loss rate.

See below:

$$HLR = (F_o + F_s) \times C$$

or

$$HLR = (F_i) \times C$$

where

HLR is the hydrogen gas loss rate in grams per hour;

F_o is the outlet air flow rate in standard litres per hour;

F_s is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration of hydrogen in grams per standard litre.

- 8) Compare the maximum calculated hydrogen gas loss rate to 0,08 g/h, on the basis of not exceeding 25 % of the lower flammability limit in a one-hour period. If the maximum calculated hydrogen gas loss rate is less than 0,08 g/h, the system passes the test for hydrogen gas loss.
- 9) Following the pressure differential test, remove the test sample from the chamber, return the sample to normal operating pressure, and perform the hydrogen gas loss measurement in accordance with B.7.2.2.
- 10) If the test sample contains a fuel cartridge, perform the hydrogen leakage measurement in accordance with B.7.2.1 on the fuel cartridge. No hydrogen leakage is allowed.
- 11) If the test sample contains an internal reservoir that contains hydrogen gas above ambient pressure, perform the hydrogen leakage measurement in accordance with B.7.2.1 on the internal reservoir. No hydrogen leakage is allowed.

e) **Passing criteria:**

- 1) No fire or flame at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss during the test shall be less than 0,08 g/h, on the basis of not exceeding 25 % of the lower flammability limit in a one-hour period. Hydrogen leakage shall meet the “no hydrogen leakage” requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Hydrogen absorbing metal alloy leakage shall be checked visually.
- 2) Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit following the type test. If the micro fuel cell power system or unit is not operational following the type test, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable.

B.7.3.2 Vibration test

Subclause B.7.3.2 replaces Subclause 7.3.2 for micro fuel cell power systems, units and fuel cartridges covered by this Annex B.

- a) **Test sample:** an unused fuel cartridge, a partially filled fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in B.7.3.1.3 or a micro fuel cell power system used in B.7.3.1.3.
- b) **Purpose:** to simulate the effects of normal transportation vibration and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure B.2 for the fuel cartridge and Figure B.4 for the micro fuel cell power system or unit.
 - 2) The test sample shall be firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.
 - 3) The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min.
 - 4) This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions of the test samples.
 - 5) The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g_n is maintained until 18 Hz is reached. The amplitude is then maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of 8 g_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.
 - 6) For the fuel cartridge, perform the hydrogen leakage measurement in accordance with B.7.2.1. See Figure B.2.
 - 7) For the micro fuel cell power system or micro fuel cell power unit, perform the hydrogen gas loss measurement in accordance with B.7.2.2. See Figure B.4.
 - 8) If the micro fuel cell power system or unit contains a fuel cartridge, perform the hydrogen leakage measurement in accordance with B.7.2.1.
 - 9) If the micro fuel cell power system or unit contains an internal reservoir that contains hydrogen gas above ambient pressure, hydrogen leakage shall be checked in B.7.3.3. See B.7.3.3 c) 7) iii).
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually. If the micro fuel cell power unit or micro fuel cell power system is not operational, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable.

B.7.3.3 Temperature cycling test

Subclause B.7.3.3 replaces Subclause 7.3.3 for micro fuel cell power systems, units and fuel cartridges covered by this Annex B.

- a) **Test sample:** a fuel cartridge used in B.7.3.2, a partially filled fuel cartridge used in B.7.3.2, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in B.7.3.2 or a micro fuel cell power system used in B.7.3.2.
- b) **Purpose:** to simulate the effects of low-temperature and high temperature exposure and the effects of extreme temperature change.
- c) **Test procedure:**

- 1) For a fuel cartridge, two fuel cartridge orientations shall be tested – valve up and valve down. For a micro fuel cell power system or a micro fuel cell power unit, only one orientation needs to be tested.
- 2) See Figure B.8 for the temperature profile to be used.
- 3) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from laboratory temperature to $55\text{ °C} \pm 2\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $55\text{ °C} \pm 2\text{ °C}$ for a minimum of 4 h.
- 4) Decrease the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$, then decrease the chamber temperature to $-40\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $-40\text{ °C} \pm 5\text{ °C}$ for a minimum of 4 h.
- 5) Increase the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$.
- 6) The above process is to be done twice.
- 7) After 1 h at $22\text{ °C} \pm 5\text{ °C}$, perform the following hydrogen leakage tests:
 - i) For the fuel cartridge, perform the hydrogen leakage measurement in accordance with B.7.2.1. See Figure B.2.
 - ii) For the micro fuel cell power system or micro fuel cell power unit, perform the hydrogen gas loss measurement in accordance with B.7.2.2. (This includes hydrogen emission testing in accordance with B.7.3.12). See Figure B.4.
 - iii) If the micro fuel cell power system or unit contains a fuel cartridge, or an internal reservoir that contains hydrogen gas above ambient pressure, perform the hydrogen leakage measurement in accordance with B.7.2.1.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit. Hydrogen emissions shall meet the passing criteria in B.7.3.12. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually. If the micro fuel cell power unit or micro fuel cell power system is not operational, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable.

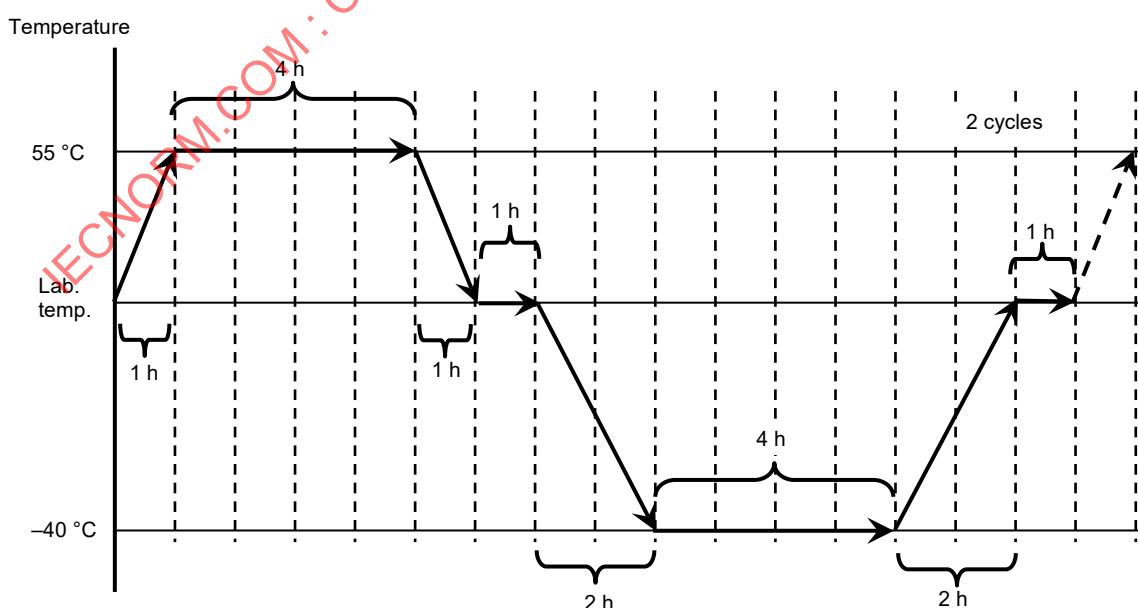


Figure B.8 – Temperature cycling – Replaces Figure 8

B.7.3.4 High temperature exposure test

Subclause B.7.3.4 replaces Subclause 7.3.4 for fuel cartridges covered by this Annex B.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of a fuel cartridge left in high temperature environments.
- c) **Test procedure:**
 - 1) Two orientations shall be tested – valve up and valve down.
 - 2) Place the test sample in a temperature controlled test chamber that is at a temperature of $70\text{ °C} \pm 2\text{ °C}$ and allow chamber temperature to recover to $70\text{ °C} \pm 2\text{ °C}$ and maintain that temperature for at least 4 h with the sample in the chamber.
 - 3) Remove the test sample to laboratory temperature.
 - 4) Perform the hydrogen leakage measurement in accordance with B.7.2.1. See Figure B.2.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.5 Drop test

Subclause B.7.3.5 replaces Subclause 7.3.5 for micro fuel cell power systems, units and fuel cartridges covered by this Annex B.

If the drop test of ISO 16111:2008, 6.2.4 is performed using the same fuel cartridge for all four drop orientations, the fuel cartridge drop test of B.7.3.5 is not required. The drop test of ISO 16111:2008 is seen to be more rigorous, and therefore more than sufficient to ensure adequate safety of the fuel cartridge. If the drop test of ISO 16111:2008 is performed using a different fuel cartridge for each drop orientation, the fuel cartridge drop test of B.7.3.5 shall be performed in addition to the drop test of ISO 16111:2008.

- a) **Test sample:** an unused fuel cartridge, a partially filled fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an inadvertent drop and ensure no leakage.
- c) **Test procedure:**
 - 1) The test sample shall be dropped on a horizontal surface that consists of hardwood at least 13 mm thick, mounted on two layers of plywood each 18 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor from a predetermined height.
 - 2) The height of the drop shall be:
 - i) $1\,200\text{ mm} \pm 10\text{ mm}$: in the case of a micro fuel cell power unit and/or a micro fuel cell power system;
 - ii) $1\,500\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge with a water capacity of more than 200 ml;
 - iii) $1\,800\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge with a water capacity of up to 200 ml.
 - 3) For the fuel cartridge tests, the drop test shall be carried out in four drop orientations with the same sample.
 - 4) For the micro fuel cell power unit or the micro fuel cell power system, one micro fuel cell power system or unit may be used for all four drop orientations, or more than one micro fuel cell power system or unit may be used in subsequent drops, at the discretion of the manufacturer.

- 5) For all tests, drop orientations shall be:
 - i) valve up;
 - ii) valve down;
 - iii) two other mutually perpendicular orientations.
- 6) After each drop test, perform the following hydrogen leakage tests.
 - i) For the fuel cartridge, perform the hydrogen leakage measurement in accordance with B.7.2.1. See Figure B.2.
 - ii) For the micro fuel cell power system or micro fuel cell power unit, perform the hydrogen gas loss measurement in accordance with B.7.2.2. (This includes hydrogen emission testing in accordance with B.7.3.12.) See Figure B.4.
 - iii) If the micro fuel cell power system or unit contains a fuel cartridge, or an internal reservoir that contains hydrogen gas above ambient pressure, perform the hydrogen leakage measurement in accordance with B.7.2.1.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit. Hydrogen emissions shall meet the passing criteria in B.7.3.12. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually. If the micro fuel cell power unit or micro fuel cell power system is not operational, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable.

If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

B.7.3.6 Compressive loading test

Subclause B.7.3.6 replaces Subclause 7.3.6 for micro fuel cell power systems, units and fuel cartridges covered by this Annex B.

B.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the micro fuel cell power unit, or micro fuel cell power system.
- c) **Test procedure:**
 - 1) The micro fuel cell power system or unit test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $245 \text{ N} \pm 9,8 \text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $245 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) The test shall be carried out in three mutually perpendicular orientations as a rule. If the sample would not stand on its own, it does not need to be tested in that orientation.
 - 5) After the compressive loading test, perform the following hydrogen leakage tests.
 - i) For the micro fuel cell power system or micro fuel cell power unit, perform the hydrogen gas loss measurement in accordance with B.7.2.2. (This includes hydrogen emission testing in accordance with B.7.3.12.) See Figure B.4.

- ii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform the hydrogen leakage measurement in accordance with B.7.2.1.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit. Hydrogen emissions shall meet the passing criteria in B.7.3.12. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually. If the micro fuel cell power unit or micro fuel cell power system is not operational, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable.

B.7.3.6.2 Fuel cartridge

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the fuel cartridge.
- c) **Test procedure:**
 - 1) The fuel cartridge test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $981 \text{ N} \pm 9,8 \text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $981 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) Fuel cartridge orientations shall be selected on the basis of likely stable resting positions when accidentally dropped (e.g. those orientations having the lowest centres of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic fuel cartridge that is sufficiently cubic and the curved surface of a cylindrical fuel cartridge with a longitudinal axis length longer than twice the diameter.
 - 5) For the sample, perform the hydrogen leakage measurement in accordance with B.7.2.1. See Figure B.2.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.7 External short-circuit test

Subclause B.7.3.7 replaces Subclause 7.3.7 for micro fuel cell power systems, units and fuel cartridges covered by this Annex B.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an external short-circuit.
- c) **Test procedure:**
 - 1) External short-circuit testing shall be done separately on both operating [DEVICE ON] and non-operating [DEVICE OFF] micro fuel cell power systems or micro fuel cell power units respectively.
 - 2) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power system or unit with wire having a maximum resistance load of $0,1 \Omega$ for at least 5 min.

- 3) Following the short-circuit test, perform the following hydrogen leakage testing in accordance with Figure B.5.
 - i) For the micro fuel cell power system or micro fuel cell power unit, perform the hydrogen gas loss measurement in accordance with B.7.2.2. (This includes hydrogen emission testing in accordance with B.7.3.12). See Figure B.4.
 - ii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurement in accordance with B.7.2.1.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power system or unit. Hydrogen emissions shall meet the passing criteria in B.7.3.12. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually. If the micro fuel cell power unit or micro fuel cell power system is not operational, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable.

Exterior surfaces shall not exceed the temperatures shown in Table 2 during or after short circuit testing.

NOTE The external short-circuit test can be done sequentially with the surface component and exhaust gas temperature test using the same sample.

B.7.3.9 Long-term storage test

B.7.3.9.1 General

Subclause B.7.3.9 replaces Subclause 7.3.9 for fuel cartridges covered by this Annex B.

Five options are available. Any option may be used:

- 1) B.7.3.9.2 Option 1 – Continuous hydrogen concentration measurement;
- 2) B.7.3.9.3 Option 2 – Controlled flow hydrogen concentration measurement;
- 3) B.7.3.9.4 Option 3 – Continuous weight measurement;
- 4) B.7.3.9.5 Option 4 – Periodic weight measurements; or,
- 5) B.7.3.9.6 Option 5 – One weight measurement.

B.7.3.9.2 Option 1 – Continuous hydrogen concentration measurement

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test apparatus:** A temperature test chamber shall be equipped with sampling and monitoring instruments capable of accurately measuring air flow through the test chamber, and the hydrogen concentration in the test chamber. This temperature test chamber may be similar to the emission test apparatus shown in Figure B.10. The temperature test chamber shall be equipped with heaters capable of maintaining an internal temperature of $50\text{ °C} \pm 2\text{ °C}$ with air flow through the system. It is recommended that the test chamber be equipped with a hydrogen sensor or other equivalent safety features to ensure that a flammable concentration of hydrogen is not permitted to accumulate in a closed volume.
- d) **Test procedure:**
 - 1) The test chamber shall be equipped with a circulation fan, ventilation and measurement instruments capable of accurately measuring air flow through the chamber and accurately measuring hydrogen concentration in the chamber similar to the configuration in Figure B.10.
 - 2) The test chamber shall be supplied with clean air from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.

- 3) Place the sample in the temperature test chamber at $50\text{ }^{\circ}\text{C} \pm 2^{\circ}\text{C}$.
- 4) The sample shall remain in the temperature test chamber at $50\text{ }^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for at least 28 days.
- 5) Hydrogen gas loss from the fuel cartridge shall be sampled continuously at the outlet of the small test chamber, at air sampling port A similar to that shown in Figure B.10.
- 6) Sample and record the gaseous contents of the test chamber through an air sampling port similar to port A shown in Figure B.10, while simultaneously measuring and recording the total air flow through the test chamber. The total air flow through the test chamber can be computed from the sum of the outlet air flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber. The flow through the test chamber and the hydrogen concentration in the chamber shall be monitored continuously.
- 7) Calculate the hydrogen gas loss rate by multiplying the concentration of hydrogen in the test chamber by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state outlet air flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the hydrogen gas loss rate.

See below:

$$HLR = (F_o + F_s) \times C$$

or

$$HLR = (F_i) \times C$$

where

HLR is the hydrogen gas loss rate in grams per hour;

F_o is the outlet air flow rate in standard litres per hour;

F_s is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration of hydrogen in grams per standard litre.

- 8) At the end of the 28 days, perform hydrogen leakage testing in accordance with the hydrogen leakage measurement test of B.7.2.1 for the fuel cartridge. If the fuel cartridge is empty of hydrogen at the end of the 28 days, refill the cartridge (or pressurize using a suitable inert gas) to rated charging pressure according to the manufacturer's instructions prior to executing the hydrogen leakage measurement.
- e) **Passing criteria:** No hydrogen absorbing metal alloy leakage, no fire, no explosion. No hydrogen leakage at the end of the 28 day period as verified by the hydrogen leakage measurement procedure of B.7.2.1 for the fuel cartridge. The hydrogen concentration in the temperature test chamber shall not exceed 25 % LFL at any time during the test. The hydrogen gas loss rate from the cartridge shall be less than 0,0032 g/h at all times during the test. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.9.3 Option 2 – Controlled flow hydrogen concentration measurement

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.

c) **Test apparatus:** A temperature test chamber shall be equipped with sampling and monitoring instruments capable of accurately measuring air flow through the test chamber, and the hydrogen concentration in the test chamber. This temperature test chamber may be similar to the emission test apparatus shown in Figure B.10. The temperature test chamber must be equipped with heaters capable of maintaining an internal temperature of $50\text{ °C} \pm 2\text{ °C}$ with air flow through the system. It is recommended that the test chamber be equipped with a hydrogen sensor or other equivalent safety features to ensure that a flammable concentration of hydrogen is not permitted to accumulate in a closed volume.

d) **Test procedure:**

- 1) The test chamber shall be equipped with a circulation fan, ventilation and measurement instruments capable of accurately measuring air flow through the chamber and a hydrogen detector calibrated to detect 25 % LFL (1 % by volume) of hydrogen concentration. The hydrogen detector shall provide an alarm or other indication of a hydrogen concentration of 25 % LFL (1 % by volume) in the test chamber. The test chamber shall have a free air volume (total volume minus volume of fuel cartridge and instrumentation inside the chamber) of less than 3,56 l to ensure adequate mixing and a homogeneous distribution in the chamber. The test chamber may utilize a configuration similar to that shown in Figure B.10, with appropriate modifications based on the free air space limitation.
- 2) The test chamber shall be supplied with clean air from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- 3) The air flow rate through the chamber shall be controlled such that a hydrogen gas loss rate from the cartridge of 0,0032 g/h will result in a hydrogen concentration of 25 % LFL (1 % by volume) and result in an alarm or other indication from the hydrogen detector, according to the following formula:

$$F_t = \frac{HLR \times SV}{C} = \frac{0,0032 \frac{\text{g}}{\text{h}} \times \left(\frac{22,4 \frac{\text{l}}{\text{mol}}}{2 \times 1,00794 \frac{\text{g}}{\text{mol}}} \right)}{0,25 \times 4\%} = 3,56 \frac{\text{l}}{\text{h}}$$

where

HLR is the hydrogen gas loss rate in grams per hour;

F_t is the air flow rate through the temperature test chamber in standard litres per hour;

C is the hydrogen concentration in grams per standard litre;

SV is the specific volume of one gram of hydrogen.

- 4) Place the sample in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$.
- 5) Allow the concentration in the chamber to equilibrate prior to beginning the test. The time required will depend on the size of the chamber and capacity of the circulation fan.
- 6) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days. The hydrogen concentration in the test chamber and the air flow rate through the test chamber shall be monitored continuously throughout the test.
- 7) If the hydrogen concentration reaches 25 % LFL (1 % by volume), this indicates 0,0032 g/h of hydrogen gas loss from the sample and the sample shall be considered to have failed the test.
- 8) At the end of the 28 days, perform hydrogen leakage testing in accordance with the hydrogen leakage measurement test of B.7.2.1 for the fuel cartridge. If the fuel cartridge is empty of hydrogen at the end of the 28 days, refill the cartridge (or pressurize using a suitable inert gas) to rated charging pressure according to the manufacturer's instructions prior to executing the hydrogen leakage measurement.

- e) **Passing criteria:** No hydrogen absorbing metal alloy leakage, no fire, no explosion. No hydrogen leakage at the end of the 28 day period as verified by the hydrogen leakage measurement procedure of B.7.2.1 for the fuel cartridge. The hydrogen concentration in the temperature test chamber shall not exceed 25 % LFL at any time during the test. The hydrogen gas loss rate from the sample shall be less than 0,0032 g/h at all times during the test. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.9.4 Option 3 – Continuous weight measurement

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test apparatus:** A temperature test chamber capable of maintaining an internal temperature of $50\text{ °C} \pm 2\text{ °C}$. It is recommended that the test chamber be equipped with a hydrogen sensor, ventilation or other equivalent safety features to ensure that a flammable concentration of hydrogen is not permitted to accumulate in a closed volume.
- d) **Test procedure** (See Figure B.9, which replaces Figure 9):
- 1) Use a load cell (continuous electronic weight sensing device) designed and calibrated for use at 50 °C inside the temperature chamber.
 - 2) Place the load cell in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Place the fuel cartridge on top of the load cell so that all the weight is being applied to the load cell. A fixture may be used to control the position of the fuel cartridge, to ensure all the weight is applied to the load cell.
 - 3) Connect a digital readout to the load cell and collect the data either manually or automatically. The data should be collected in a manner sufficient to provide a high degree of confidence that the hydrogen gas loss does not exceed 0,0032 g/h.
 - 4) Measure and record initial mass M_{initial} and time t_i .
 - 5) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
 - 6) If the fuel cartridge still has fuel in the test sample at the end of the test, then calculate the hydrogen mass loss rate by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . Calculate the hydrogen mass loss rate using the difference in mass ($M_{\text{initial}} - M_{\text{final}}$) divided by the elapsed time ($t_f - t_i$) according to the following formula:
 - i) $\frac{(M_{\text{initial}} - M_{\text{final}})}{\Delta t} = \text{hydrogen mass loss rate};$
 - ii) $\Delta t = t_f - t_i = 28\text{ days} \times 24\text{ h/day} = 672\text{ h};$
 - iii) M_{initial} = the initial mass of the fuel cartridge;
 - iv) M_{final} = the final mass of the fuel cartridge.
 - 7) If the hydrogen mass loss rate is less than 0,0032 g/h, then the test sample passes the test for hydrogen gas loss.

- 8) If the fuel cartridge contains no more hydrogen prior to the end of the test, the hydrogen mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. If the hydrogen mass loss rate is less than 0,0032 g/h, then the test sample passes the test for hydrogen gas loss.
 - i) $\frac{(M_{\text{initial}} - M_{\text{final}})}{\Delta t}$ = hydrogen mass loss rate;
 - ii) Δt_{last} = the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when fuel still remained in the fuel cartridge;
 - iii) M_{last} = the last weight measurement taken when fuel still remained in the fuel cartridge.
- 9) At the end of the 28 days, perform hydrogen leakage testing in accordance with the hydrogen leakage measurement test of B.7.2.1 for the fuel cartridge. If the fuel cartridge is empty of hydrogen at the end of the 28 days, refill the cartridge (or pressurize using a suitable inert gas) to rated charging pressure according to the manufacturer's instructions prior to executing the hydrogen leakage measurement.
- e) **Passing criteria:** No hydrogen absorbing metal alloy leakage, no fire, no explosion. No hydrogen leakage at the end of the 28 day period as verified by the hydrogen leakage measurement procedure of B.7.2.1 for the fuel cartridge. The hydrogen mass loss rate shall be determined according to the test procedure and Figure B.9. The hydrogen mass loss rate shall be less than the 0,0032 g/h impermissible hydrogen gas loss criterion. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.9.5 Option 4 – Periodic weight measurements

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test apparatus:** A temperature test chamber capable of maintaining an internal temperature of $50\text{ °C} \pm 2\text{ °C}$. It is recommended that the test chamber be equipped with a hydrogen sensor, ventilation or other equivalent safety features to ensure that a flammable concentration of hydrogen is not permitted to accumulate in a closed volume.
- d) **Test procedure** (See Figure B.9, which replaces Figure 9):
 - 1) Place the fuel cartridge in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Weight measurements shall be collected in a manner sufficient to provide a high degree of confidence to determine if the hydrogen gas loss does not exceed 0,0032 g/h, with a minimum of once every three days.
 - 2) Measure and record initial mass M_{initial} and time t_i .
 - 3) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
 - 4) The time in which the test samples are removed from the chamber for measurement shall not be included in the time the test sample is to be tested (28 days). Additional time should be added to get the test sample to the test temperature ($50\text{ °C} \pm 2\text{ °C}$) each time the test sample is removed from the chamber. The test samples should only be stabilised at laboratory temperature if the mass loss will be affected.

- 5) If the fuel cartridge still has fuel in the test sample at the end of the test, then calculate the hydrogen mass loss rate by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . Calculate the hydrogen mass loss rate using the difference in mass ($M_{\text{initial}} - M_{\text{final}}$) divided by the elapsed time ($t_f - t_i$) according to the following formula:
 - i) $\frac{(M_{\text{initial}} - M_{\text{final}})}{\Delta t} = \text{hydrogen mass loss rate};$
 - ii) $\Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h};$
 - iii) M_{initial} = the initial mass of the fuel cartridge;
 - iv) M_{final} = the final mass of the fuel cartridge.
- 6) If the hydrogen mass loss rate is less than 0,0032 g/h, then the test sample passes the test for hydrogen gas loss.
- 7) If the fuel cartridge contains no more hydrogen prior to the end of the test, the hydrogen mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. If the hydrogen mass loss rate is less than 0,0032 g/h, then the test sample passes the test for hydrogen gas loss.
 - i) $\frac{(M_{\text{initial}} - M_{\text{final}})}{\Delta t} = \text{hydrogen mass loss rate};$
 - ii) Δt_{last} = the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when fuel still remained in the fuel cartridge;
 - iii) M_{last} = the last weight measurement taken when fuel still remained in the fuel cartridge.
- 8) At the end of the 28 days, perform hydrogen leakage testing in accordance with the hydrogen leakage measurement test of B.7.2.1 for the fuel cartridge. If the fuel cartridge is empty of hydrogen at the end of the 28 days, refill the cartridge (or pressurize using a suitable inert gas) to rated charging pressure according to the manufacturer's instructions prior to executing the hydrogen leakage measurement.
- e) **Passing criteria:** No hydrogen absorbing metal alloy leakage, no fire, no explosion. No hydrogen leakage at the end of the 28 day period as verified by the hydrogen leakage measurement procedure of B.7.2.1 for the fuel cartridge. The hydrogen mass loss rate shall be determined according to the test procedure and Figure B.9. The hydrogen mass loss rate shall be less than the 0,0032 g/h impermissible hydrogen gas loss criterion. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.9.6 Option 5 – One weight measurement

This option is intended for fuel cartridges containing more than 2 g of hydrogen gas.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test apparatus:** A temperature test chamber capable of maintaining an internal temperature of $50 \text{ °C} \pm 2 \text{ °C}$. It is recommended that the test chamber be equipped with a hydrogen sensor, ventilation or other equivalent safety features to ensure that a flammable concentration of hydrogen is not permitted to accumulate in a closed volume.

d) **Test procedure:**

- 1) Measure and record initial mass M_{initial} and time t_i .
- 2) Place the fuel cartridges in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$.
- 3) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
- 4) After 28 days, remove the fuel cartridges from the chamber for measurement. The test samples should be stabilised at laboratory temperature if the mass loss will be affected.
- 5) Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the fuel cartridge still has fuel in the test sample at the end of the test, then calculate hydrogen mass loss rate using the difference in mass ($M_{\text{initial}} - M_{\text{final}}$) divided by the elapsed time ($t_f - t_i$) according to the following formula:

- i)
$$\frac{(M_{\text{initial}} - M_{\text{final}})}{\Delta t} = \text{hydrogen mass loss rate};$$

- ii) $\Delta t = t_f - t_i = 28\text{ days} \times 24\text{ h/day} = 672\text{ h};$

- iii) M_{initial} = the initial mass of the fuel cartridge;

- iv) M_{final} = the final mass of the fuel cartridge.

- 6) If the hydrogen mass loss rate is less than 0,0032 g/h, then the test sample passes the test for hydrogen gas loss.
- 7) At the end of the 28 days, perform hydrogen leakage testing in accordance with the hydrogen leakage measurement test of B.7.2.1 for the fuel cartridge.
- 8) If the fuel cartridge no longer contains hydrogen after 28 days, then the type test according to one of the following procedures shall be performed:
 - i) B.7.3.9.2 Option 1 – Continuous hydrogen concentration measurement;
 - ii) B.7.3.9.3 Option 2 – Controlled flow hydrogen concentration measurement;
 - iii) B.7.3.9.4 Option 3 – Continuous weight measurement; or
 - iv) B.7.3.9.5 Option 4 – Periodic weight measurements.
- e) **Passing criteria:** No hydrogen absorbing metal alloy leakage, no fire, no explosion. No hydrogen leakage at the end of the 28 day period as verified by the hydrogen leakage measurement procedure of B.7.2.1 for the fuel cartridge. The hydrogen mass loss rate shall be less than the 0,0032 g/h impermissible hydrogen gas loss criteria. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually

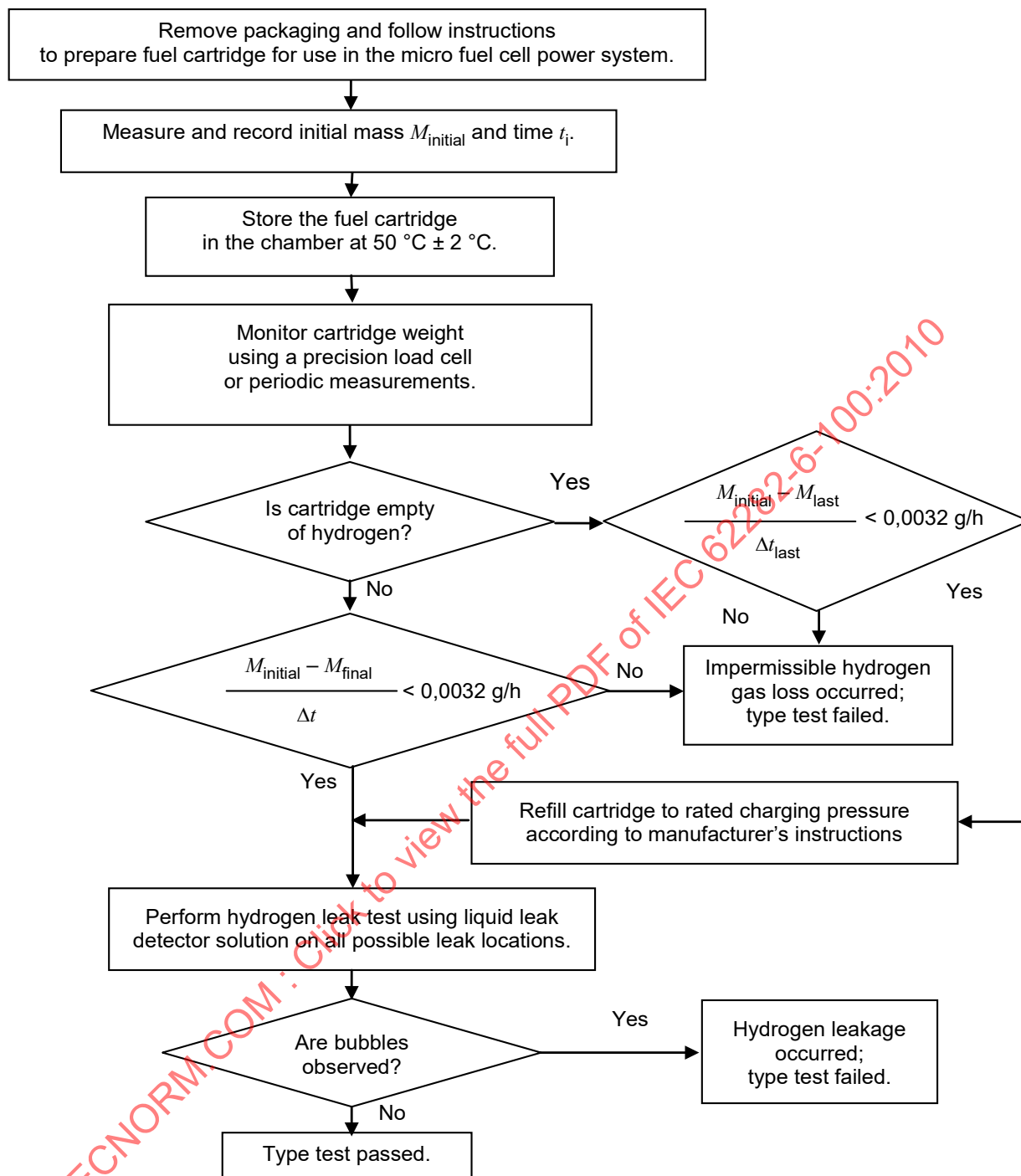


Figure B.9 – Fuel cartridge hydrogen leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

B.7.3.10 High-temperature connection test

Subclause B.7.3.10 replaces Subclause 7.3.10 for micro fuel cell power systems, units and fuel cartridges covered by this Annex B.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge and a micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry.

- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage, no fire, no explosion.
- c) **Test procedure:**
 - 1) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of $50\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for at least 4 h.
 - 2) The micro fuel cell power unit or test fixture with micro fuel cell power unit valve is kept at laboratory temperature.
 - 3) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or test fixture with micro fuel cell power unit valve within 5 min of removal from the chamber.
 - 4) Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 upon connection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 5) Disconnect the fuel cartridge and check for hydrogen leakage:
 - i) for the fuel cartridge, perform hydrogen leakage measurement in accordance with B.7.2.1. See Figure B.3;
 - ii) for the micro fuel cell power unit or test fixture with micro fuel cell power unit valve, use a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 on the fuel supply interface or valve to ensure no hydrogen leakage from the valve.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, the test is acceptable. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.11 Connection cycling tests:

Subclause B.7.3.11 replaces Subclause 7.3.11 for micro fuel cell power systems, units and fuel cartridges covered by this Annex B.

B.7.3.11.1 Fuel cartridge

B.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

- a) **Test sample:** an unused insert cartridge, exterior cartridge or attached cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve and fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 upon connection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 4) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 upon disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.

- 5) Repeat steps 1 through 4, inclusive, twice more for a total of three connections and disconnections.
 - 6) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
 - 7) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 8) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 9) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 10) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 11) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 12) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 upon disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.11.1.2 Satellite cartridge

- a) **Test sample:** an unused satellite fuel cartridge and an unused micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the satellite fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and initiate or simulate fuel flow. Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 upon connection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 2) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 upon disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 3) Repeat steps 1 and 2 twice more for a total of three connections and disconnections.
 - 4) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
 - 5) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 6) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 7) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.

- 8) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and initiate or simulate fuel flow.
 - 9) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 upon disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
 - 10) Repeat steps 1 through 9 four more times for a total of 55 cycles, waiting 1 h between each set of 11 cycles.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 for the fuel cartridge. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually.

B.7.3.11.2 Micro fuel cell power unit

- a) **Test sample:** a minimum of two unused fuel cartridges and an additional 98 fuel cartridges or suitable test fixtures with fuel cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the fuel cartridge valve geometry and material and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage both at initial use and after suitable ageing of the micro fuel cell power unit connection.

First fuel cartridge (#1) and final fuel cartridge (#100) are inspected; the other 980 cycles are only to age the micro fuel cell power unit.

In the case of a micro fuel cell power unit using satellite cartridge, it shall be tested according to the following procedure by simulating fuel flow between the satellite cartridge and the micro fuel cell power unit.

c) **Test procedure:**

- 1) Connect the first fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 at the connection point, and all other points where hydrogen leakage may occur on connection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1, in particular at the connection valves of the fuel cartridge and the micro fuel cell power unit, and all other points where hydrogen leakage may occur on disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 5) Repeat steps 1 through 4, inclusive, twice more for a total of three connections and disconnections.
- 6) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 7) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 in particular at the connection valves of the fuel cartridge and the micro fuel cell power unit, and all other points where hydrogen leakage may occur on disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.

- 8) Connect and disconnect the first fuel cartridge three more times for a total of ten connections and disconnections.
- 9) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1, in particular at the connection valves of the fuel cartridge and the micro fuel cell power unit, and all other points where hydrogen leakage may occur on disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 10) Connect the fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 at the connection point, and all other points where hydrogen leakage may occur on connection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 11) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 13) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1, in particular at the connection valves of the fuel cartridge and the micro fuel cell power unit, and all other points where hydrogen leakage may occur on disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 14) In order to age the micro fuel cell power unit fuel cartridge connection, perform the following steps.
 - i) Using either fuel cartridges or a suitable test fixture with fuel cartridge valves, cycle the micro fuel cell power unit fuel cartridge connection for a total of 980 connections and disconnections.
 - ii) Simulate fuel flow after each set of 50 connection-disconnection cycles.
 - iii) Following this ageing, a final unused fuel cartridge will be tested.
- 15) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 at the connection point, and all other points where hydrogen leakage may occur on connection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 16) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 17) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 18) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1, in particular at the connection valves of the fuel cartridge and the micro fuel cell power unit, and all other points where hydrogen leakage may occur on disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 19) Repeat steps 15 through 18, inclusive, twice more for a total of three connections and disconnections.
- 20) Connect and disconnect the final fuel cartridge four more times for a total of seven connections and disconnections.
- 21) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1, in particular at the connection valves of the fuel cartridge and the micro fuel cell power unit, and all other points where hydrogen leakage may occur on disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1. Connect and disconnect the final fuel cartridge three more times for a total of ten connections and disconnections.

- 22) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1, in particular at the connection valves of the fuel cartridge and the micro fuel cell power unit, and all other points where hydrogen leakage may occur on disconnection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 23) Connect the fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 at the connection point, and all other points where hydrogen leakage may occur on connection. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 24) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 25) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 26) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with B.7.2.1 for the fuel cartridge and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in B.7.2.1.
- 27) Perform the following hydrogen leakage tests.
 - i) For the micro fuel cell power system or micro fuel cell power unit, perform hydrogen gas loss measurement in accordance with B.7.2.2 (this includes hydrogen emission testing in accordance with B.7.3.12). See Figure B.4.
 - ii) If the micro fuel cell power system or unit contains a fuel cartridge or an internal reservoir that contains hydrogen gas above ambient pressure, perform hydrogen leakage measurement in accordance with B.7.2.1.
- d) **Passing criteria:** No fire at any time, no explosion at any time, and no hydrogen absorbing metal alloy leakage. Hydrogen gas loss shall meet the applicable requirements of B.7.2.2 for the micro fuel cell power unit. Hydrogen leakage shall meet the no hydrogen leakage requirements of B.7.2.1 at connection points when the fuel cartridge is connected to the micro fuel cell power unit, and at connection valves when disconnected, and for the fuel cartridge and the internal reservoir, if applicable. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen absorbing metal alloy leakage shall be checked visually. If the micro fuel cell power unit or micro fuel cell power system is not operational following the test, but the applicable requirements of B.7.2.1 and B.7.2.2 are met, the test is acceptable.

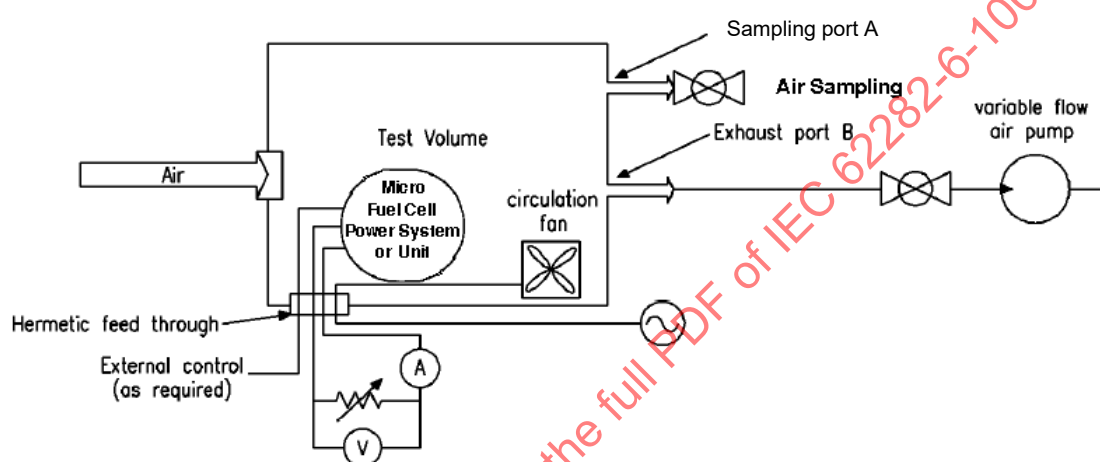
B.7.3.12 Emission test

This Subclause B.7.3.12 shall replace Subclause 7.3.12 for micro fuel cell power systems or micro fuel cell power units tested in accordance with this Annex B. The included Table B.7, Emission limits, replaces Table 7 in Subclause 7.3.12. Figure B.10 replaces Figure 10 and is identical to Figure 10. Hydrogen emissions are the only possible emission from these micro fuel cell power systems and micro fuel cell power units using hydrogen stored in metal hydride storage systems. The procedure for hydrogen emission testing is detailed in Figure B.12, which is to be used as an additional figure when testing is done in accordance with this Annex B.

Micro fuel cell power systems or units shall be tested according to B.7.3.12.1, Hydrogen emission test, DEVICE-ON. A second test procedure, B.7.3.12.2, Hydrogen emission test, DEVICE-OFF, is provided for use in conjunction with B.7.2.2, Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures.

B.7.3.12.1 Hydrogen emission test, DEVICE-ON

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or micro fuel cell power unit – that is fuelled with hydrogen – emissions of hydrogen are the only possible emissions. The purpose of this test is to make sure that hydrogen emissions are maintained low enough to ensure that, in addition to not permitting a flammable concentration to build up in the reference volume, there is no gas loss of hydrogen from the specimen that could support a flame ($< 0,016$ g/h, or 3 standard cubic centimeters per minute). Maintaining these limits not only prevents flammable mixtures from arising due to hydrogen emissions but also ensures that an adequate supply of oxygen is maintained in the operating environment.

**Figure B.10 – Operational emission rate testing apparatus – Replaces Figure 10**

- c) **Test apparatus:** An example of the operational emission rate testing apparatus is shown in Figure B.10. The configuration shown in Figure B.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex B. Hydrogen emission rate testing in accordance with B.7.3.12.1 d) is required for micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex B.

To analyse the hydrogen emissions, a mass spectrometer, gas chromatograph, or other suitable instrument calibrated to measure hydrogen concentration shall be used and connected to sampling port A in Figure B.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

A hydrogen detector calibrated for the zero-to-one-percent mass concentration hydrogen range can be used to measure the hydrogen concentration.

d) Test procedure:

- 1) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure B.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the hydrogen emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
- 2) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.

- 3) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure B.10.
- 4) Allow the test chamber inlet air flow rate, outlet air flow rate, circulation fan flow and sample flow rate to stabilise.
- 5) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure B.10, while simultaneously measuring and recording the total air flow through the test chamber. The total air flow through the test chamber may be computed from the sum of the outlet air flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber. The flow through the test chamber and the hydrogen concentration in the chamber shall be monitored continuously.
- 6) Record the hydrogen concentration.
- 7) Calculate the hydrogen emission rate being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state outlet air flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the hydrogen gas loss rate.

See below:

$$ER = (F_o + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the hydrogen emission rate in grams per hour;

F_o is the outlet air flow rate in litres per hour;

F_S is the sample flow rate in litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per litre.

- 8) Compare the maximum measured "DEVICE – ON" hydrogen emission rate to Table B.7.

NOTE This is a stabilised concentration measurement.

- 9) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 10) If the hydrogen emission rate is less than 0,016 g/h with the "DEVICE – ON", the test is complete.
- 11) If the hydrogen emission rate is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON", perform hydrogen point source gas loss detection test in accordance with B.7.3.13.
- 12) If the hydrogen emission rate is greater than 0,8 g/h with the "DEVICE – ON", the test fails. No further testing is necessary.

e) **Passing criteria:**

The procedure for hydrogen emission testing is detailed in Figure B.12, which is to be used as an additional figure when testing is done in accordance with Annex B. Hydrogen emissions are evaluated as follows: If the total hydrogen emission rate is less than 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or micro fuel cell power unit passes the emission test and no further testing is required. If the total hydrogen emission rate is not less than 0,8 g/h with the "DEVICE – ON", the micro fuel cell power system or unit fails the emission test and no further testing is required. If the hydrogen emission rate is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON", B.7.3.13, hydrogen point source gas loss detection test shall be performed with acceptable results to show no more than 0,016 g/h hydrogen leakage from any single point leak. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding the limit for non-operating systems in Table B.7, the test is acceptable.

NOTE 1 The allowable flammable hydrogen emission level that will not support a standing flame is 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). The non-flammable hydrogen emissions limit is based on the criteria that hydrogen emission does not build up to more than 25 % of LFL in the reference volume.

NOTE 2 Hydrogen is defined as a simple asphyxiant but for this risk to exist, oxygen levels have to fall less than 18 % at normal atmospheric pressure. Hydrogen related flammability risk arises at hydrogen-in-air concentrations greater than 4 %, while the asphyxiant risk arises at hydrogen-in-air concentrations greater than 12 %. Therefore, the flammability limits are used in defining the limits for hydrogen emissions.

B.7.3.12.2 Hydrogen emission test, DEVICE-OFF

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under storage, or non-operating, conditions of a micro fuel cell power system or micro fuel cell power unit – that is fuelled with hydrogen – emissions of hydrogen are the only possible emissions. This test procedure is intended to be used in conjunction with the hydrogen gas loss test of B.7.2.2, to ensure that a non-operating micro fuel cell power system or micro fuel cell power unit does not exceed the impermissible hydrogen gas loss limit of 0,0032 g/h.
- c) **Test apparatus:** An example of the operational emission rate testing apparatus is shown in Figure B.10. The configuration shown in Figure B.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex B.

To analyse the hydrogen emissions, a mass spectrometer, gas chromatograph, or other suitable instrument calibrated to measure hydrogen concentration shall be used and connected to sampling port A in Figure B.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

A hydrogen detector calibrated for the zero-to-one-percent mass concentration hydrogen range can be used to measure the hydrogen concentration.

d) **Test procedure:**

- 1) Turn the micro fuel cell power system or unit off ("DEVICE – OFF") and measure the hydrogen emission, or hydrogen gas loss, rates with the micro fuel cell power system or unit off ("DEVICE – OFF") inside the small test chamber shown in Figure B.10.
- 2) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- 3) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown on Figure B.10.
- 4) Allow the test chamber inlet air flow rate, outlet air flow rate, circulation fan flow and sample flow rate to stabilise.

- 5) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure B.10, while simultaneously measuring and recording the total air flow through the test chamber. The total air flow through the test chamber may be computed from the sum of the outlet air flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber. The flow through the test chamber and the hydrogen concentration in the chamber shall be monitored continuously.
- 6) Record the hydrogen concentration.
- 7) Calculate the hydrogen gas loss rate being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state outlet air flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the hydrogen gas loss rate.

$$HLR = (F_o + F_s) \times C$$

or

$$HLR = (F_i) \times C$$

where

HLR is the emission rate in grams per hour;

F_o is the outlet air flow rate in litres per hour;

F_s is the sample flow rate in litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per litre.

- 8) Compare the maximum measured "DEVICE – OFF" hydrogen gas loss rate to Table B.7.

NOTE This is a stabilised concentration measurement.

- 9) Hydrogen gas loss rate measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 10) Evaluate the hydrogen gas loss rate as follows.
 - i) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF", the micro fuel cell power system or unit passes the test and no further testing is necessary.
 - ii) If the hydrogen emission rate measurement is not below the allowable 0,0032 g/h with the "DEVICE – OFF", the micro fuel cell power system or unit fails the test and no further testing is necessary.

e) **Passing criteria:**

Passing criteria for non-operating systems: The hydrogen gas loss rate shall be less than 0,0032 g/h with the "DEVICE – OFF".

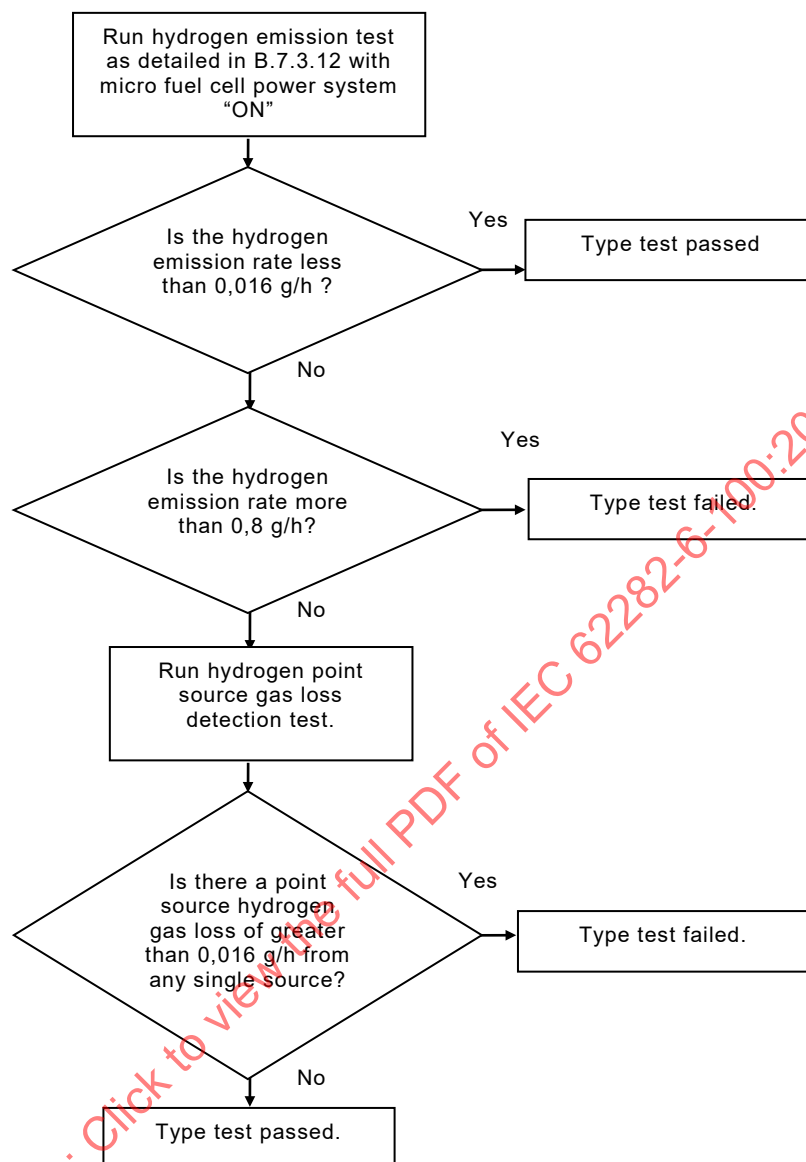


Figure B.12 – Hydrogen emission test procedure for operating micro fuel cell power system

Table B.7 – Emission limits – Replaces Table 7

Emissions	Operating system Permissible emissions rate limit ^a ("DEVICE – ON")	Non-operating system impermissible gas loss ^b (including "DEVICE – OFF")
Water	Unlimited	Unlimited
Hydrogen	0,8 g/h total 0,016 g/h from single point leak	0,0032 g/h

Table B.7 replaces Table 7.

^a The operating emission rate limit is based on a product of a reference volume times air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume allocation per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is usually over 20 m³, so a product of 10 is conservative. A further factor of safety of 10 has been added in this specific case.

^b The "impermissible hydrogen gas loss" criteria for non-operating micro fuel cell power systems has been chosen based on a scenario of micro fuel cell power systems in an enclosed space with no ventilation. The space chosen has a volume of 0,28 m³, or approximately 10 cubic feet. The criterion has been prescribed so that a hydrogen concentration of greater than 25 % LFL is not permitted to develop over a twenty-four hour (24 h) period, if three micro fuel cell power systems are in the enclosed space.

B.7.3.13 Hydrogen point source gas loss detection test

This subclause shall only be used if required by Subclause B.7.3.12.1 d) 11) to show compliance with Table B.7, for micro fuel cell power systems and micro fuel cell power units using hydrogen stored in metal hydride as fuel. *The procedure for hydrogen emission testing is detailed in Figure B.12, which is to be used as an additional figure when testing is done in accordance with Annex B.* This subclause is required to be performed to meet the passing criteria of Subclause B.7.3.12.1 e) if the total hydrogen emission rate from an operational micro fuel cell power system or unit is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON". This subclause is additional to the requirements in Clause 7.

- Test sample:** A micro fuel cell power unit or a micro fuel cell power system used in B.7.3.12.1.
- Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or a micro fuel cell power unit within the scope of this Annex B, emission of hydrogen shall be maintained at less than the specified values in Table B.7. The hydrogen point source gas loss detection test shall be performed to determine that no single source on the micro fuel cell power system or unit can support a flame in all cases where such compliance cannot be definitively determined by the hydrogen emission test. Maintaining these limits ensures that, in addition to not permitting a flammable concentration to build up in the reference volume, there is no gas loss of hydrogen from the specimen that could support a flame.
- Test apparatus:** The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, a hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL.

NOTE The response of the aforementioned hydrogen detectors is commonly slow, with a response time of many seconds, thus high sweep speeds may cause underestimation of the hydrogen concentration. It is important that the sweep speed is slow enough to accurately measure the hydrogen concentration.

d) Test procedure:

- 1) The micro fuel cell power system or micro fuel cell power unit shall remain turned on ("DEVICE – ON") throughout the duration of the hydrogen point source gas loss detection test.
- 2) The testing shall be conducted in a space with no substantial air movement. The measured wind speed 10 cm above the micro fuel cell power system or unit shall not exceed 0,02 m/s.

NOTE 1 The local concentration of hydrogen diffusion measured in this test is very susceptible to the effect of wind. It is desirable that wind speed anywhere in the test space is as close to zero as possible. Testing in a closed space, such as a glove box or equivalent chamber, is one available method to achieve this requirement.

- 3) The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL.

NOTE 2 The response of the aforementioned hydrogen detectors is commonly slow – in the range of seconds – thus such high sweep speed may cause the underestimation of hydrogen concentration. It is noted that the sweep speed is slow enough to accurately measure the hydrogen concentration.

- 4) The sensor of the hydrogen detector shall sweep the micro fuel cell power system or unit at a distance no more than 3 mm normal to the surface of the micro fuel cell power system or unit. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the micro fuel cell power system or unit. The entire surface of the micro fuel cell power system or unit shall be swept in this manner.
- 5) An effective method for completing these sweeps would be to attach a stand off to the sensor that ensures that a spacing of 3 mm from the micro fuel cell power system or unit is maintained at all times. A pen or other marking utensil attached to the stand off could be used to identify swept areas and ensure that the distance between sweeps does not exceed 8 mm.
- 6) The sensor should always face directly downward, and the micro fuel cell power system or unit should be moved beneath it such that the surface directly below the sensor is always horizontal.
- 7) If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the micro fuel cell power system or unit shall be considered to have passed.

NOTE 3 When some point source sweeps show a large region of 25 % LFL or greater in the initial linear sweeps, recording the measured concentration values will assist in determining the starting point of secondary spiral sweeps. Point sources are supposed to be where local maximum values exist in the distribution of measured concentration values.

- 8) If any points are detected to have a hydrogen concentration of 25 % LFL or greater, a second test shall be conducted to ensure that the emission does not exceed 0,016 g/h of pure hydrogen from any single source.
- 9) The second test shall be performed with the sensor height adjusted to 6,5 mm above the micro fuel cell power system or unit.
- 10) A spiral sweep shall then be made, originating from the point where the detection of 25 % LFL or greater of hydrogen occurred during the initial linear sweep. The spiral sweep shall have a spacing of 1 mm or less between sweeps, and shall spiral out to a radial distance of at least 4 mm and far enough to detect the maximum hydrogen level from the particular hydrogen source.
- 11) If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the micro fuel cell power system or unit passes the test.

- e) **Passing criteria:** No gas loss of hydrogen from any single source at greater than 0,016 g/h as indicated by sweep testing. No indications of hydrogen that is 25 % of LFL during the primary sweep testing or no indications of hydrogen that is 25 % of LFL during the secondary sweep testing at 6,5 mm above the micro fuel cell power system or unit. If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. See Table B.7.

B.7.3.14 Fuel cartridge integrity test

Subclause B.7.3.14 is to be done in addition to testing required in Clause 7 for fuel cartridges covered by this Annex B.

- a) **Test sample:** fuel cartridges as required by ISO 16111:2008.
- b) **Purpose:** to assure fuel cartridge integrity.
- c) **Test procedure:**

Fuel cartridges shall be tested as a metal hydride assembly in accordance with ISO 16111:2008 and shall meet all requirements of that standard.

- d) **Passing criteria:** Passing criteria is given in ISO 16111:2008.

B.7.3.15 Internal reservoir integrity test

Subclause B.7.3.15 is to be done in addition to testing required in Clause 7 for micro fuel cell power units covered by this Annex B that have a pressure regulator or valve between the micro fuel cell power unit and the internal fuel reservoir and the reservoir contains hydrogen absorbing metal alloy in the internal reservoir.

- a) **Test sample:** a micro fuel cell power unit internal reservoir.
- b) **Purpose:** to assure internal reservoir integrity.
- c) **Test procedure:**

Internal reservoirs that have a pressure regulator or valve between the micro fuel cell power unit and the internal fuel reservoir and that contain metal hydride for the storage of hydrogen shall be tested in accordance with ISO 16111:2008 as a metal hydride assembly and shall meet all requirements of that standard.

- d) **Passing criteria:** Passing criteria is given in ISO 16111:2008.

Annex C (normative)

Reformed methanol micro fuel cell power systems

C.1 Scope

C.1.2 Fuels and technologies covered by this annex

Annex C covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that convert methanol or methanol and water solutions through a reformer into hydrogen rich methanol reformat, which is then immediately fed to the fuel cell or fuel cell stack, as fuel. These systems and units use proton exchange membrane fuel cell technologies.

Figure C.1 replaces Figure 1 showing a reformed methanol micro fuel cell power system block diagram for use with this Annex C.

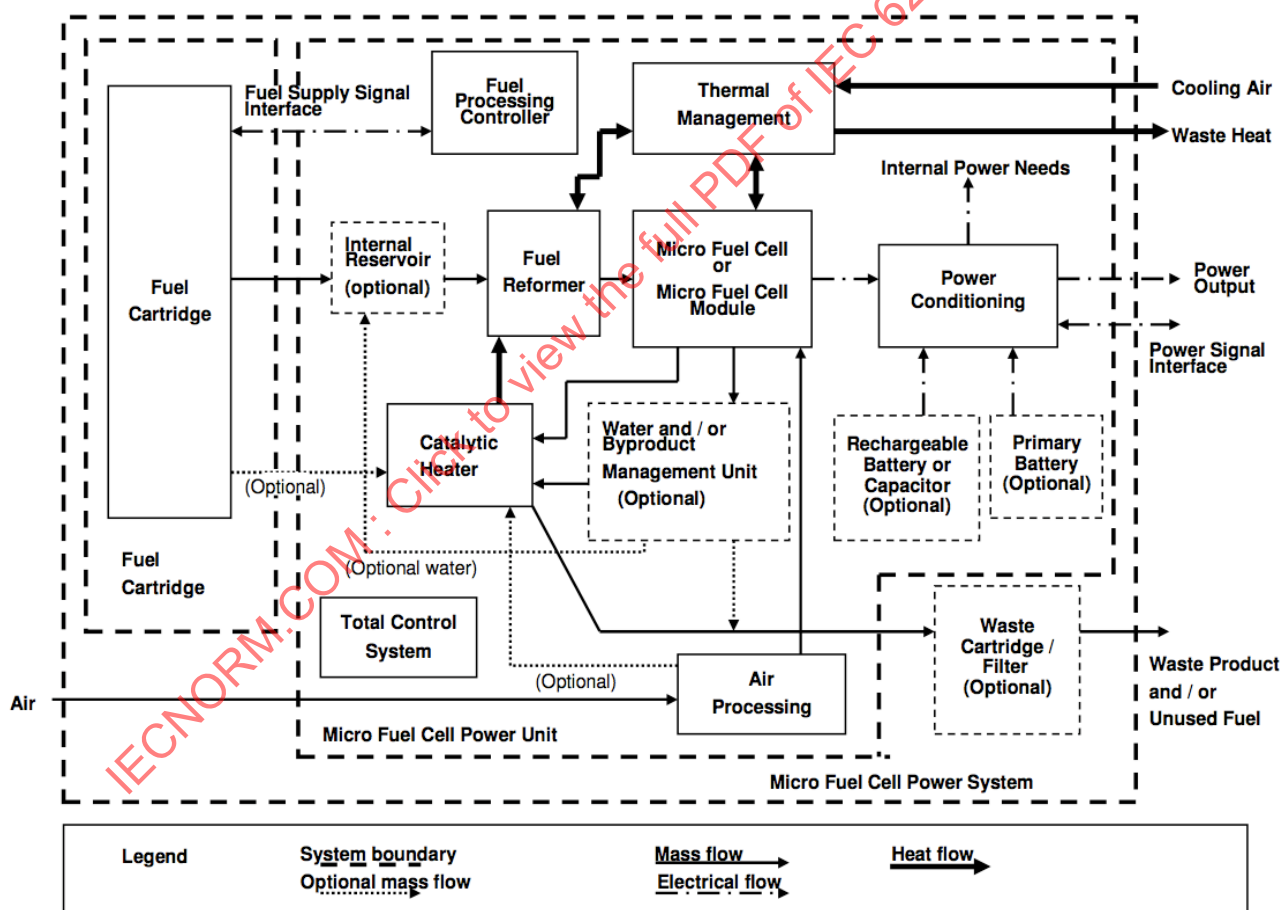


Figure C.1 – General block diagram of a reformed methanol micro fuel cell power system – Replaces Figure 1

C.3 Terms and definitions

The additional terms and their definitions below are needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex C in addition to those given in Clause 3.

C.3.37

catalytic heater

device that oxidizes a fuel (e.g., methanol, hydrogen) and produces heat without a flame for applicable micro fuel cell power systems

C.3.38

impermissible hydrogen gas loss

hydrogen gas escaping non-operating micro fuel cell power system or micro fuel cell power unit greater than or equal to 0,0032 g/h

C.3.39

methanol fuel reformer (also referred to as “reformer”)

device that converts methanol and water to hydrogen reformat (hydrogen, carbon dioxide, methanol, formaldehyde, carbon monoxide and methyl formate) for applicable micro fuel cell power systems

C.3.40

"DEVICE – ON"

device with its power switch turned on and operating to produce power or unable to produce power due to a failure or other reasons

C.4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges

C.4.10 Protection against fire, explosion, corrosivity and toxicity hazard

These requirements apply to micro fuel cell power systems and units covered by this Annex C. *These requirements replace the corresponding requirements of Subclause 4.10.*

C.4.10.1 Flammable, toxic and corrosive fluids shall be kept within a closed containment system such as within fuel piping, in a reservoir, a fuel cartridge or similar enclosure. Compliance shall be verified by type testing in accordance with Clause 7.

C.4.10.2 A micro fuel cell power system or unit may be equipped with a means of detecting concentration levels of fluids in Table 7 and shutting down the micro fuel cell power system or unit prior to exceeding the concentration limit.

C.4.10.3 Internal wiring and insulation in general shall not be exposed to fuel, oils, grease or similar substances, unless the insulation has been evaluated for contact with these substances.

C.4.10.4 Micro fuel cell power systems shall be designed in such a way that there is no risk of open flame in catalytic heaters (start, main and auxiliary catalytic heaters of a reformer section, tail gas catalytic heaters).

C.4.10.5 If air for catalytic heating is mixed with fuel gas, an effective means shall be provided to prevent the air from returning to the fuel gas line and to prevent the fuel gas from flowing into the air supply unit.

C.4.10.6 Controls for fuel and air feeds for reformers and catalytic heaters shall be designed to reliably maintain the fuel to air ratio.

C.4.10.7 Upon shutdown, hazardous gases in the reformer and catalytic heater process systems shall be safely contained, oxidized, or disposed.

C.4.10.8 For air-rich catalytic heater systems: The fuel and air supply shall be suitably controlled to provide air prior to reaction initiation and to prevent fuel from entering the reactor until the air supply is available.

C.4.10.9 For fuel-rich catalytic heater systems: The fuel and air supply shall be suitably controlled to provide fuel prior to reaction initiation and to prevent air from entering the reactor until the fuel is available.

C.4.10.10 The reaction initiation time of the catalytic heater shall be determined by considering the response time of the system control devices and the time required to build up the maximum allowable quantity of flammable mixture that can safely be contained in the system based on flow rates, fuel-air mixture flammability, and system dynamics and geometry.

C.4.10.11 The manufacturer shall ensure that the maximum quantity of flammable mixture that could credibly accumulate, if combusted, produces pressures and temperatures that can be contained within the components exposed to such conditions. All parts of reformer and catalytic heater systems shall be an open design (i.e., gases flow from reformer to stack to catalytic heater to exhaust), and there shall not be the possibility of building up high pressure within the components exposed to these open conditions.

C.4.10.12 Tubing and other fuel pathways shall be designed in such a way that there is no danger of leakage of gases from the fuel reformer or catalytic heater under normal use and reasonably foreseeable abuse generated by vibration, heat, pressure, etc.

C.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

C.7.1 General

This Subclause C.7.1 replaces Subclause 7.1 for this annex when testing reformed methanol micro fuel cell power systems, reformed methanol micro fuel cell power units and reformed methanol fuel cartridges.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table C.5 lists the type tests that must be performed. *Table C.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table C.6. *Table C.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of $22\text{ °C} \pm 5\text{ °C}$ for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table C.5 – List of type tests – Replaces Table 5

Test reference	Test item	Test sample
7.3.1	Pressure differential tests	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.2	Vibration test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.3	Temperature cycling test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.4	High temperature exposure test	Fuel cartridge Partially filled fuel cartridge
7.3.5	Drop test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.6	Compressive loading test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
7.3.9	Long-term storage test	Fuel cartridge Partially filled fuel cartridge
7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Partially filled fuel cartridge and micro fuel cell power unit
7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit
C.7.3.12	Emission test	Micro fuel cell power system or power unit
C.7.3.13	Hydrogen point source gas loss detection test	Micro fuel cell power system or power unit, if required
C.7.3.15	High temperature operation test	Micro fuel cell power system or power unit

Table C.5 replaces Table 5.

Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or partially filled, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test.

Test sequence: Tests 7.3.2 and 7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests 7.3.1, 7.3.2, and 7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or power units.

Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.

Table C.6 – Laboratory standard conditions – Replaces Table 6

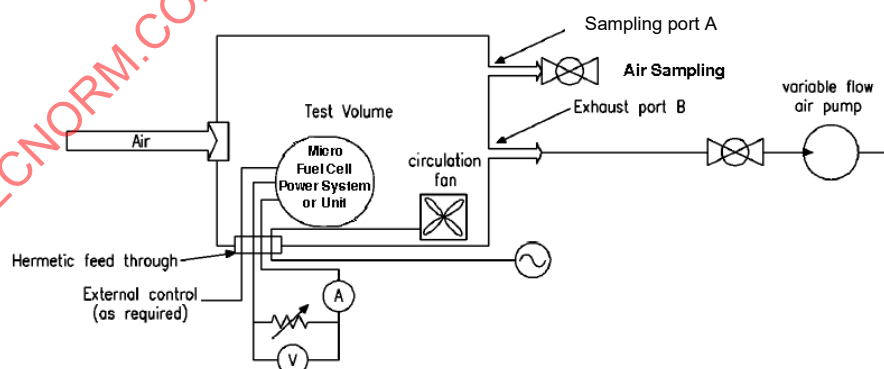
Item	Condition
Laboratory temperature	Laboratory temperature is "room temperature" (standard temperature condition, $22\text{ °C} \pm 5\text{ °C}$)
Laboratory room atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide, not more than 0,002 % carbon monoxide, and not more than 0,008 % hydrogen. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen.
Table C.6 replaces Table 6.	

C.7.3.12 Emission test

This Subclause C.7.3.12 shall replace Subclause 7.3.12 for reformed methanol micro fuel cell power systems or units tested in accordance with Annex C. Table C.7, Emission limits, replaces Table 7 in Subclause 7.3.12. Figure C.10 replaces Figure 10. The new additional Table C.8, Occupational exposure limits, is provided to inform the user regarding exposure limits. Hydrogen emissions are evaluated separately, and the procedure for hydrogen emission testing is detailed in Figure C.12, which is to be used as an additional figure when testing is done in accordance with Annex C.

Reformed methanol micro fuel cell power systems do not produce or store hydrogen when they are not operating. Since this is the case, hydrogen gas loss measurement is not needed for non operating reformed methanol micro fuel cell power units and micro fuel cell power systems. The emission test in C.7.3.12 is only done on operating (or attempts at operating) systems.

- Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- Purpose:** Under operating conditions (or attempted operating conditions) of a reformed methanol micro fuel cell power system or a micro fuel cell power unit emissions of methanol vapours, carbon dioxide, carbon monoxide, formaldehyde, hydrogen, and water vapour shall be maintained at less than the specified values. Maintaining these limits not only prevents inadvisable exposure but also ensures an adequate supply of oxygen is maintained in the operating environment.

**Figure C.10 – Operational emission rate testing apparatus – Replaces Figure 10**

- Test apparatus:** An example of the operational emission test apparatus is shown in Figure C.10. The configuration shown in Figure C.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex C. Emission

rate testing in accordance with C.7.3.12 d) 1) is required for all types of micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex C.

For micro fuel cell power systems or units that are intended to be used in close proximity to a consumer's mouth or nose (such as micro fuel cell power systems or units used to power cell phones, handheld games, etc.) additional testing in accordance with C.7.3.12 d) 3) and C.7.3.12 d) 4) is required to verify that emission concentrations in the vicinity of a user's mouth or nose are kept within appropriate limits. This emission concentration testing shall be done in a large open room using a different emission concentration testing apparatus. An example of the operational emission concentration testing apparatus is shown in Figure C.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell power system or unit to a consumer's mouth or nose when in use) for emissions concentration limit testing.

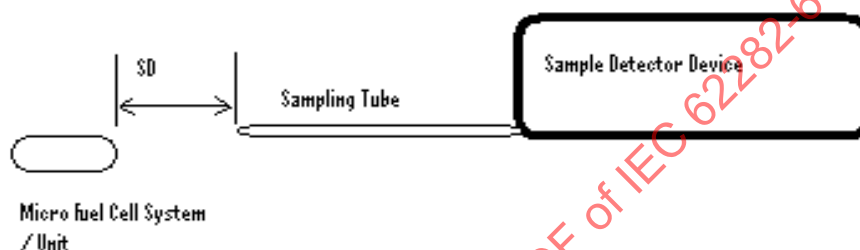


**Figure C.11 – Operational emission concentration testing apparatus –
Replaces Figure 11**

Emission gases might be composed of toxic organic materials such as methanol vapours, carbon dioxide, carbon monoxide and formaldehyde, which are potentially exhausted from a micro fuel cell power system or a micro fuel cell power unit.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) shall be used by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyzer through sampling port A in Figure C.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

A hydrogen detector calibrated for the zero-to-one-percent mass concentration hydrogen range can be used to measure the hydrogen concentration.

The concentration of CO and CO₂ gas can be measured by a non-dispersive infrared absorption analyzer. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) Test procedure:

Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure C.12, which is to be used as an additional figure when testing is done in accordance with Annex C.*

Emission rate sampling tests shall be performed both with the micro fuel cell power system or unit on ("DEVICE – ON") as follows.

- 1) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed with the micro fuel cell power system or unit on ("DEVICE – ON") as follows.

- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure C.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the “on” position (“DEVICE – ON”).
- ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- iii) Gaseous emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure C.10.
- iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure C.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vi) Record the concentrations of chemical compounds of interest. See Table C.7.
- vii) Calculate the emission rate of chemical compounds being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE 1 The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- viii) Compare the maximum measured emission rate to Table C.7. If the emission rate is not less than the emission rate limit in Table C.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria C.7.3.12 e) 1) i) and C.7.3.12 e) 2) i).
- ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

- 2) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emissions concentration sampling test shall be performed with the micro fuel cell power system or unit on "DEVICE – ON" as follows.
 - i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling system do not contribute emissions (that is, contaminants) to the test. Prior to testing, a system check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results. Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - ii) Operate the micro fuel cell power system or micro fuel cell power unit at rated power in the large open room while sampling the emission concentrations using the operational emission concentration testing apparatus shown in Figure C.11. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission concentration test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "ON" position ("DEVICE – ON").
 - iii) Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - iv) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the operational emission concentration testing apparatus shown in Figure C.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - v) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - vi) Allow the sample flow rate to stabilise.
 - vii) Sample and record the fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - viii) Record the concentrations of the chemical compounds of interest. See Table C.7.
 - ix) Compare the maximum measured concentrations to Table C.7. If the emission concentrations are not less than the emission concentration limits in Table C.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria C.7.3.12 e) 2) ii).
 - x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 3) Upon completion of the emissions measurements with "DEVICE – ON" in accordance with Table C.7, "DEVICE – ON" hydrogen emissions are evaluated as follows.
 - i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure C.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test

shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").

- ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- iii) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure C.10.
- iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure C.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vi) Record the hydrogen concentration.
- vii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE 2 The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- viii) Compare the maximum measured "DEVICE – ON" hydrogen emission rate to Table C.7.

NOTE 3 This is a stabilised concentration measurement.

- ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

4) Evaluate the hydrogen emission rate as follows.

- i) If the hydrogen emission rate measurement is below the allowable 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or unit passes the test and no further testing is necessary.

- ii) If the hydrogen emission rate measurement is not below the total allowable 0,8 g/h with the "DEVICE – ON", the system or unit fails the test and no further testing is necessary.
- iii) If the hydrogen emission rate measurement is below the total allowable 0,08 g/h with the "DEVICE – ON" but is not below 0,016 g/h with the "DEVICE – ON", then proceed with C.7.3.13, Hydrogen point source gas loss detection test to verify that no single source of hydrogen exceeds 0,016 g/h.

e) **Passing criteria:**

- 1) For micro fuel cell power systems and micro fuel cell power units not intended to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table C.7 shall be less than the emission rate limit value in Table 7 when tested in accordance with C.7.3.12 d) 1) for "DEVICE – ON." If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 2) For micro fuel cell power systems and micro fuel cell power units to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table C.7 shall be less than the emission rate limit value in Table C.7 when tested in accordance with C.7.3.12 d) 1) for "DEVICE – ON." If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
 - ii) For micro fuel cell power systems and micro fuel cell power units intended to be used in close proximity to a consumer's mouth or nose; in addition to meeting the emission rate limit above, the maximum emission concentration for each of the constituents of interest shall not exceed the emission concentration limit in Table C.7 when tested in accordance with C.7.3.12 d) 3) for "DEVICE – ON." If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 3) Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure C.12, which is to be used as an additional figure when testing is done in accordance with Annex C.* Upon completion of the hydrogen emissions measurements in accordance with Table C.7, hydrogen emissions are evaluated as follows:
 - i) **Passing criteria for operational systems:** If the total Hydrogen emission rate is less than 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or micro fuel cell power unit passes the emission test and no further testing is required. If the total Hydrogen emission rate is not less than 0,8 g/h with the "DEVICE – ON", the micro fuel cell power system or unit fails the emission test and no further testing is required. If the Hydrogen emission rate is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON", C.7.3.13, Hydrogen point source gas loss detection test must be performed with acceptable results to show no more than 0,016 g/h hydrogen leakage from any single point leak.

NOTE 4 The allowable flammable hydrogen emission level that will not support a standing flame is 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, Codes and Standards Analysis, 2001 (USA)). The non-flammable hydrogen emissions limit is based on the criteria that hydrogen emission does not build up to more than 25 % of LFL in the reference volume.

NOTE 5 Hydrogen is defined as a simple asphyxiant but for this risk to exist, oxygen levels have to fall less than 18 % at normal atmospheric pressure. Hydrogen related flammability risk arises at hydrogen-in-air concentrations greater than 4 %, while the asphyxiant risk arises at hydrogen-in-air concentrations greater than 12 %. Therefore, the flammability limits are used in defining the limits for hydrogen emissions.

NOTE 6 Carbon dioxide, carbon monoxide and formic acid vapour emission level limits are based on toxicity and corrosivity (formic acid only) effects on humans while the hydrogen emissions level limit is based on the risk of creating a flammable atmosphere in confined spaces and the risk of a potential standing hydrogen flame.

NOTE 7 The formic acid flammability risk, based on the criteria of maintaining the concentration-in-air below 25 % of LFL, is orders of magnitude lower than the toxicity risk (flammability limit = 42 500 ppmv to toxicity limit = 5 ppmv). Thus, the formic acid toxicity level is used to set the limits of its emissions.

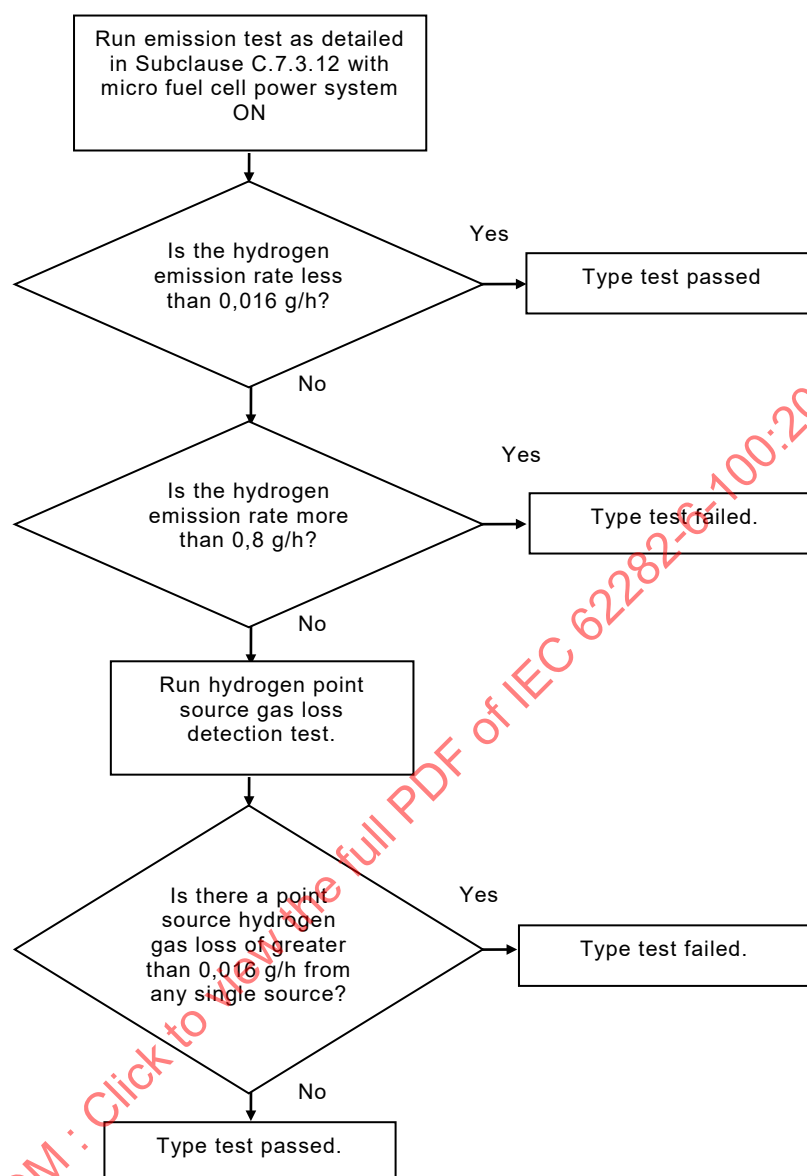


Figure C.12 – Hydrogen emission test procedure for operating micro fuel cell power system

Table C.7 – Emission limits – Replaces Table 7

	Concentration limit	Emission rate limit ^a
Water	Unlimited	No limit
Methanol	0,26 g/m ³	2,6 g/h
Formaldehyde	0,000 1 g/m ³ ^b	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Formic acid	0,009 g/m ³	0,09 g/h
Methyl formate	0,245 g/m ³	2,45 g/h
Hydrogen	Not applicable	0,8 g/h total 0,016 g/h from single point leak

^a The emission rate limit was based on 10 m³ ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is over 20 m³, so a product of 10 is conservative.

^b WHO guideline limit is 0,000 1 g/m³. Background levels are 0,000 03 g/m³. The emission limit cannot push the background level above the guideline limit.

^c A seated human adult has a CO₂ emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO₂ concentration does not reach the WHO eight-hour concentration limit of 9 g/m³. In an environment with 10 m³ ACH, this limits the contribution from the fuel cell to 60 g/h.

Table C.8 – Occupational exposure limits

Emissions	TWA exposure limit (TWA – time weighted average over 8 h of operation)	STEL value (15 min exposures to a maximum of 4 times a day)
CO₂	< 5 000 ppmv	<30 000 ppmv
Formic acid	< 5 ppmv	<10 ppmv
CO	< 25 ppmv	<200 ppmv

C.7.3.13 Hydrogen point source gas loss detection test

The procedure for hydrogen emission testing is detailed in Figure C.12, which is to be used as an additional figure when testing is done in accordance with Annex C. This subclause is additional to the requirements in Clause 7.

This subclause shall be used if required by Subclause C.7.3.12 d) 4) iii) to show compliance with Table C.7, for reformed methanol micro fuel cell power systems and reformed methanol micro fuel cell power units. This subclause is required to be performed to meet the passing criteria of Subclause C.7.3.12 e) 3) i) if the total hydrogen emission rate from an operational reformed methanol micro fuel cell power system or unit is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON".

- Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or a micro fuel cell power unit, emission of hydrogen shall be maintained at less than the specified values in Table C.7. The hydrogen point source gas loss detection test shall be performed to determine that no single source on the micro fuel cell power system or unit can support a flame in all cases where such compliance cannot

be definitively determined by the hydrogen emission test. Maintaining these limits ensures that, in addition to not permitting a flammable concentration to build up in the reference volume, there is no gas loss of hydrogen from the specimen that could support a flame and along with the other emissions testing ensures an adequate supply of oxygen is maintained in the operating environment

- c) **Test apparatus:** The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, a hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL. The response of the aforementioned hydrogen detectors is commonly slow, with a response time of many seconds, thus high sweep speeds may cause underestimation of the hydrogen concentration. It is important that the sweep speed shall be slow enough to accurately measure the hydrogen concentration.
- d) **Test procedure:**
- 1) The micro fuel cell power system or micro fuel cell power unit shall remain turned on ("DEVICE – ON") throughout the duration of the hydrogen point source gas loss detection test.
 - 2) The testing shall be conducted in a space with no substantial air movement. The measured wind speed 10 cm above the micro fuel cell power system or unit shall not exceed 0,02 m/s. The local concentration of hydrogen diffusion measured in this test is very susceptible to the effect of wind. It is desirable that wind speed anywhere in the test space is as close to zero as possible. Testing in a closed space, such as a glove box or equivalent chamber, is one available method to achieve this requirement.
 - 3) The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL.
 - 4) The sensor of the hydrogen detector shall sweep the micro fuel cell power system or unit at a distance no more than 3 mm normal to the surface of the micro fuel cell power system or unit. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the micro fuel cell power system or unit. The entire surface of the micro fuel cell power system or unit shall be swept in this manner.
 - 5) An effective method for completing these sweeps would be to attach a stand off to the sensor that ensures that a spacing of 3 mm from the micro fuel cell power system or unit is maintained at all times. A pen or other marking utensil attached to the stand off could be used to identify swept areas and ensure that the distance between sweeps does not exceed 8 mm.
 - 6) The sensor should always face directly downward, and the micro fuel cell power system or unit should be moved beneath it such that the surface directly below the sensor is always horizontal.
 - 7) If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the micro fuel cell power system or unit shall be considered to have passed.
 - 8) When some point source sweeps show a large region of 25 % LFL or greater in the initial linear sweeps, recording the measured concentration values will assist in determining the starting point of secondary spiral sweeps. Point sources are supposed to be where local maximum values exist in the distribution of measured concentration values.
 - 9) If any points are detected to have a hydrogen concentration of 25 % LFL or greater, a second test shall be conducted to ensure that the emission does not exceed 0,016 g/h of pure hydrogen from any single source.

- 10) The second test shall be performed with the sensor height adjusted to 6,5 mm above the micro fuel cell power system or unit.
 - 11) A spiral sweep shall then be made, originating from the point where the detection of 25 % LFL or greater of hydrogen occurred during the initial linear sweep. The spiral sweep shall have a spacing of 1 mm or less between sweeps, and shall spiral out to a radial distance of at least 4 mm and far enough to detect the maximum hydrogen level from the particular hydrogen source.
 - 12) If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the micro fuel cell power system or unit passes the test.
- e) **Passing criteria:** No gas loss of hydrogen from any single source at greater than 0,016 g/h as indicated by sweep testing. No indications of hydrogen that is 25 % of LFL during the primary sweep testing or no indications of hydrogen that is 25 % of LFL during the secondary sweep testing at 6,5 mm above the micro fuel cell power system or unit. If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. See Table C.7.

C.7.3.14 High temperature shutdown test

This subclause is additional to the requirements in Clause 7.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to verify that the micro fuel cell power system initiates a shutdown sequence within a reasonable time period if the reformer reaches an abnormal high temperature.
- c) **Test procedure:**
 - 1) While the micro fuel cell power unit is operating at rated output, use the manufacturer's specified method for setting temperature to set a temperature 10 °C above the maximum operating temperature inside the reformer.
 - 2) Verify that the micro fuel cell power system shutdown sequence is initiated within 5 s of the reformer reaching the temperature set point.
- d) **Passing criteria:** The micro fuel cell power system shutdown sequence is initiated within 5 s of the reformer reaching the temperature set point.

C.7.3.15 High temperature operation test

This subclause is additional to the requirements in Clause 7.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to verify that the micro fuel cell power system operates safely even if the reformer is at a temperature of 30 °C above the maximum operating temperature.
- c) **Test procedure:**
 - 1) Disable the automatic shutdown mechanism described in C.7.3.14. Set the reformer temperature at 30 °C above the maximum operating temperature.
 - 2) Run the micro fuel cell power system at full load as specified by the manufacturer for 1 h at this elevated temperature.
- d) **Passing criteria:** There shall be no emission of flame, and the micro fuel cell power system shall be in compliance with the emission requirements in Table 7 and C.7.3.12.

Annex D (normative)

Methanol clathrate compound micro fuel cell power systems

D.1 Scope

D.1.2 Fuels and technologies covered by this annex

Annex D covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use methanol or methanol and water solutions – derived from methanol clathrate compounds – as fuel. These systems and units use direct methanol fuel cell technologies.

Figure D.1 replaces Figure 1 showing a methanol clathrate compound micro fuel cell power system block diagram for use with this annex.

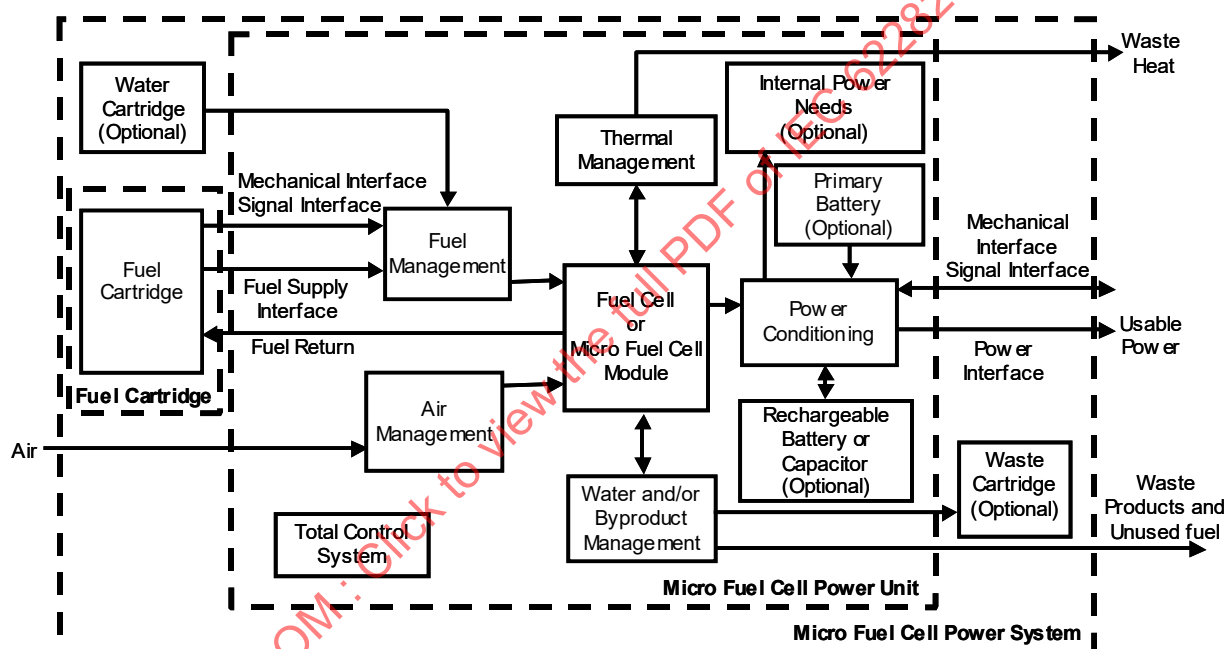


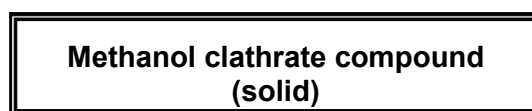
Figure D.1 – Methanol clathrate compound micro fuel cell power system block diagram
– Replaces Figure 1

D.1.3 Equivalent level of safety

This subclause replaces Subclause 1.3.

- The requirements of this standard are not intended to constrain innovation. The manufacturer may consider fuels, materials, designs or constructions not specifically dealt with in this standard. These alternatives should be evaluated as to their ability to yield levels of safety equivalent to those prescribed by this standard.
- It is understood that all micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall comply with applicable country and local requirements including, but not limited to, those concerning transportation, child-resistance, and storage, where required.
- The following discussion provides additional information regarding micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use methanol or methanol and water solutions – derived from methanol clathrate compounds – as fuel.

- 1) Methanol clathrate compound (MCC)³ is a solid⁴ that includes methanol. The fuel cartridge containing MCC does not contain liquid prior to use; therefore liquid leakage from an unused cartridge cannot occur. MCC is not classified as dangerous goods by the United Nations Recommendations on the Transport of Dangerous Goods Manual of Tests and Criteria, Fourth Revised Edition.



MCC fuel cartridge

Figure D.12 – Fuel cartridge of methanol clathrate compound

- 2) When the fuel cartridge filled with the MCC is installed in the micro fuel cell power unit, water is injected into the fuel cartridge. Methanol solution is formed by the emission of methanol from the MCC into the injected water. The methanol solution is then used as fuel (Figure D.13).

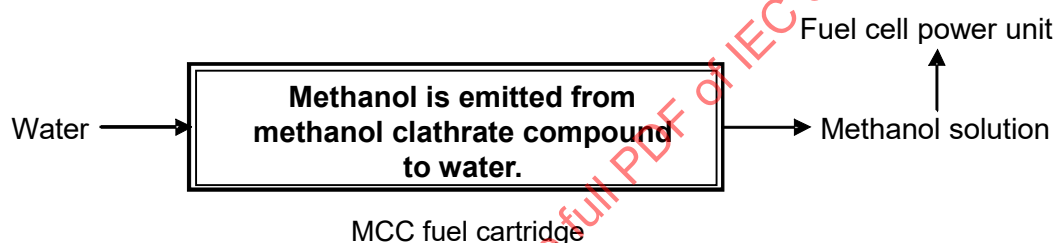


Figure D.13 – Usage of methanol clathrate compound with micro fuel cell power unit

- 3) An unused fuel cartridge only contains a solid material so no liquid leakage can occur. However, because a fuel cartridge used in a DMFC micro fuel cell power system contains a methanol solution, a leak evaluation of a fuel cartridge including water is carried out. Both an unused fuel cartridge and a used fuel cartridge (as defined by D.3.40) are used for type tests.

D.3 Terms and definitions

The terms and definitions below replace those corresponding terms and definitions in Clause 3 for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex D. All terms and conditions in Clause 3 not specifically mentioned here also apply.

D.3.5 fuel

methanol and water solution, formed by the contact of methanol clathrate compound (MCC) and water

MCC is a solid substance and consists of methanol and non-hazardous materials that form a matrix to include MCC.

³ An organic addition compound that has an internal space that is completely enclosed. It is formed by the inclusion of methanol molecules in cavities formed by crystal lattices or present in large molecules.

⁴ Examined by ASTM D 4359-90: *Standard test method for determining whether a material is a liquid or a solid.*

D.3.23**satellite cartridge**

not applicable to this Annex D

The additional terms and their definitions below are needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex D in addition to those given in Clause D.3 and in Clause 3.

D.3.37**no accessible MCC powder**

MCC powder fuel that is not subject to contact by consumers

D.3.38**no MCC powder leakage**

no accessible MCC powder outside the micro fuel cell power system or fuel cartridge

D.3.39**non-hazardous**

materials which when tested in accordance with the UN manual of tests and criteria are not classified as dangerous goods

D.3.40**used fuel cartridge**

fuel cartridge to be used in type tests instead of actual used fuel cartridge

NOTE A used fuel cartridge is prepared by filling an unused fuel cartridge with water thereby forming a methanol solution.

D.4.12 Fuel supply construction**D.4.12.1 Fuel cartridge construction**

These requirements apply to micro fuel cell power systems and units covered by this Annex D. These requirements replace the corresponding requirements of Subclause 4.12.1.

Fuel cartridges shall conform to the following requirements.

D.4.12.1.1 There shall be no leakage from the fuel cartridge in the temperature range of $-40\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$. Compliance shall be determined by type testing in accordance with 7.3.3 and 7.3.4.

D.4.12.1.2 There shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at $22\text{ }^{\circ}\text{C}$ or two times the gauge pressure of the fuel cartridge at $55\text{ }^{\circ}\text{C}$, whichever is greater. Compliance shall be determined by type testing in accordance with D.7.3.1.

D.4.12.1.3 Maximum fuel volume in the fuel cartridge shall not exceed 1 l.

D.4.12.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a micro fuel cell power unit by a consumer, means to prevent fuel leakage prior to, during, and after connection or transfer of fuel to the micro fuel cell power unit shall be provided. Compliance is checked by D.7.3.11.

D.4.12.1.5 A fuel cartridge shall be resistant to corrosion in its usage environment.

D.4.12.1.6 A fuel cartridge shall be provided with a means to prevent mis-connection that would result in leakage of fuel when it is installed in a micro fuel cell power system. Compliance is checked by the connection cycling test, D.7.3.11.

D.4.12.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel when not attached to a micro fuel cell power unit during normal usage, reasonably foreseeable misuse, and consumer transportation. Compliance is checked by the drop test, D.7.3.5, and the connection cycling test, D.7.3.11.

D.4.12.1.8 In the case where a pressure release valve or similar means is provided, such pressure release valve shall satisfy the performance requirement for each type test. This valve shall pass all type tests with no leakage.

D.4.12.1.9 The structure at the connection to the fuel cartridge shall not allow fuel to leak.

D.4.12.1.10 A fuel cartridge, including the fuel cartridge interface to the micro fuel cell power unit, including the valve, shall have a construction sufficient to withstand normal use and reasonably foreseeable misuse generated by vibration, heat, pressure, being dropped or otherwise subject to a mechanical shock etc. Compliance is checked by:

- pressure differential tests, D.7.3.1;
- vibration test, D.7.3.2;
- temperature cycling test, D.7.3.3;
- high temperature exposure test, D.7.3.4;
- drop test, D.7.3.5;
- compressive loading test, D.7.3.6;
- long-term storage test, D.7.3.9;
- high-temperature connection test, D.7.3.10;
- connection cycling tests, D.7.3.11.

D.4.12.1.11 The fuel cartridge valves shall operate as intended without the use of tools and without excessive force needed to connect or disconnect.

D.4.12.2 Fuel cartridge fill requirement

The fuel cartridge design and fuel fill amount shall allow fuel expansion without leakage to a fuel cartridge temperature of 70 °C in the case of the fuel cartridge alone and when the fuel cartridge is constrained by the micro fuel cell power system or a comparable test fixture.

D.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

D.7.1 General

This Subclause D.7.1 replaces Subclause 7.1 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use methanol or methanol and water solutions – derived from methanol clathrate compounds – as fuel.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table D.5 lists the type tests that must be performed. *Table D.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table D.6. *Table D.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of 22 °C ± 5 °C for a minimum of 3 h prior to each test being performed.

- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table D.5 – List of type tests – Replaces Table 5

Test reference	Test item	Test sample
D.7.3.1	Pressure differential tests	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
D.7.3.2	Vibration test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
D.7.3.3	Temperature cycling test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
D.7.3.4	High temperature exposure test	Fuel cartridge Used fuel cartridge
D.7.3.5	Drop test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
D.7.3.6	Compressive loading test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
D.7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
D.7.3.9	Long-term storage test	Fuel cartridge Used fuel cartridge
D.7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
D.7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
7.3.12	Emission test	Micro fuel cell power system or power unit

Table D.5 replaces Table 5.

Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or used, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test.

Test sequence: Tests D.7.3.2 and D.7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests D.7.3.1, D.7.3.2, and D.7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or units.

Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.

Table D.6 – Laboratory standard conditions – Replaces Table 6

Item	Condition
Laboratory temperature	Laboratory temperature is "room temperature" (standard temperature condition, 22 °C ± 5 °C)
Laboratory room atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen.
Table D.6 replaces Table 6.	

D.7.2 Leakage measurement of MCC and methanol, and the measuring procedure

This Subclause D.7.2 replaces Subclause 7.2 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use methanol or methanol and water solutions – derived from methanol clathrate compounds – as fuel.

These figures and their procedures, replace the corresponding figures in Subclause 7.2.

Inspection of MCC powder leakage shall be executed in type tests, because MCC powder is packed in an unused fuel cartridge. The leakage measurement of MCC powder and methanol shall be executed in principle in accordance with the procedure shown in Figures D.2 through D.5 respectively.

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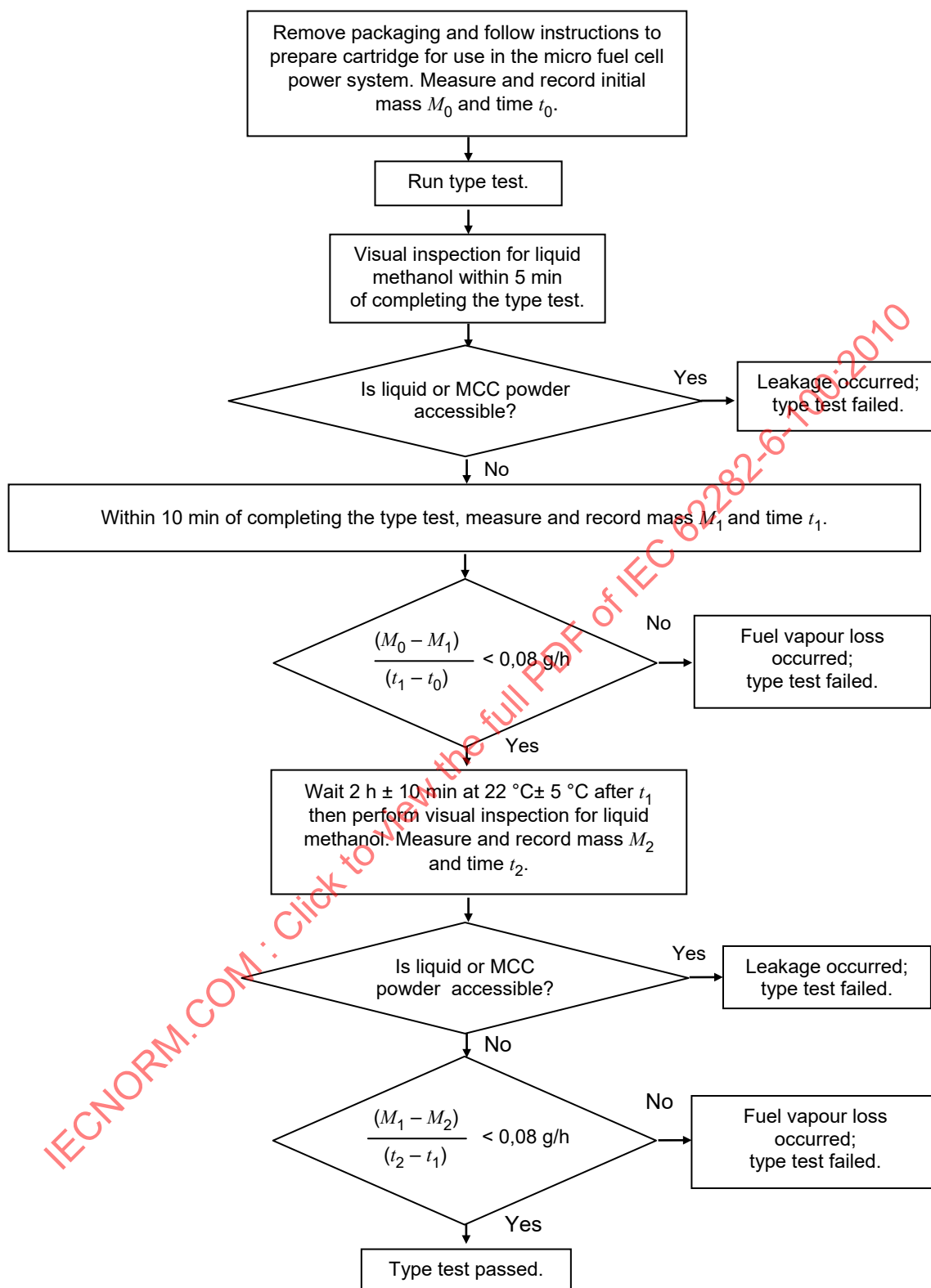


Figure D.2 – Fuel cartridge leakage and mass loss test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

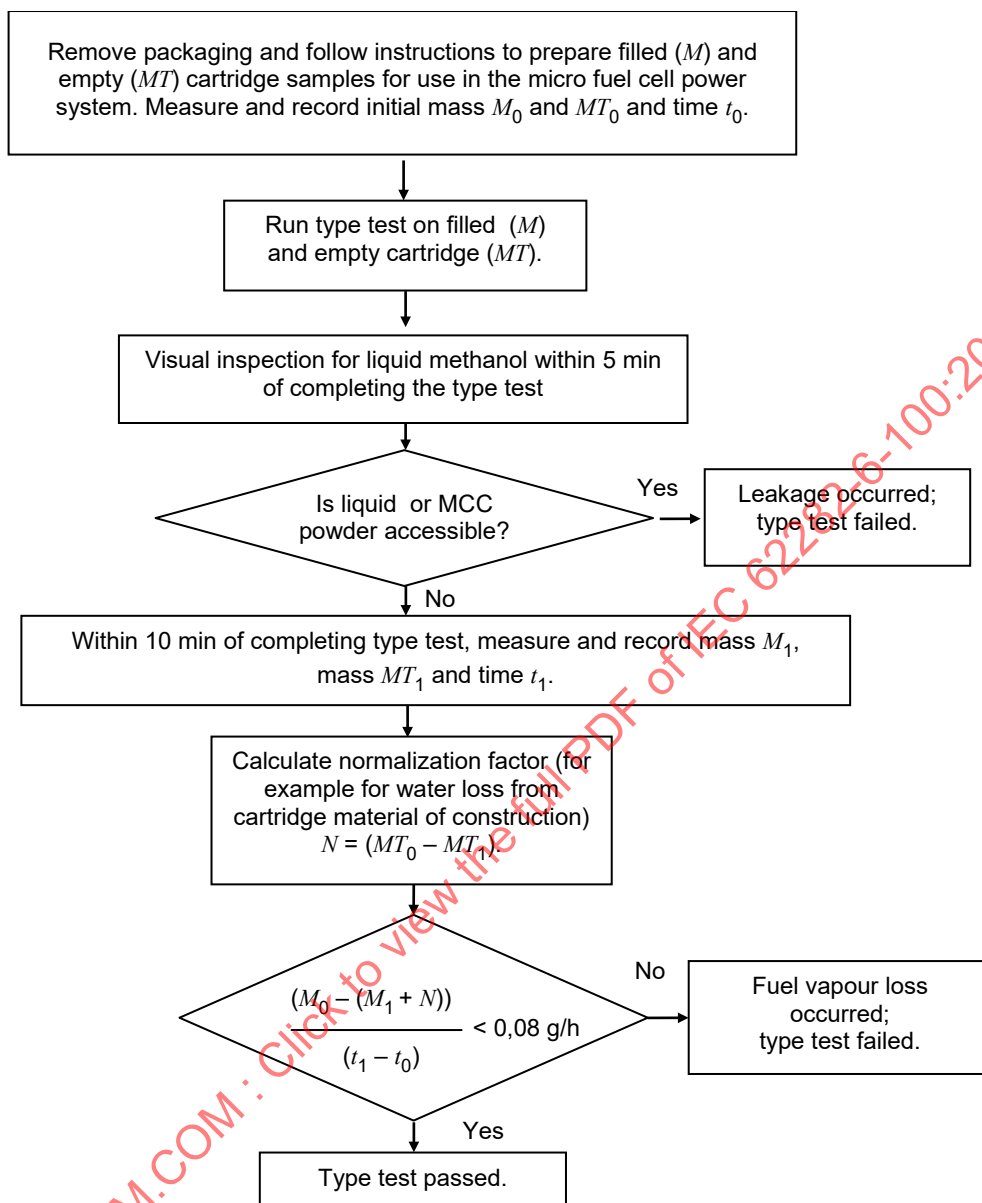


Figure D.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

The maximum time interval $t_1 - t_0$ shall be set so that no more than half the fuel would be lost if it were escaping at the maximum allowable mass loss rate.

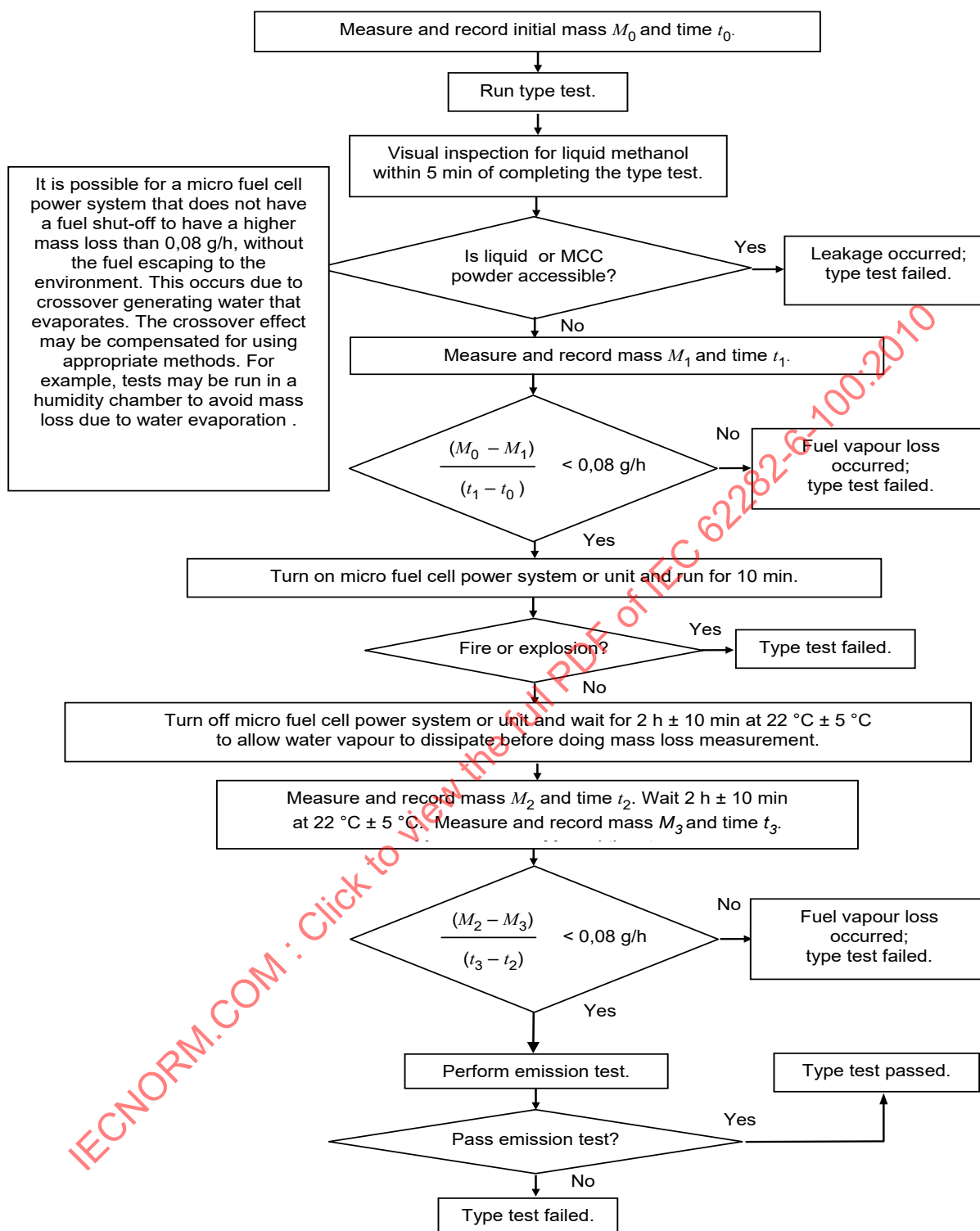


Figure D.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

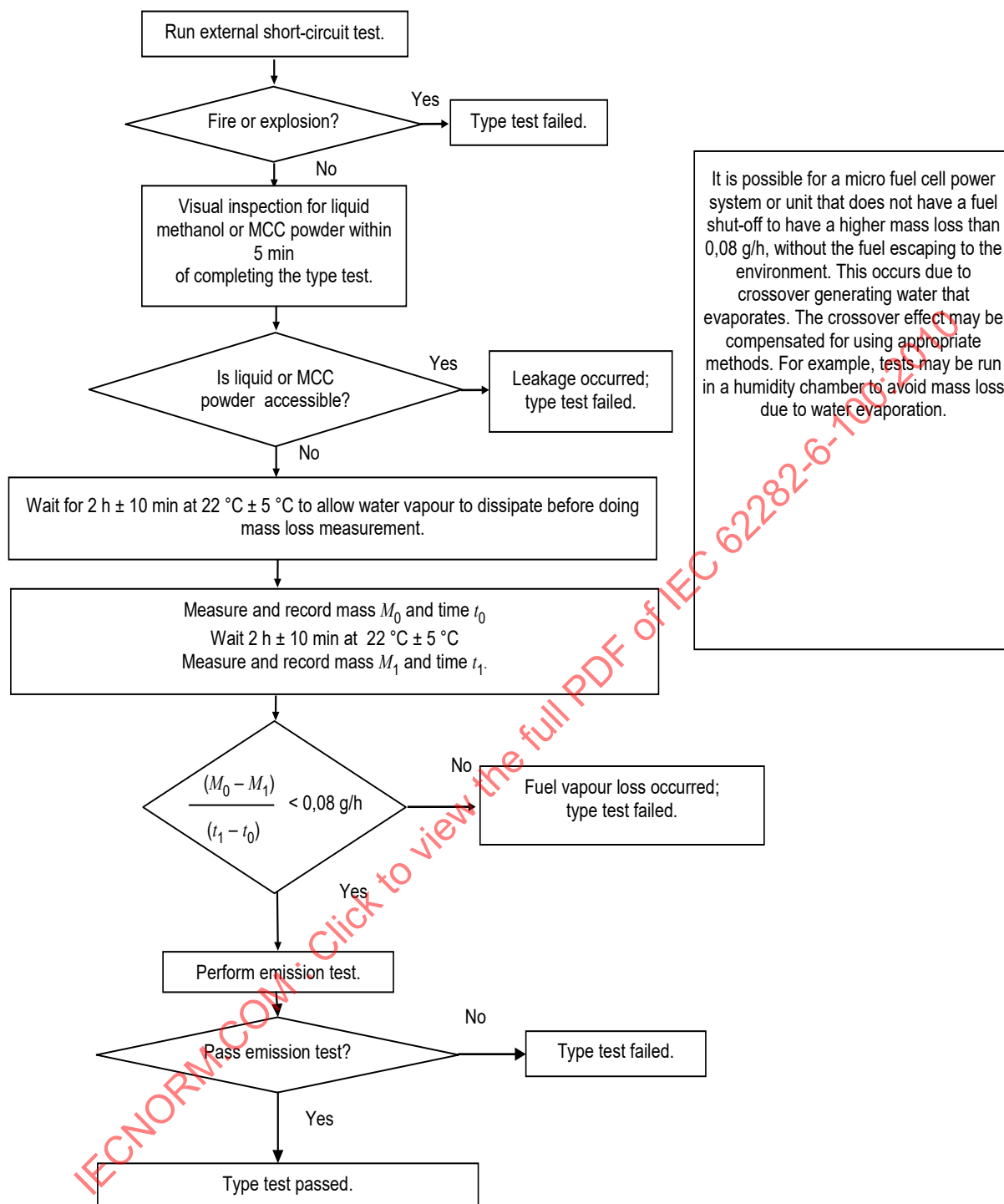


Figure D.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

D.7.3 Type tests

D.7.3.1 Pressure differential tests

D.7.3.1.1 General

Subclause D.7.3.1 replaces Subclause 7.3.1.

Portions of this test check compliance with Subclause 4.12.1.2 to verify that there shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Depending upon which of the two limiting pressure conditions is greater, two options for testing are provided.

- a) If 95 kPa internal gauge pressure plus normal working pressure of the fuel cartridge at 22 °C is greater than two times the gauge pressure of the fuel cartridge at 55 °C, either Subclause D.7.3.1.2 or Subclause D.7.3.1.3 may be used to verify compliance with Subclause 4.12.1.2.
- b) If two times the gauge pressure of the fuel cartridge at 55 °C is greater than 95 kPa internal gauge pressure plus normal working pressure at 22 °C, subclause D.7.3.1.2 must be used to verify compliance with Subclause 4.12.1.2.

D.7.3.1.2 Fuel cartridge internal pressurization test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**

For the internal pressurization test, the fuel cartridge body and the fuel cartridge valve shall be tested separately.

- 1) Using a suitable fluid medium such as water, pressurize the fuel cartridge body to an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. The pressure rise shall not exceed a rate of 60 kPa/s.
 - 2) Maintain the maximum pressure for 30 min at laboratory temperature.
 - 3) Using a suitable fluid medium such as water, pressurize the closed fuel cartridge valve to 95 kPa gauge pressure plus the normal working pressure of the cartridge at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. The pressure rise shall not exceed a rate of 60 kPa/s.
 - 4) Maintain the maximum pressure for 30 min at laboratory temperature.
- d) **Passing criteria:** No accessible liquid test medium leakage and no sudden drop of pressure during the course of the test. Leakage shall be checked visually. Invert the fuel cartridge and the fuel cartridge valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails.

D.7.3.1.3 Fuel cartridge low external pressure test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**

Perform this test in accordance with Figure D.2.

- 1) The sample shall be placed in a vacuum chamber and the pressure in the vacuum chamber shall be reduced to 95 kPa below normal atmospheric pressure.
- 2) Maintain the vacuum for 30 min.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage, no accessible MCC powder leakage and no fuel vapour loss. See Figure D.2. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

D.7.3.1.4 Micro fuel cell power system or micro fuel cell power unit pressure differential tests

D.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex D.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
- 1) Perform this test in accordance with Figure 6.
 - 2) Test samples shall be stored at a low external pressure of 68 kPa absolute pressure for 6 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure 6.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no accessible MCC powder leakage. See Figure 6. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test result is acceptable. During the 6 h test at 68 kPa absolute external pressure the fuel vapour loss shall be less than 0,08 g/h.

D.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex D.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
- 1) Perform this test in accordance with Figure 7.
 - 2) Test samples shall be stored at a low external pressure of 11,6 kPa absolute pressure for 1 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure 7, with a fuel vapour loss at 11,6 kPa YES/NO passing

criteria of less than 2,0 g/h on the basis of not exceeding 25 % of the lower flammability limit (LFL).

- 3) For the micro fuel cell power system or unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage and no accessible MCC powder leakage. See Figure 7. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test result is acceptable. During the 1 h test at 11,6 kPa absolute external pressure, the fuel vapour loss shall be less than 2,0 g/h.

D.7.3.2 Vibration test

Subclause D.7.3.2 replaces Subclause 7.3.2.

- a) **Test sample:** an unused fuel cartridge, a used fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in D.7.3.1 or a micro fuel cell power system used in D.7.3.1.
- b) **Purpose:** to simulate the effects of normal transportation vibration and ensure no leakage.
- c) **Test procedure:**
- 1) Perform these tests in accordance with Figure D.2 for the fuel cartridge and Figure D.4 for the micro fuel cell power system or unit.
 - 2) The test sample shall be firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.
 - 3) The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min.
 - 4) This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions of the test samples.
 - 5) The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g_n is maintained until 18 Hz is reached. The amplitude is then maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of 8 g_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.
 - 6) For the micro fuel cell power system or unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage, no accessible MCC powder leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured based upon Figure D.2 for the fuel cartridge and Figure D.4 for the micro fuel cell power system or unit. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

D.7.3.3 Temperature cycling test

Subclause D.7.3.3 replaces Subclause 7.3.3.

- a) **Test sample:** a fuel cartridge used in D.7.3.2, a used fuel cartridge used in D.7.3.2, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in D.7.3.2 or a micro fuel cell power system used in D.7.3.2.
- b) **Purpose:** to simulate the effects of low-temperature and high temperature exposure and the effects of extreme temperature change.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure D.3 for the fuel cartridge and Figure D.4 for the micro fuel cell power system or unit.
 - 2) For a fuel cartridge, two fuel cartridge orientations shall be tested – valve up and valve down. For a micro fuel cell power system or a micro fuel cell power unit, only one orientation needs to be tested.
 - 3) See Figure 8 for the temperature profile to be used.
 - 4) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from laboratory temperature to $55\text{ °C} \pm 2\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $55\text{ °C} \pm 2\text{ °C}$ for a minimum of 4 h.
 - 5) Decrease the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$ then decrease the chamber temperature to $-40\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $-40\text{ °C} \pm 5\text{ °C}$ for a minimum of 4 h.
 - 6) Increase the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$.
 - 7) The above process is to be done twice.
 - 8) After 1 h at $22\text{ °C} \pm 5\text{ °C}$, leakage and fuel vapour loss shall be measured based upon the procedure described in Figure 3 (for fuel cartridge) and Figure 4 (for micro fuel cell power system or unit).
 - 9) For the micro fuel cell power system or micro fuel cell power unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No accessible liquid leakage, no accessible MCC powder leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured based upon Figure D.3 for the fuel cartridge and Figure D.4 for the micro fuel cell power system or unit. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

D.7.3.4 High temperature exposure test

Subclause D.7.3.4 replaces Subclause 7.3.4.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of a fuel cartridge left in high temperature environments.
- c) **Test procedure:**
 - 1) Two orientations shall be tested – valve up and valve down.
 - 2) Place the test sample in a temperature controlled test chamber that is at a temperature of $70\text{ °C} \pm 2\text{ °C}$ and allow chamber temperature to recover to $70\text{ °C} \pm 2\text{ °C}$ and maintain that temperature for at least 4 h with the sample in the chamber.

- 3) Remove the test sample to laboratory temperature.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage, no MCC powder leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure D.3 for a fuel cartridge. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

D.7.3.5 Drop test

Subclause D.7.3.5 replaces Subclause 7.3.5.

- a) **Test sample:** an unused fuel cartridge, a used fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an inadvertent drop and ensure no leakage.
- c) **Test procedure:**
- 1) The test sample shall be dropped on a horizontal surface that consists of hardwood at least 13 mm thick, mounted on two layers of plywood each 18 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor from a predetermined height.
 - 2) The height of the drop shall be:
 - i) 1 200 mm $\pm$ 10 mm: in the case of a micro fuel cell power unit and/or a micro fuel cell power system.
 - ii) 1 500 mm $\pm$ 10 mm: in the case of a fuel cartridge of more than 200 ml.
 - iii) 1 800 mm $\pm$ 10 mm: in the case of a fuel cartridge of up to 200 ml.
 - 3) For the fuel cartridge tests, the drop test shall be carried out in four drop orientations with the same sample.
 - 4) For the micro fuel cell power unit or the micro fuel cell power system, one micro fuel cell power system or unit may be used for all four drop orientations, or more than one micro fuel cell power system or unit may be used in subsequent drops, at the discretion of the manufacturer.
 - 5) For all tests, drop orientations shall be:
 - i) valve up;
 - ii) valve down;
 - iii) two other mutually perpendicular orientations.
 - 6) For micro fuel cell power system or micro fuel cell power unit tests, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage, no MCC powder leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured based upon Figure D.2 for the fuel cartridge and Figure D.4 for the micro fuel cell power system or unit. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

D.7.3.6 Compressive loading test

Subclause D.7.3.6 replaces Subclause 7.3.6.

D.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused or used fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the micro fuel cell power unit, or micro fuel cell power system.
- c) **Test procedure:**
 - 1) The micro fuel cell power system or unit test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $245\text{ N} \pm 9,8\text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $245\text{ N} \pm 9,8\text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) The test shall be carried out in three mutually perpendicular orientations as a rule. If the sample would not stand on its own, it does not need to be tested in that orientation.
 - 5) Perform emission testing in accordance with 7.3.12 following the compressive loading test.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage, no MCC powder leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure D.4. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power system over indicating paper in such a way that the valve(s) point downward toward the indicating paper and look for signs of leakage. If any accessible liquid or MCC powder leakage is found, the test fails. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions from micro fuel cell power system or unit shall meet the passing criteria in 7.3.12. If the micro fuel cell power system or unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

D.7.3.6.2 Fuel cartridge

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the fuel cartridge.
- c) **Test procedure:**
 - 1) The fuel cartridge test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $981\text{ N} \pm 9,8\text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $981\text{ N} \pm 9,8\text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) Fuel cartridge orientations shall be selected on the basis of likely stable resting positions when accidentally dropped (e.g. those orientations having the lowest centres of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic fuel cartridge that is sufficiently cubic and the curved surface of a cylindrical fuel cartridge with a longitudinal axis length longer than twice the diameter.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage, no MCC powder leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure D.2. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

D.7.3.7 External short-circuit test

Subclause D.7.3.7 replaces Subclause 7.3.7.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused or used fuel cartridge.
- b) **Purpose:** to simulate the effects of an external short-circuit.
- c) **Test procedure:**
- 1) External short-circuit testing shall be done separately on both operating [DEVICE ON] and non-operating [DEVICE OFF] micro fuel cell power systems or micro fuel cell power units respectively.
 - 2) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power system or unit with wire having a maximum resistance load of 0,1 Ω for at least 5 min.
 - 3) Perform emission testing in accordance with 7.3.12 after each short-circuit test.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No leakage, no MCC powder leakage and no fuel vapour loss. Leakage and fuel vapour loss shall be measured on the basis of the procedure described in Figure D.5. Leakage shall be checked visually. Remove the fuel cartridge, if present, from the micro fuel cell power system. Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valves point downward toward the indicating paper and look for signs of leakage. If any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed temperatures in Table 2 during or after short circuit testing.

Emissions shall meet the passing criteria in 7.3.12. If the micro fuel cell power system or unit does not operate but emissions do not exceed the limits of 7.3.12, the emission test is acceptable.

NOTE The external short-circuit test can be done sequentially with the surface, component and exhaust gas temperature test using the same sample.

D.7.3.9 Long-term storage test

Subclause D.7.3.9 replaces Subclause 7.3.9.

D.7.3.9.1 General

Either D.7.3.9.2 (Option 1), D.7.3.9.3 (Option 2) or D.7.3.9.4 (Option 3) may be used.

D.7.3.9.2 Option 1 – Continuous weight measurement

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure D.9):

- 1) Use a load cell (continuous electronic weight sensing device) designed and calibrated for use at 50 °C inside the temperature chamber.
- 2) Place the load cell in a temperature chamber at 50 °C ± 2 °C. Place the fuel cartridge on top of the load cell so that all the weight is being applied to the load cell. A fixture may be used to control the position of the fuel cartridge, to ensure all the weight is applied to the load cell.
- 3) Connect a digital readout to the load cell and collect the data either manually or automatically. The data should be collected with a high degree of confidence to assure that the fuel vapour loss does not exceed 0,08 g/h.
- 4) Measure and record initial mass M_{initial} and time t_i .
- 5) The sample shall remain in the temperature test chamber at 50 °C ± 2 °C for at least 28 days.
- 6) If the fuel cartridge still has fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,08 g/h, then the test sample passes the test for fuel vapour loss.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{final}} = \text{the final mass of the fuel cartridge.}$$

- 7) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,08 g/h.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$$

$$\text{ii) } \Delta t_{\text{last}} = \text{the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{last}} = \text{the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss, no liquid leakage and no MCC powder leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure D.9. If the fuel cartridge exceeds the 0,08 g/h fuel vapour loss criteria, then the test sample fails the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

D.7.3.9.3 Option 2 – Periodic weight measurements

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.

c) **Test procedure** (See Figure D.9):

- 1) Place the fuel cartridge in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Weight measurements should be collected with a high degree of confidence to determine if the fuel vapour loss does not exceed 0,08 g/h with a minimum of once every three days.
- 2) Measure and record initial mass M_{initial} and time t_i .
- 3) The sample shall remain in the temperature test chamber at $50\text{ °C} \pm 2\text{ °C}$ for at least 28 days.
- 4) The time in which the test samples are removed from the chamber for measurement shall not be included in the time the test sample is to be tested (28 days). Additional time should be added to get the test sample to the test temperature ($50\text{ °C} \pm 2\text{ °C}$) each time the test sample is removed from the chamber. The test samples should only be stabilised at laboratory temperature if the mass loss will be affected.
- 5) If the fuel cartridge still has fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,08 g/h, then the test sample passes the test for fuel vapour loss.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{final}} = \text{the final mass of the fuel cartridge.}$$

- 6) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,08 g/h.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$$

$$\text{ii) } \Delta t_{\text{last}} = \text{the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{last}} = \text{the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss, no liquid leakage and no MCC powder leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure D.9. If the fuel cartridge exceeds the 0,08 g/h fuel vapour loss criteria, then the test sample fails the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

D.7.3.9.4 Option 3 – One weight measurement

This option is intended for fuel cartridges with very small leak rates.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.

c) **Test procedure** (See Figure D.9):

- 1) Measure and record initial mass M_{initial} and time t_i .
- 2) Place the fuel cartridges in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. After 28 days, the fuel cartridges are removed from the chamber for measurement. The test samples should be stabilised at laboratory temperature if the mass loss will be affected. Then weight measurement is executed.
- 3) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,08 g/h, then the test sample passes the test for fuel vapour loss.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{final}} = \text{the final mass of the fuel cartridge.}$$

- 4) If the fuel cartridge is empty after 28 days, then the type test according to D.7.3.9.2 Option 1 or D.7.3.9.3 Option 2 shall be done.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No fuel vapour loss, no liquid leakage and no MCC powder leakage. Leakage and fuel vapour loss shall be measured based upon the procedure described in Figure D.9. If the fuel cartridge did exceed the 0,08 g/h fuel vapour loss criteria, then the test sample fails the test. Leakage shall be checked visually. Invert the fuel cartridge over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

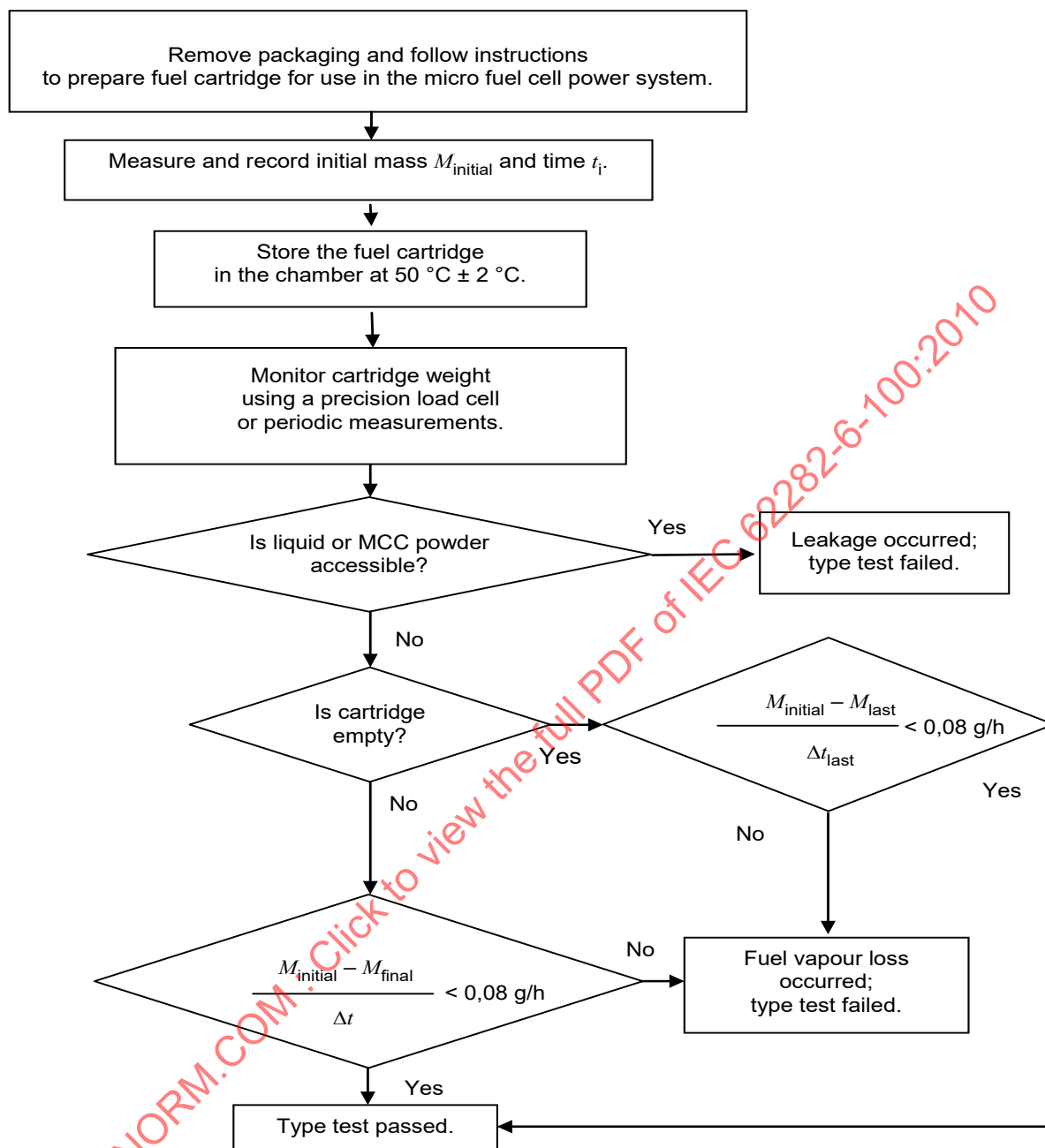


Figure D.9 – Fuel cartridge leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

D.7.3.10 High-temperature connection test

Subclause D.7.3.10 replaces Subclause 7.3.10.

- Test sample:** an unused fuel cartridge or a used fuel cartridge and a micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry.
- Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage, no fire, no explosion.

c) **Test procedure:**

- 1) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of $50\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for at least 4 h.
- 2) The micro fuel cell power unit or test fixture with micro fuel cell power unit valve is kept at laboratory temperature.
- 3) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or test fixture with micro fuel cell power unit valve within 5 min of removal from the chamber.
- 4) Check for leakage upon connection.
- 5) Disconnect the fuel cartridge and check for leakage.

- d) **Passing criteria:** No leakage, no MCC powder leakage, no fire or flame, and no explosion. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, this is acceptable. Leakage shall be checked visually. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power unit valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit.

D.7.3.11 Connection cycling tests

D.7.3.11.1 Fuel cartridge

D.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

- a) **Test sample:** an unused or used insert cartridge, exterior cartridge or attached cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve and fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection.
 - 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 4) Disconnect the fuel cartridge and check for leakage.
 - 5) Repeat this twice more for a total of three connections and disconnections.
 - 6) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
 - 8) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 10) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper such that the valve points downward toward the indicating paper and look for signs of leakage.

- 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 13) Disconnect the fuel cartridge and check for leakage.
- d) **Passing criteria:** No leakage, no MCC powder leakage, no fire or flame, and no explosion. Leakage shall be checked visually. Invert the fuel cartridge and the micro fuel cell power unit or micro fuel cell power unit valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit.

D.7.3.11.1.2 Satellite cartridge

Not applicable to this Annex D.

D.7.3.11.2 Micro fuel cell power unit

- a) **Test sample:** a minimum of two unused or used fuel cartridges and an additional 98 fuel cartridges or suitable test fixtures with fuel cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the fuel cartridge valve geometry and material and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage both at initial use and after suitable ageing of the micro fuel cell power unit connection.
- First fuel cartridge (#1) and final fuel cartridge (#100) are inspected; the other 980 cycles are only to age the micro fuel cell power unit.

In the case of a micro fuel cell power unit using satellite cartridge, it shall be tested according to the following procedure by simulating fuel flow between the satellite cartridge and the micro fuel cell power unit.

c) **Test procedure:**

- 1) Connect the first fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the fuel cartridge and check for leakage.
- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 7) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
- 9) Connect and disconnect the first fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

- 11) Connect the first fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
 - 12) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 13) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 14) Disconnect the first fuel cartridge and check for leakage.
 - 15) In order to age the micro fuel cell power unit fuel cartridge connection, perform the following steps.
 - i) Using either fuel cartridges or a suitable test fixture with fuel cartridge valves, cycle the micro fuel cell power unit fuel cartridge connection for a total of 980 connections and disconnections.
 - ii) Simulate fuel flow after each set of 50 connection-disconnection cycles.
 - iii) Inversion of the micro fuel cell power unit or the fuel cartridges is not necessary, but, if leakage is found, the test fails.
 - iv) Following this ageing, a final unused fuel cartridge will be tested.
 - 16) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
 - 17) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 18) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 19) Disconnect the fuel cartridge and check for leakage.
 - 20) Repeat this twice more for a total of three connections and disconnections.
 - 21) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 22) Connect and disconnect the final fuel cartridge four more times for a total of seven connections and disconnections.
 - 23) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 24) Connect and disconnect the final fuel cartridge three more times for a total of ten connections and disconnections.
 - 25) Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.
 - 26) Connect the fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.
 - 27) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 28) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 29) Disconnect the fuel cartridge and check for leakage.
- d) **Passing criteria:** No leakage, no MCC powder leakage, no fire or flame, and no explosion. Leakage shall be checked visually. Invert the fuel cartridge and the micro fuel cell power unit over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid or MCC powder leakage is found, the test fails. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit.

Annex E (normative)

Borohydride micro fuel cell power systems: Class 8 (corrosive) compounds in indirect borohydride fuel cells

E.1 Scope

E.1.2 Fuels and technologies covered by this annex

Annex E covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges using hydrogen produced from Class 8 (corrosive) borohydride formulations as fuel. These systems and units use proton exchange membrane fuel cell technologies. The designs may include fuel processing subsystems to derive hydrogen gas from the borohydride compound fuel.

Figure E.1 replaces Figure 1, and Figures E.13, E.14 and E.15 are additional figures showing micro fuel cell power system block diagrams for use with this annex.

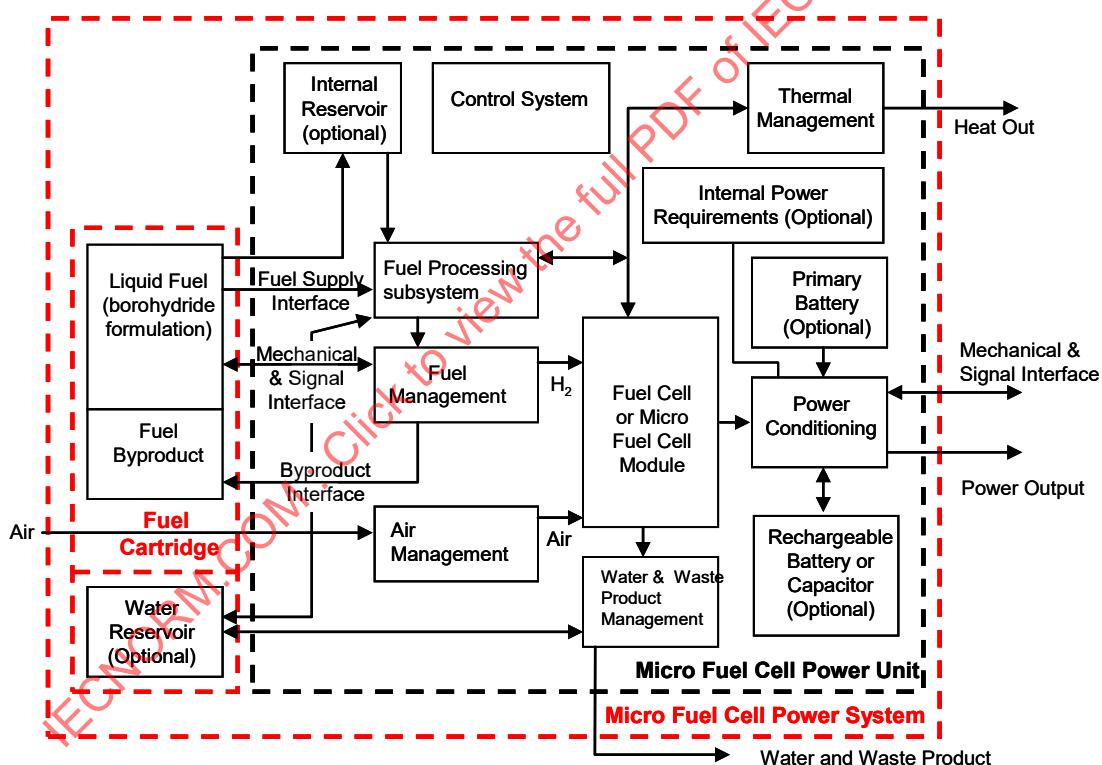


Figure E.1 – Micro fuel cell power system block diagram for liquid Class 8 indirect (corrosive) borohydride compound fuel with onboard fuel processing – Replaces Figure 1

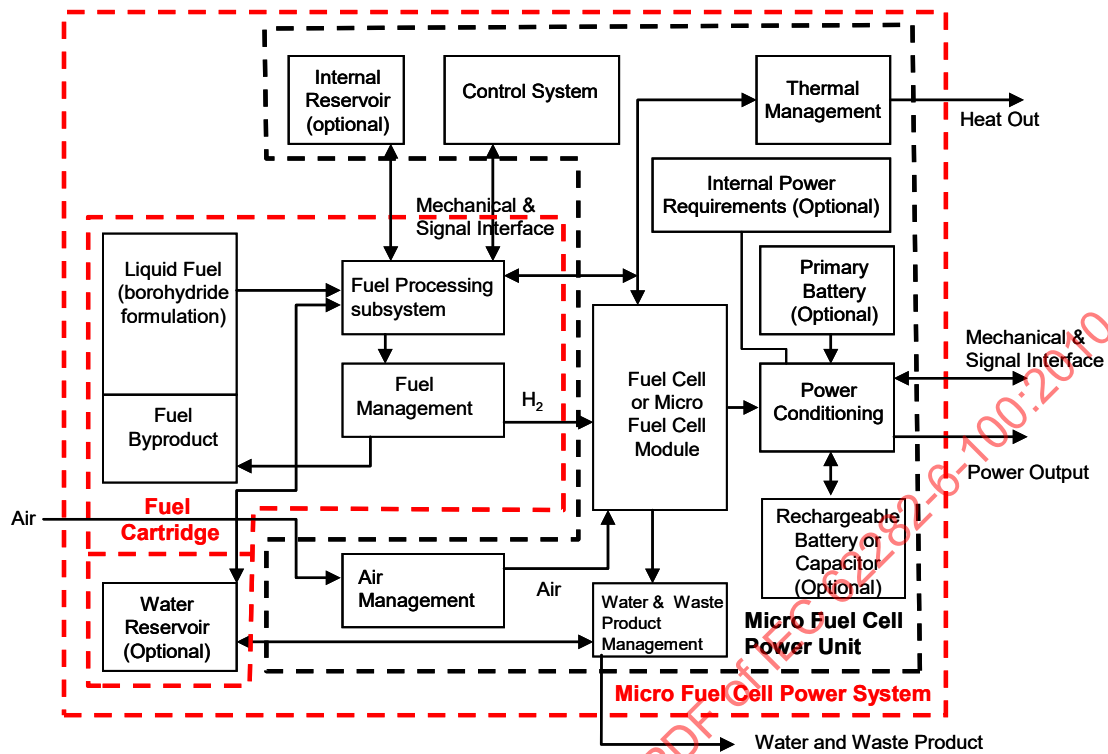


Figure E.13 – Micro fuel cell power system block diagram for liquid Class 8 (corrosive) indirect borohydride compound fuel with fuel cartridge fuel processing

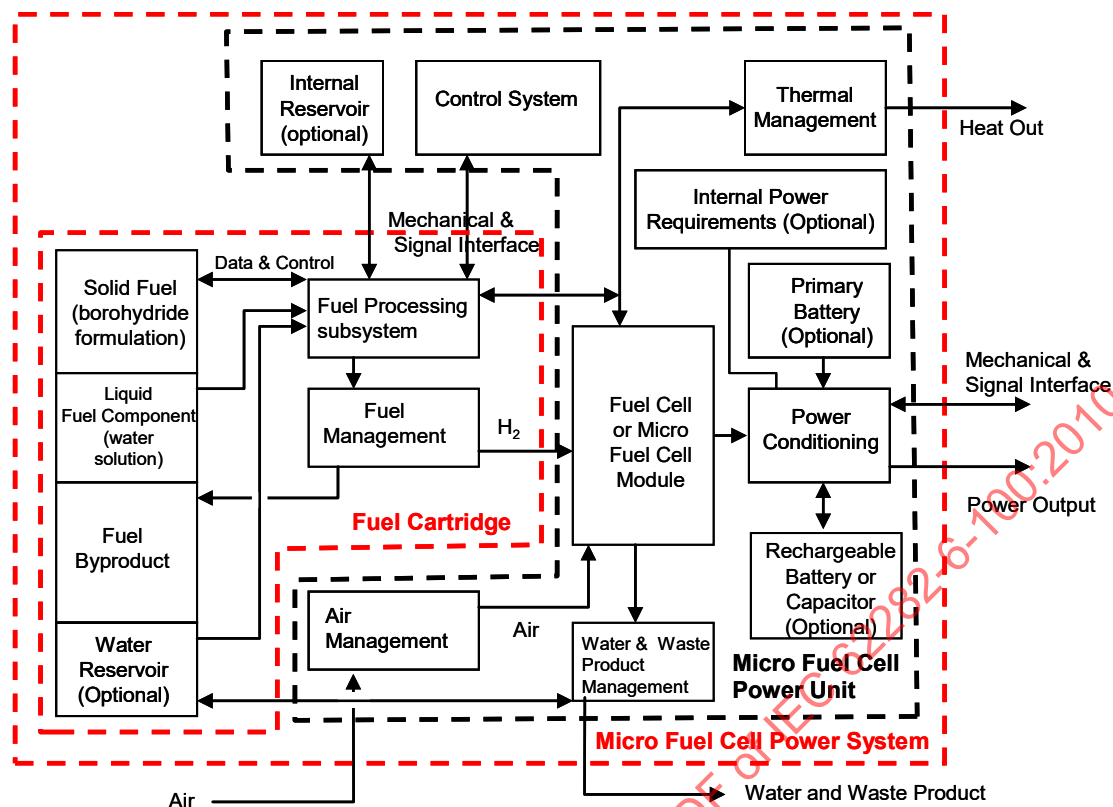


Figure E.14 – Micro fuel cell power system block diagram for solid Class 8 (corrosive) indirect borohydride compound fuel with fuel cartridge fuel processing and cartridge fuel management

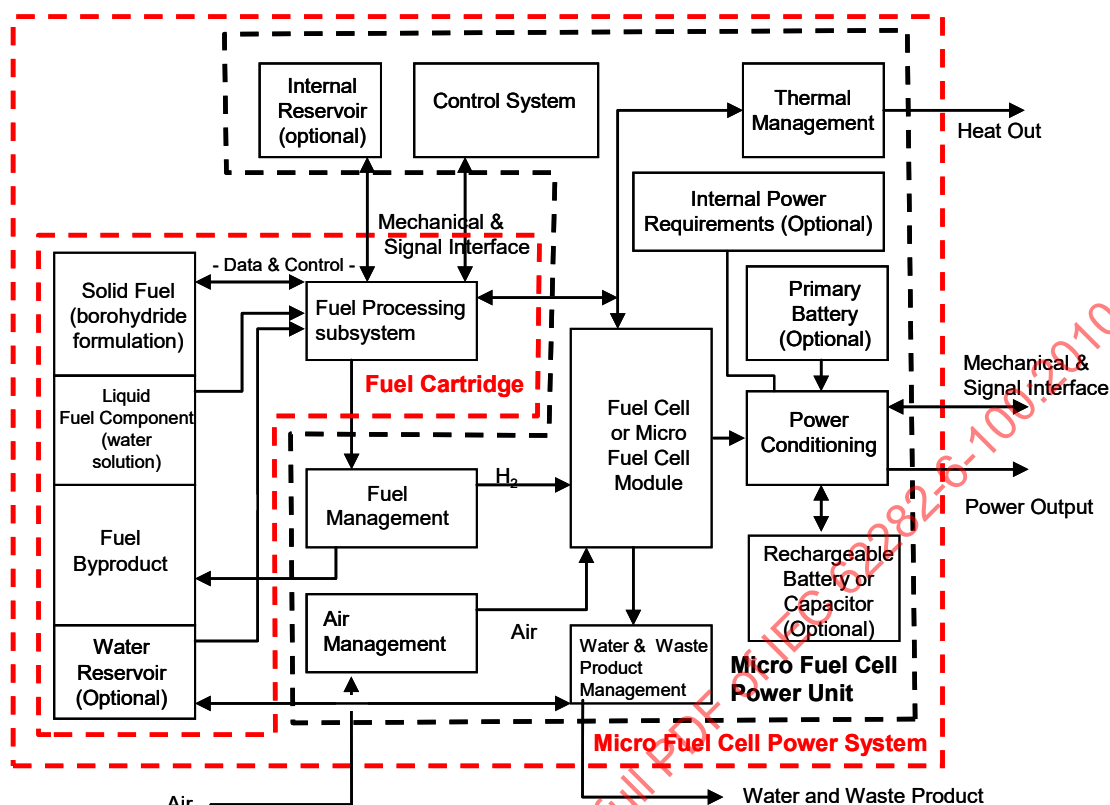


Figure E.15 – Micro fuel cell power system block diagram for solid Class 8 (corrosive) compound fuel with cartridge fuel processing and fuel management internal to the micro fuel cell power unit

E.2 Normative references

In addition to the normative references specified in Clause 2, 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 16111:2008, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

E.3 Terms and definitions

The terms and definitions below replace those corresponding terms and definitions in Clause 3 for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex E. All terms and conditions in Clause 3 not specifically mentioned here also apply.

E.3.5 fuel

Class 8 (corrosive) formulation of borohydride compounds used to produce electricity indirectly in a micro fuel cell power system

E.3.8**liquid fuel, corrosive**

liquid Class 8 (corrosive) formulation of borohydride compounds and one or more alkali metal hydroxides used as fuel for an indirect borohydride micro fuel cell power system

E.3.11**leakage**

accessible fuel, fuel byproducts, electrolyte or liquid fuel components outside the micro fuel cell power system or fuel cartridge; hydrogen leakage or impermissible hydrogen gas loss

The additional terms and their definitions below are needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex E in addition to those given in Clause E.3 and in Clause 3.

E.3.37**solid fuel, corrosive**

solid Class 8 (corrosive) formulation of borohydride compounds and one or more alkali metal hydroxides used as fuel for an indirect borohydride micro fuel cell power system

E.3.38**indirect borohydride micro fuel cell power system**

micro fuel cell power system in which a solid or liquid formulation of borohydride compounds, is processed to produce hydrogen which reacts on an anode of a fuel cell to produce electricity in a micro fuel cell power system

E.3.39**borohydride compounds**

sodium or potassium borohydride, or a mixture thereof

E.3.40**liquid fuel component**

Class 8 (corrosive), or non-hazardous, water solutions used to produce hydrogen within the fuel processing subsystem

E.3.41**electrolyte**

ion conducting membrane used to complete an electric circuit within a fuel cell

E.3.42**fuel byproducts**

Class 8 (corrosive), or non-hazardous, compounds produced after hydrogen and/or electricity is produced from fuel

E.3.43**impermissible hydrogen gas loss**

hydrogen gas escaping non-operating micro fuel cell power system or micro fuel cell power unit greater than or equal to 0,0032 g/h

E.3.44**accessible fuel, fuel byproducts, electrolyte or liquid fuel components**

fuel, fuel byproducts, electrolyte or liquid fuel components that the consumer may come into physical contact with during normal use, reasonably foreseeable misuse, and consumer transportation

E.3.45**fuel processing subsystem**

subsystem within the micro fuel cell power unit or fuel cartridge used to produce hydrogen from formulations of borohydride compounds

E.3.46

incompatible materials

materials which are likely to cause a dangerous evolution of heat, or flammable or poisonous gas or vapours if allowed to mix in ways other than those specifically provided for by the micro fuel cell power system design

E.3.47

uncontrolled mixing

mixing of incompatible materials that occurs in ways not specifically provided for by the micro fuel cell power system design

E.3.48

Class 8 (corrosive)

materials which are classified as Class 8: Corrosive Substance under the guidelines of the 15th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

E.3.49

non-hazardous

materials which are not subject to guidelines of the 15th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

E.3.50

alkali metal hydroxide

hydroxides of sodium, potassium and lithium used in Class 8 (corrosive) solid and liquid fuel formulations

E.3.51

used fuel cartridge

fuel cartridge that has been put into operation such that at least 45 % of the initial fuel has been utilized and that the operation of the micro fuel cell power system has been halted for at least 1 h

E.3.52

hydrogen leakage

hydrogen gas outside fuel containment system, including fuel cartridge, fuel management and internal reservoir (see E.7.2.2)

E.3.53

positive pH indication of liquid borohydride fuel and by product

a positive indication of the presence of acid (pH less than 3,0) or base (pH greater than 10) on acid base indicator paper attached to the possible leak areas of the micro fuel cell power system during the type test.

E.4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges

E.4.4 Selection of materials

These requirements replace the corresponding requirements of Subclause 4.4.

These requirements of Subclause E.4.4 below apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex E.

E.4.4.1 Micro fuel cell power systems and units are expected to be exposed to a number of environmental conditions over the manufacturer-defined life span of the product such as vibration, shock, varying humidity levels and corrosive environments. Materials employed in the micro fuel cell power system or unit shall be resistant to these environmental conditions. If a micro fuel cell power system or unit is to be used in service where specific environmental

conditions are beyond those accounted for in the required tests of this standard, then additional testing shall be performed to verify safety under those environmental conditions.

E.4.4.2 Metallic and non-metallic materials used to construct internal or external parts of the micro fuel cell power system or unit, in particular those exposed directly or indirectly to moisture, fuel and/or byproducts in either a gas or liquid form as well as all parts and materials used to seal or interconnect the same, e.g. welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable under the normal transportation and normal usage conditions within the manufacturer-defined life span of the product and for all test conditions; in particular, they shall be designed to retain their mechanical stability under normal use;

- they shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation;
- the chemical and physical properties necessary for operational safety shall not be significantly affected within the manufacturer-defined life span of the product; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, ageing resistance, the effects of temperature variations, the effects arising when materials are put together (e.g. galvanic corrosion), and the effects of ultraviolet radiation;
- where conditions of erosion, abrasion, corrosion or other chemical attack may arise, adequate measures shall be taken to
 - minimize that effect by appropriate design, e.g. additional thickness, or by appropriate protection, e.g. use of liners, cladding materials or surface coatings, taking due account of normal use;
 - permit replacement of parts which are most affected;
 - and draw attention, in the manual referred to in Clause 6, to type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement.

E.4.4.3 Elastomeric materials such as gaskets and tubing in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperatures that they are exposed to during normal use. Compliance shall be determined by the following: ISO 188 and ISO 1817.

E.4.4.4 Polymeric materials in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperature they are exposed to during normal use. Compliance shall be determined by ISO 175.

E.4.4.5 Piping systems exposed to hydrogen shall employ materials suitable for exposure to hydrogen, as defined in ISO 16111.

E.4.7 Materials and construction – system

E.4.7.1 *These requirements of Subclause E.4.7 apply to micro fuel cell power systems and units covered by this Annex E. These requirements replace the corresponding requirements of Subclause 4.7. The maximum quantity of liquid fuel or liquid fuel components stored in the micro fuel cell power unit shall not be more than 1 l. Solid fuel shall not be present in the micro fuel cell power unit.*

E.4.7.2 The micro fuel cell power system or unit shall be designed such that an explosion cannot occur even if fuel leaks from or inside the micro fuel cell power system or unit. The design criteria for such means (for example, required ventilation rate) shall be provided by the micro fuel cell power system or unit manufacturer. The means shall be provided either by the micro fuel cell power system or unit manufacturer or by the manufacturer of the device powered by the micro fuel cell power system or unit.

E.4.7.3 Components and materials inside the micro fuel cell power system or unit shall be constructed or shall make use of such materials that propagation of fire and ignition is mitigated. The material flammability shall be such that a sustained fire will not be supported after electrical power and the fuel and oxidant supply have been terminated. This may be demonstrated through the selection of materials meeting FV 0, FV 1 or FV 2 in accordance with IEC 60695-1-1 and IEC 60695-11-10.

E.4.7.4 Micro fuel cell stack membranes are not required to have flammability ratings.

E.4.7.5 Other materials within the micro fuel cell stack which comprise less than 30 % of the total micro fuel cell stack mass are considered to be of limited quantity and are permissible without flammability ratings.

E.4.12 Fuel supply construction

E.4.12.1 Fuel cartridge construction

These requirements of Subclause E.4.12.1 apply to micro fuel cell cartridges covered by this Annex E. These requirements replace the corresponding requirements of Subclause 4.12.1.

Fuel cartridges shall conform to the following requirements.

E.4.12.1.1 There shall be no leakage from the fuel cartridge in the temperature range of –40 °C to +70 °C. Compliance shall be determined by type testing in accordance with E.7.3.3 and E.7.3.4.

E.4.12.1.2 There shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Compliance shall be determined by type testing in accordance with E.7.3.1.

E.4.12.1.3 The maximum fuel charge is limited to 1 l for either liquid fuel or liquid fuel components, and 200 g for solid fuel.

E.4.12.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a micro fuel cell power unit by a consumer, means to prevent fuel leakage prior to, during, and after connection or transfer of fuel to the micro fuel cell power unit shall be provided. Compliance is checked by E.7.3.11.

E.4.12.1.5 A fuel cartridge shall be resistant to corrosion in its usage environment.

E.4.12.1.6 A fuel cartridge shall be provided with a means to prevent mis-connection that would result in leakage of fuel when it is installed in a micro fuel cell power system. Compliance is checked by the connection cycling test, E.7.3.11.

E.4.12.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel when not attached to a micro fuel cell power unit during normal usage, reasonably foreseeable misuse, and consumer transportation. Compliance is checked by the drop test, E.7.3.5, and the connection cycling test, E.7.3.11.

E.4.12.1.8 In the case where a pressure release valve or similar means is provided, such pressure release valve shall satisfy the performance requirement for each type test. This valve shall pass all type tests with no leakage.

E.4.12.1.9 The structure at the connection to the fuel cartridge shall not allow fuel to leak.

E.4.12.1.10 A fuel cartridge, including the fuel cartridge interface to the micro fuel cell power unit, including the valve, shall have a construction sufficient to withstand normal use and reasonably foreseeable misuse generated by vibration, heat, pressure, being dropped or otherwise subject to a mechanical shock etc. Compliance is checked by:

- Pressure differential tests, E.7.3.1;
- Vibration test, E.7.3.2;
- Temperature cycling test, E.7.3.3;
- High temperature exposure test, E.7.3.4;
- Drop test, E.7.3.5;
- Compressive loading test, E.7.3.6;
- External short-circuit test, E.7.3.7;
- Long-term storage test, E.7.3.9;
- High-temperature connection test, E.7.3.10;
- Connection cycling tests, E.7.3.11;
- Emission test, E.7.3.12.

E.4.12.1.11 The fuel cartridge valves shall operate as intended without the use of tools and without excessive force needed to connect or disconnect.

E.4.12.1.12 In cases where materials (either solid or liquid) are present that are incompatible with either the borohydride fuel or liquid fuel component, the design of the fuel cartridge and micro fuel cell power system shall provide a means for preventing inadvertent or uncontrolled mixing of these materials.

Two independent means for preventing inadvertent or uncontrolled mixing of these materials shall be provided during transportation and storage prior to use. Illustrative examples of these means include but are not limited to: positive activation by the control system; physical removal of an impermeable barrier preventing contact; opening of a normally closed manually controlled valve preventing contact. For at least one of these means for preventing uncontrolled mixing, it shall be necessary for the user to take positive action to remove or deactivate it prior to use.

At least one means for preventing uncontrolled mixing of these materials shall be provided during use and storage after use. This means may include active control by system electronics, subject to the FMEA analysis of 4.2.

E.6 Instructions and warnings for fuel cartridges, micro fuel cell power units, and micro fuel cell power systems

E.6.2 Minimum markings required on the fuel cartridge

These markings replace the markings required by Subclause 6.2.

As a minimum, the following shall be marked on the fuel cartridge.

- a) CONTENTS ARE CORROSIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) KEEP AWAY FROM CHILDREN.
- d) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- e) DO NOT EXPOSE TO ACIDS, OXIDIZERS, ALCOHOL OR HOUSEHOLD CLEANING PRODUCTS.
- f) DO NOT IMMERSE IN WATER OR OTHER LIQUIDS.
- g) FOLLOW USAGE INSTRUCTIONS.
- h) IN THE CASE OF INGESTION OR INHALATION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- i) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- j) COMPOSITION AND AMOUNT OF FUEL.
- k) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.
- l) MAY CONTAIN FLAMMABLE GAS.

In the case that the contents of the fuel cartridge may be flammable, the marking required under “a)” above shall be changed as follows:

- a) CONTENTS ARE FLAMMABLE, CORROSIVE AND TOXIC. DO NOT DISASSEMBLE.

E.6.3 Minimum markings required on the micro fuel cell power system

These markings replace the markings required by Subclause 6.3.

In addition, as a minimum, the following shall also be marked on the micro fuel cell power system to show:

- a) CONTENTS ARE CORROSIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- d) DO NOT IMMERSE IN WATER OR OTHER LIQUIDS.
- e) FOLLOW USAGE INSTRUCTIONS.
- f) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- g) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.

- h) COMPOSITION OF FUEL.
- i) MAXIMUM CAPACITY OF FUEL IN THE INTERNAL RESERVOIR, IF APPLICABLE
- j) TEXT OR MARKING THAT INDICATES THAT THE MICRO FUEL CELL POWER SYSTEM COMPLIES WITH IEC 62282-6-100.
- k) MAY CONTAIN FLAMMABLE GAS.
- l) ELECTRICAL OUTPUT (VOLTAGE, CURRENT, RATED POWER).

In the case that the contents of the fuel cartridge are corrosive, the marking required under “a)” above shall be changed as follows:

- a) CONTENTS ARE WATER-REACTIVE, CORROSIVE AND TOXIC. DO NOT DISASSEMBLE.

In the case that the contents of the fuel cartridge are flammable, the marking required under “a)” above shall be changed as follows:

- a) CONTENTS ARE WATER-REACTIVE, CORROSIVE, TOXIC AND FLAMMABLE. DO NOT DISASSEMBLE.

E.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

E.7.1 General

This Subclause E.7.1 replaces Subclause 7.1 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges using hydrogen produced from Class 8 (corrosive) borohydride compounds as fuel.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table E.5 lists the type tests that must be performed. *Table E.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table E.6. *Table E.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of $22\text{ °C} \pm 5\text{ °C}$ for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table E.5 – List of type tests – Replaces table 5

Test reference	Test item	Test sample
E.7.3.1	Pressure differential tests	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
E.7.3.2	Vibration test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
E.7.3.3	Temperature cycling test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
E.7.3.4	High temperature exposure test	Fuel cartridge Used fuel cartridge
E.7.3.5	Drop test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
E.7.3.6	Compressive loading test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
E.7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface component and exhaust gas temperature test	Micro fuel cell power system or power unit
E.7.3.9	Long-term storage test	Fuel cartridge Used fuel cartridge
E.7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
E.7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
E.7.3.12	Emission test	Micro fuel cell power system or power unit
E.7.3.13	Hydrogen point source gas loss detection test	Micro fuel cell power system or power unit
Table E.5 replaces Table 5. Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or used, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test. Test sequence: Tests E.7.3.2 and E.7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests E.7.3.1, E.7.3.2, and E.7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or power units. Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.		

Table E.6 – Laboratory standard conditions – Replaces Table 6

Item	Condition
Laboratory temperature	Laboratory temperature is “room temperature” (standard temperature condition, 22 °C ± 5 °C)
Laboratory atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen. The laboratory atmosphere contains not more than 0,008 % hydrogen
Table E.6 replaces Table 6.	

E.7.2 Leakage, hydrogen leakage, and hydrogen gas loss measurement and the measuring procedure

This Subclause E.7.2 replaces Subclause 7.2 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use Class 8 (corrosive) borohydride compounds as fuel.

- a) *The leakage measurement shall be executed in principle in accordance with the procedures shown in Figures E.2 through E.5. These figures and their procedures, replace the corresponding figures in Subclause 7.2.*
- b) Compliance with the “no leakage”, “no hydrogen leakage” and “no impermissible hydrogen gas loss” requirement for all type tests specified in Subclause E.7.3 shall be determined by the leakage measurement procedure of Subclause E.7.2.1, the hydrogen leakage measurement procedure of Subclause E.7.2.2 and the hydrogen gas loss measurement procedure of E.7.3.13 in conjunction with the definition of “leakage” in Subclause E.3.11, “hydrogen leakage” in Subclause E.3.52 and the definition of “impermissible hydrogen gas loss” in Subclause E.3.43, unless otherwise specified.

E.7.2.1 Leakage test and measuring procedures

- a) For micro fuel cell power systems, micro fuel cell power units and fuel cartridges containing Class 8 (corrosive) borohydride fuel, the leakage measurement of fuel, fuel byproducts, electrolyte or liquid fuel components shall be done following each type test by performing visual inspection of all possible leak locations. Any drops of fuel, fuel byproducts, electrolyte or liquid fuel component and/or white crystals on the exterior of the micro fuel cell power system or unit or fuel cartridge are indications of leakage. If crystals are accessible, the micro fuel cell power system or unit or fuel cartridge fails the leakage test. As an additional tool for finding fuel, fuel byproducts, electrolyte or liquid fuel component leaks, pH paper, attached to the possible leak areas of the micro fuel cell power system, shall be used to aid in the visual check for leakage. This is an additional requirement in Annex F for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel components. Any existence of a substance with a pH lower than 3,5 or greater than 10,5 is an indication of leakage. See Figure E.2 and Figure E.3. For operational tests, reactant air passages into the micro fuel cell power system and exhaust ports should not be blocked with pH paper.

E.7.2.2 Hydrogen leakage measurement from fuel cartridges and measurement procedures

For fuel cartridges containing Class 8 (corrosive) borohydride compounds, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the fuel cartridge. See Figure E.2 and Figure E.3.

E.7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures

For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure E.4 as follows.

- a) Perform hydrogen emission testing in accordance with E.7.3.12 with the exception that the micro fuel cell power system or unit shall be off ("DEVICE – OFF"). Hydrogen point source testing in accordance with E.7.3.13 is not applicable. Hydrogen gas loss shall be less than 0,0032 g/h. See Table E.7.
- b) Perform hydrogen emission testing in accordance with E.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h and hydrogen leakage from any single point leak shall be less than 0,016 g/h. See Table E.7.

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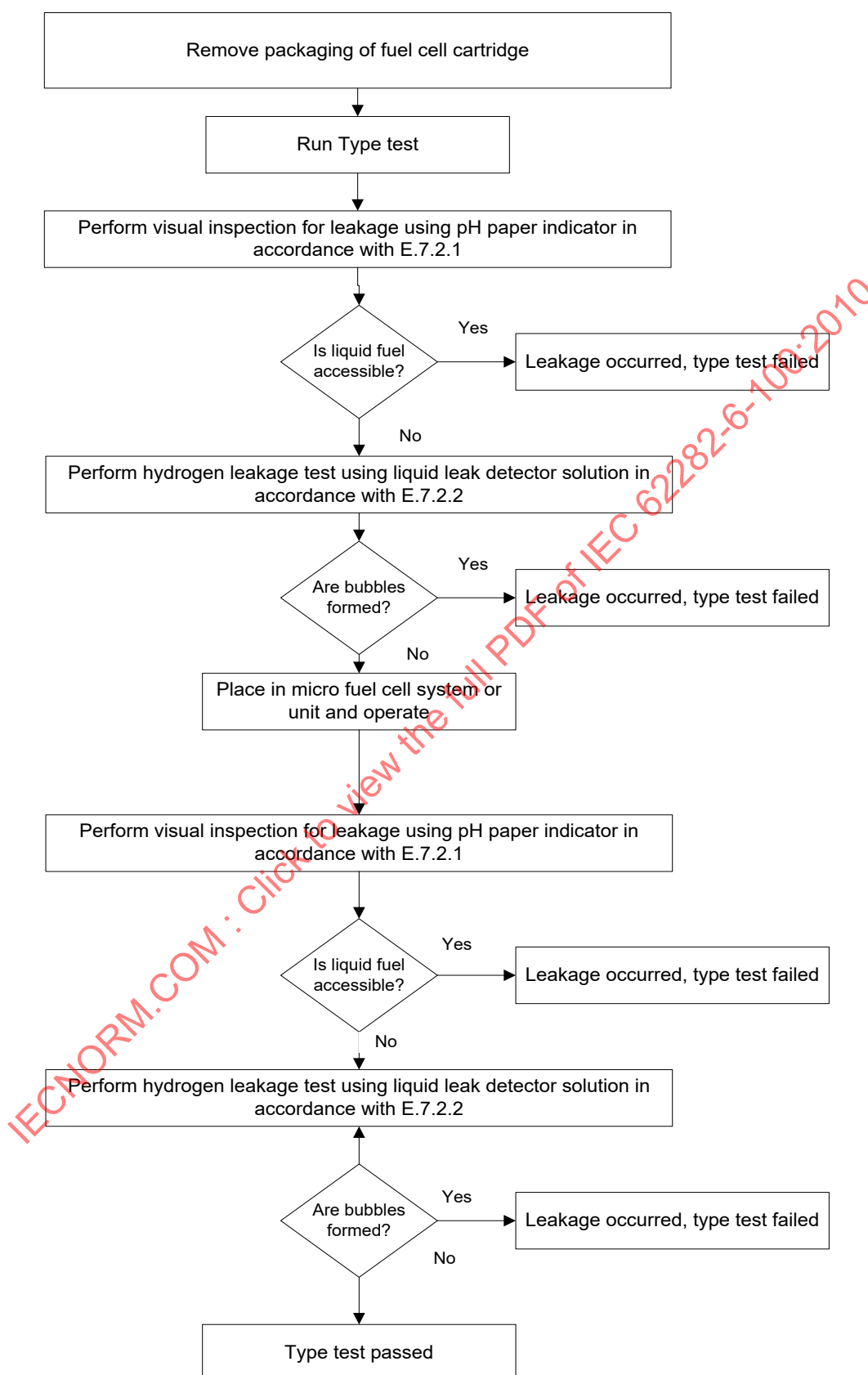


Figure E.2 – Fuel cartridge leakage test flow chart for vibration, drop, compressive loading – Replaces Figure 2

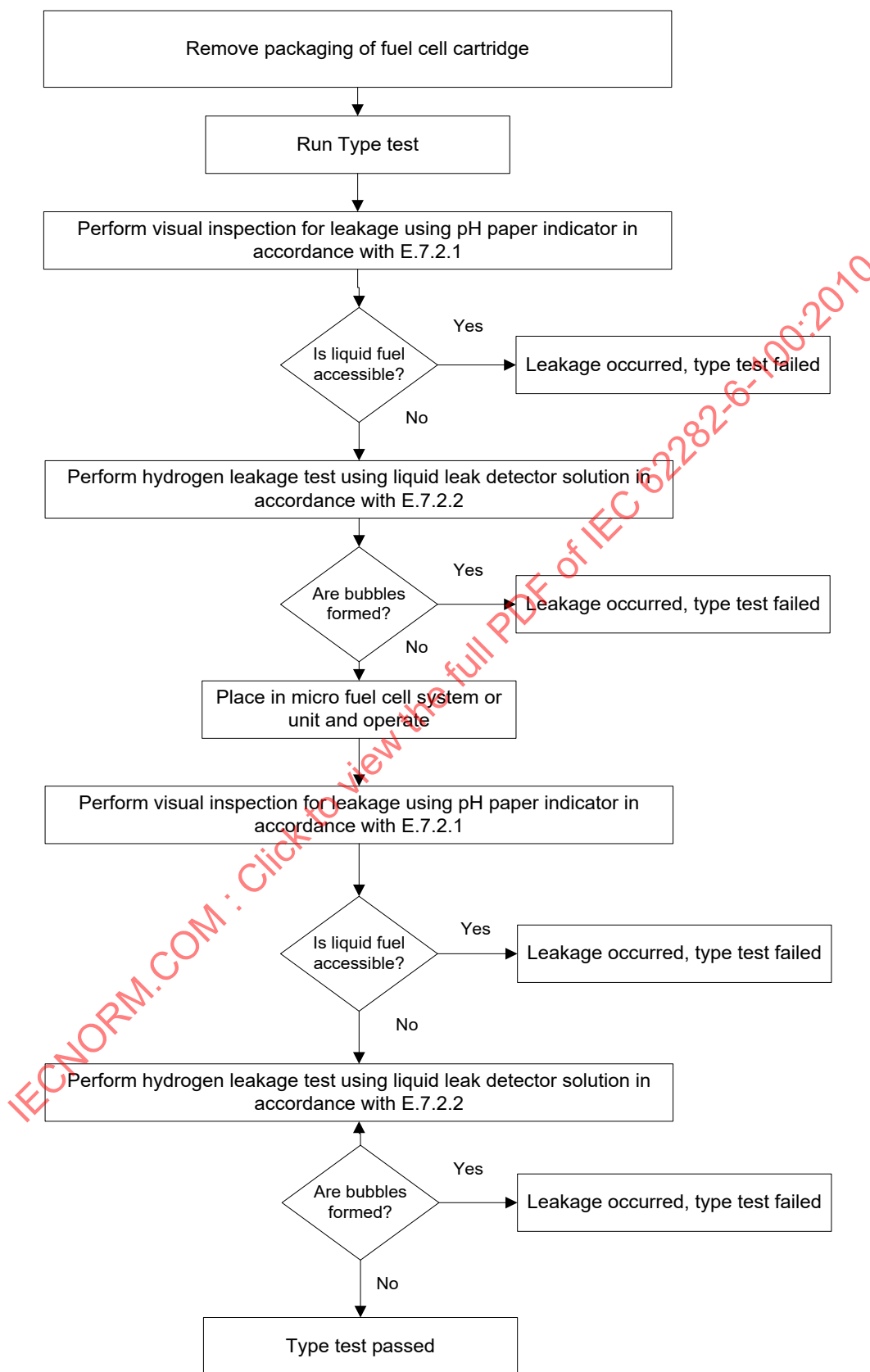


Figure E.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

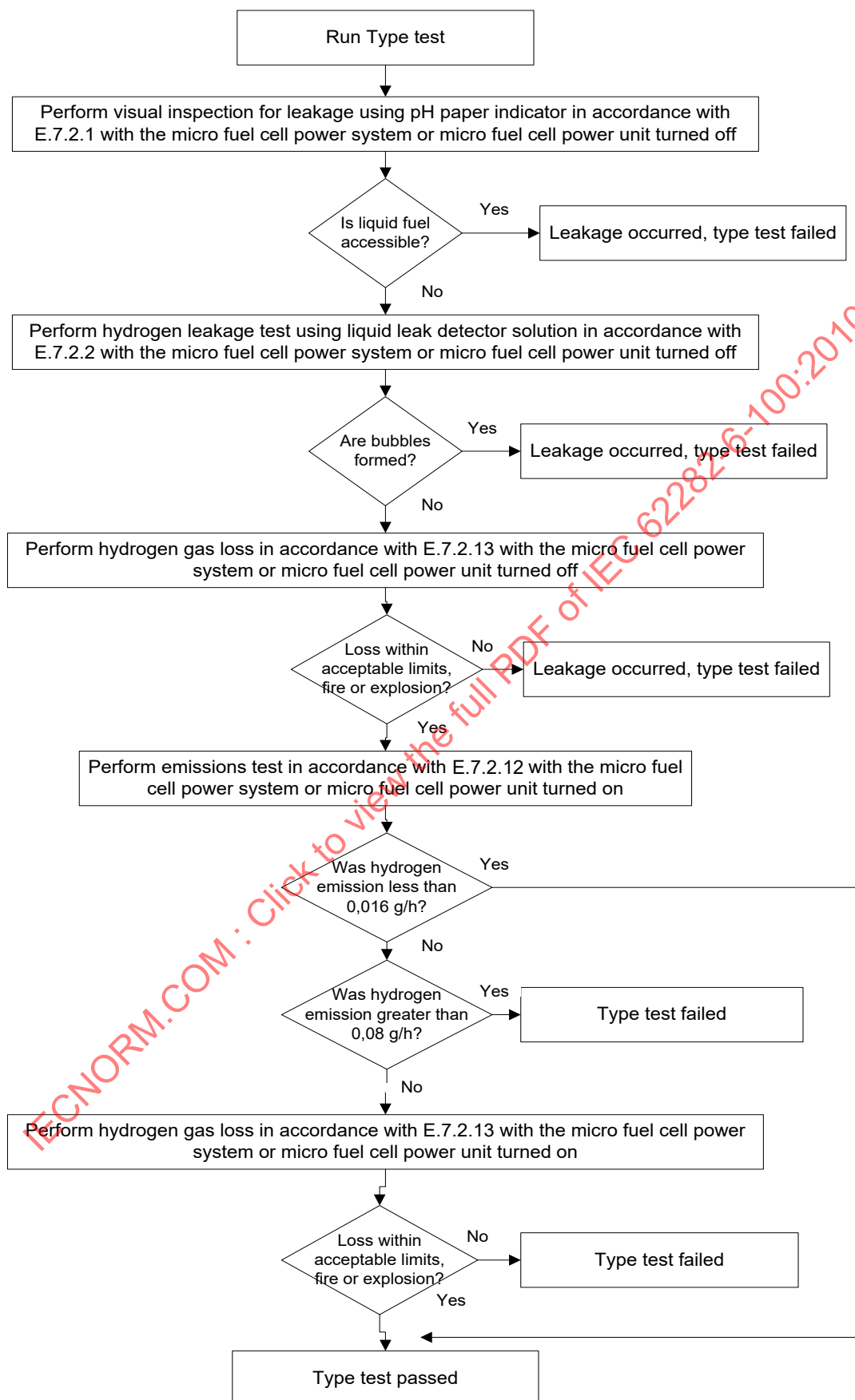


Figure E.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

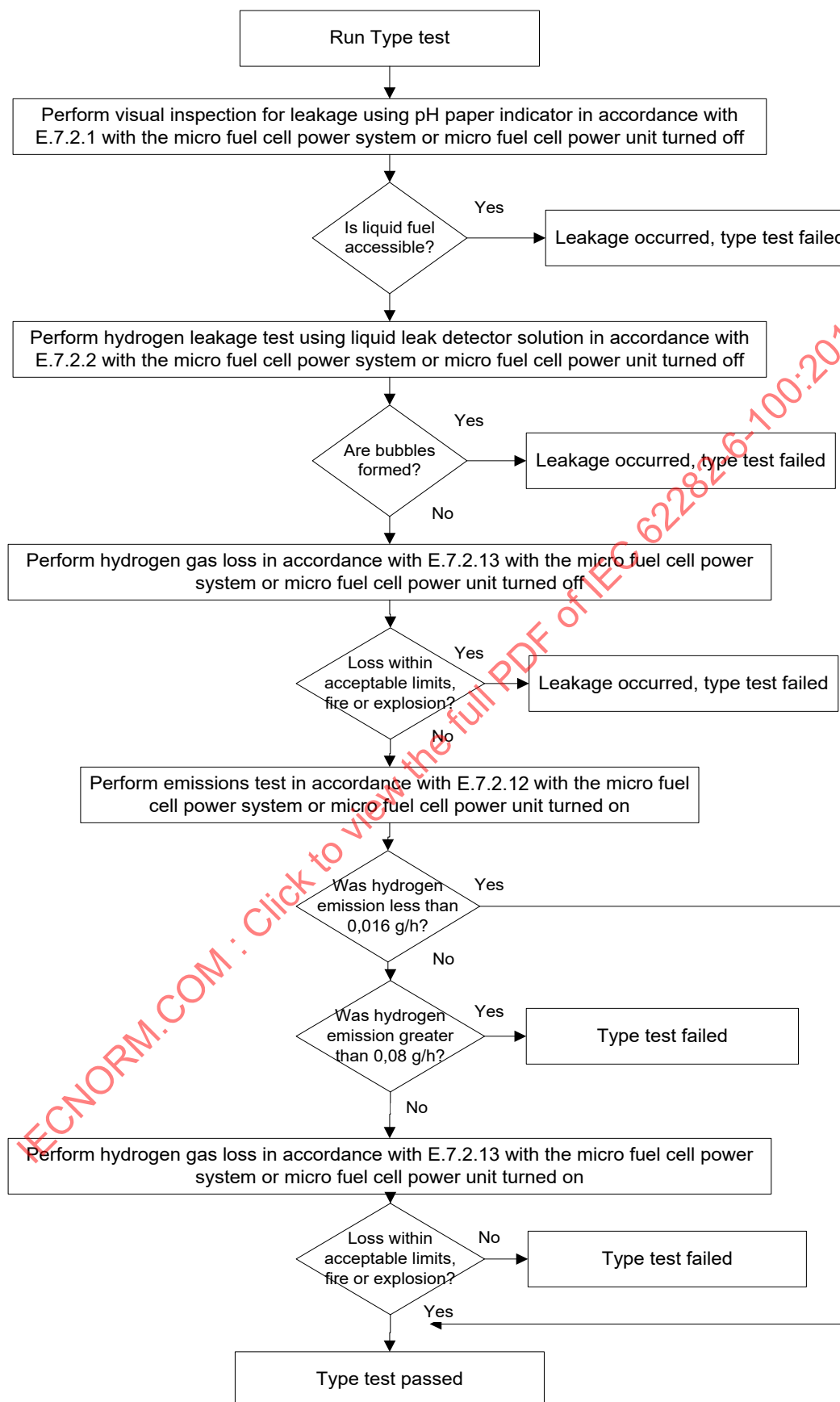


Figure E.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

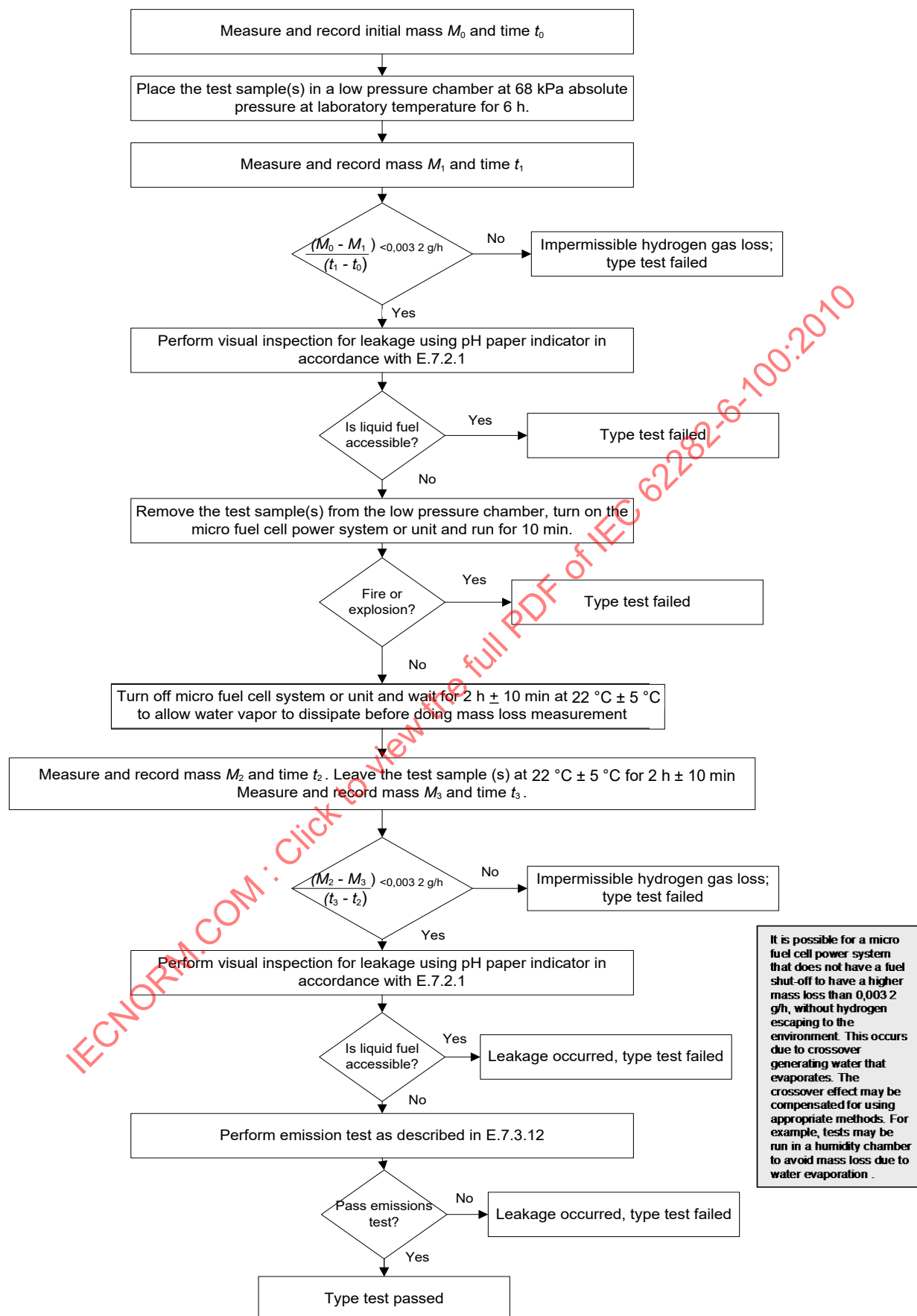


Figure E.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

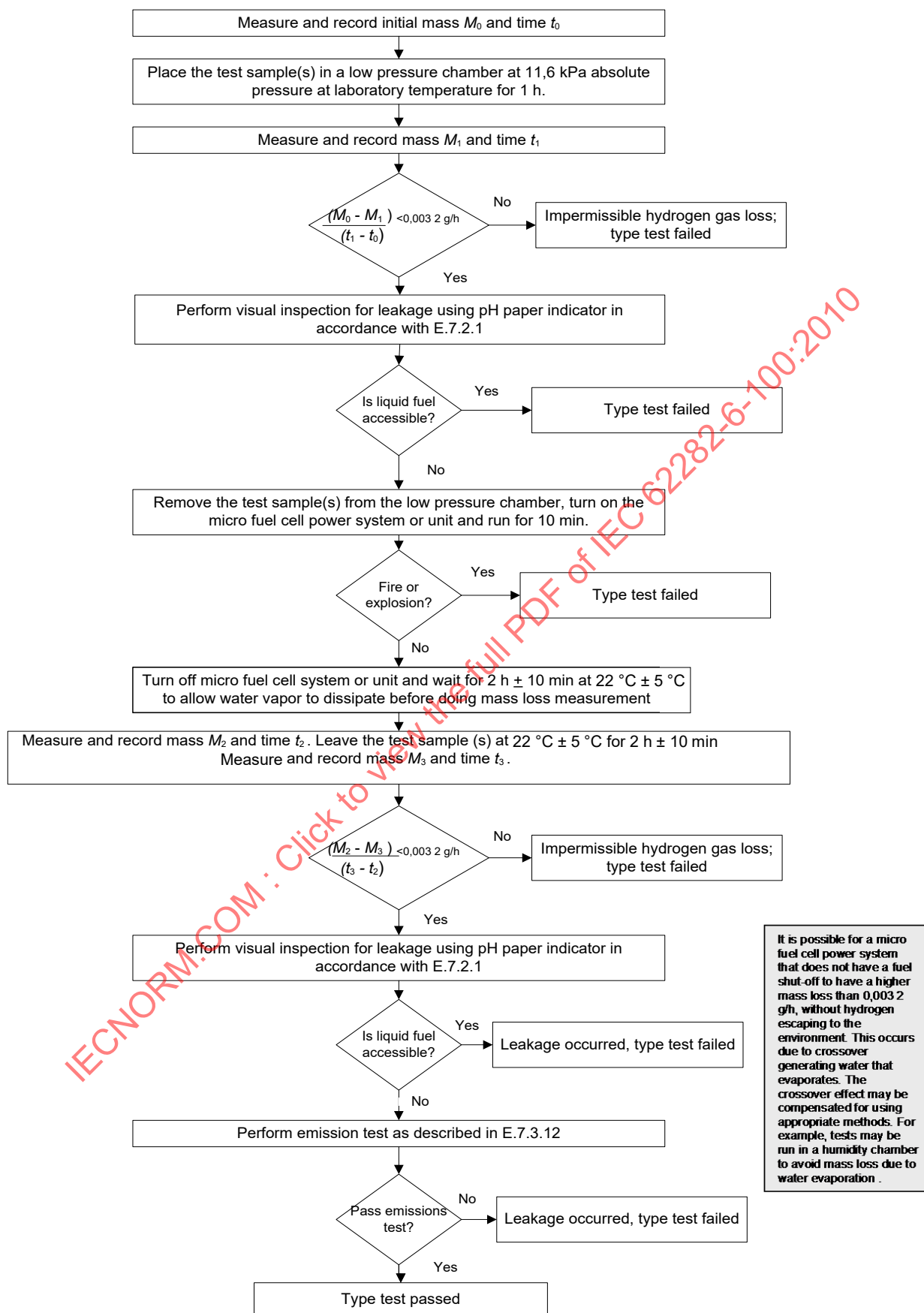


Figure E.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

E.7.3 Type tests

E.7.3.1 Pressure differential tests

E.7.3.1.1 General

Subclause E.7.3.1 replaces Subclause 7.3.1.

Portions of this test check compliance with Subclause E.4.12.1.2 to verify that there shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Depending upon which of the two limiting pressure conditions is greater, two options for testing are provided:

- a) If 95 kPa internal gauge pressure plus normal working pressure of the fuel cartridge at 22 °C is greater than two times the gauge pressure of the fuel cartridge at 55 °C, either Subclause E.7.3.1.2 or Subclause E.7.3.1.3 may be used to verify compliance with Subclause E.4.12.1.2.
- b) If two times the gauge pressure of the fuel cartridge at 55 °C is greater than 95 kPa internal gauge pressure plus normal working pressure at 22 °C, Subclause E.7.3.1.2 must be used to verify compliance with Subclause E.4.12.1.2.

E.7.3.1.2 Fuel cartridge internal pressurization test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**

For the internal pressurization test, the fuel cartridge body and the fuel cartridge valve shall be tested separately.

- 1) Using a suitable fluid medium pressurize the fuel cartridge body to an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. The pressure rise shall not exceed a rate of 60 kPa/s.
 - 2) Maintain the maximum pressure for 30 min at laboratory temperature.
 - 3) Using a suitable fluid medium pressurize the closed fuel cartridge valve to 95 kPa gauge pressure plus the normal working pressure of the cartridge at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. The pressure rise shall not exceed a rate of 60 kPa/s.
 - 4) Maintain the maximum pressure for 30 min at laboratory temperature.
- d) **Passing criteria:** no accessible liquid test medium leakage and no sudden drop of pressure during the course of the test. Leakage shall be checked visually. Invert the fuel cartridge and the fuel cartridge valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails.

NOTE Class 8 (corrosive) borohydride fuel will chemically react with water, therefore, water or water-containing substances should not be used as the fluid test medium. Class 8 (corrosive) borohydride fuels have the potential to react with substances other than water, therefore, the chemical reactivity and stability of the particular Class 8 (corrosive) borohydride fuel being tested should be used to guide the selection of a suitable liquid test medium.

E.7.3.1.3 Fuel cartridge low external pressure test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure E.16.

- 2) Record the initial mass of the test sample M_0 and starting time t_0 . Place the sample in a vacuum chamber and reduce the pressure in the vacuum chamber to 95 kPa below normal atmospheric pressure.
 - 3) Maintain the vacuum for 30 min.
 - 4) Remove the sample from the vacuum chamber and record the final mass M_1 and time t_1 . Determine hydrogen gas loss and check for leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel components using visual inspection with pH indicator as described in Subclause E.7.2.1.
 - 5) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator as described in Subclause E.7.2.1. See Figure E.16.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen gas loss shall meet the requirements of Subclause E.7.2.3 (less than 0,0032 g/h) for the fuel cartridge and micro fuel cell power system or unit. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated.

E.7.3.1.4 Micro fuel cell power system or micro fuel cell power unit pressure differential tests

E.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex E.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure E.6.
 - 2) Test samples shall be stored at a low external pressure of 68 kPa absolute pressure for 6 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure E.6.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with E.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen gas loss shall be determined by the mass loss measurement as shown in Figure E.6. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there

is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex E.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figures E.7.
 - 2) Test samples shall be stored at a low external pressure of 11,6 kPa absolute pressure for 1 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure E.7.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with E.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen gas loss shall be determined by the mass loss measurement as shown in Figure E.7. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.2 Vibration test

Subclause E.7.3.2 replaces Subclause 7.3.2 for micro fuel cell power systems, units and fuel cartridges covered by this Annex E.

- a) **Test sample:** an unused fuel cartridge, a used fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in E.7.3.1 or a micro fuel cell power system used in used in E.7.3.1.
- b) **Purpose:** to simulate the effects of normal transportation vibration and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure E.2 for the fuel cartridge and Figure E.4 for the micro fuel cell power system or unit.
 - 2) The test sample shall be firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.
 - 3) The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min.
 - 4) This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions of the test samples.
 - 5) The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g_n is maintained until 18 Hz is reached. The amplitude is then maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of 8 g_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.

- 6) For the micro fuel cell power system or unit, perform emission testing in accordance with E.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and micro fuel cell power system or unit. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.3 Temperature cycling test

Subclause E.7.3.3 replaces Subclause 7.3.3 for micro fuel cell power systems, units and fuel cartridges covered by this Annex E.

- a) **Test sample:** a fuel cartridge used in E.7.3.2, a used fuel cartridge used in E.7.3.2, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in E.7.3.2 or a micro fuel cell power system used in E.7.3.2.
- b) **Purpose:** to simulate the effects of low-temperature and high temperature exposure and the effects of extreme temperature change and ensure no leakage.
- c) **Test procedure:**
- 1) Perform these tests in accordance with Figure E.3 for the fuel cartridge and Figure E.4 for the micro fuel cell power system or unit.
 - 2) For a fuel cartridge, two fuel cartridge orientations shall be tested – valve up and valve down. For a micro fuel cell power system or a micro fuel cell power unit, only one orientation needs to be tested.
 - 3) See Figure E.8 for the temperature profile to be used.
 - 4) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from laboratory temperature to $55\text{ °C} \pm 2\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $55\text{ °C} \pm 2\text{ °C}$ for a minimum of 4 h.
 - 5) Decrease the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$ then decrease the chamber temperature to $-40\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $-40\text{ °C} \pm 5\text{ °C}$ for a minimum of 4 h.
 - 6) Increase the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$.
 - 7) The above process is to be done twice.
 - 8) After 1 h at $22\text{ °C} \pm 5\text{ °C}$, leakage shall be measured based upon the procedure described in Figure E.3 for fuel cartridge and Figure E.4 for micro fuel cell power system or unit.
 - 9) For the micro fuel cell power system or micro fuel cell power unit, perform emission testing in accordance with E.7.3.12.
 - 10) For the fuel cartridge, connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector

(bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator as described in Subclause E.7.2.1.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1 for the fuel cartridge and the micro fuel cell power system or unit. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and the micro fuel cell power system or unit. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

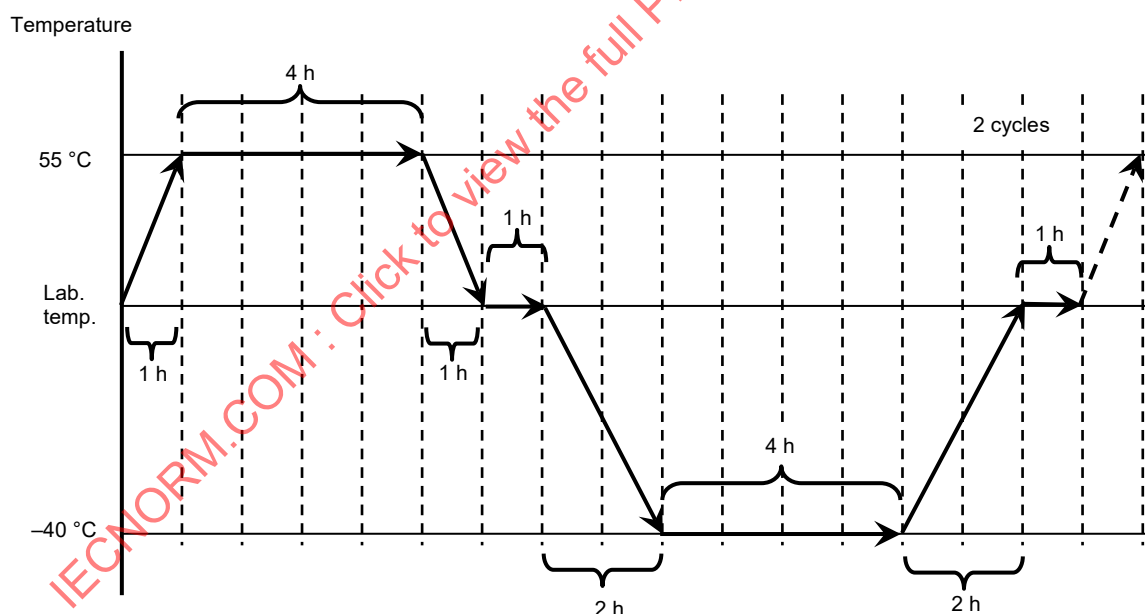


Figure E.8 – Temperature cycling – Replaces Figure 8

E.7.3.4 High temperature exposure test

Subclause E.7.3.4 replaces Subclause 7.3.4 for fuel cartridges covered by this Annex E.

- Test sample:** an unused fuel cartridge or a used fuel cartridge.
- Purpose:** to simulate the effects of a fuel cartridge left in high temperature environments and ensure no leakage.

c) **Test procedure:**

- 1) Perform these tests in accordance with Figure E.3 for the fuel cartridge.
- 2) Two orientations shall be tested – valve up and valve down.
- 3) Place the test sample in a temperature controlled test chamber that is at a temperature of $70\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ and allow chamber temperature to recover to $70\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ and maintain that temperature for at least 4 h with the sample in the chamber.
- 4) Remove the test sample to laboratory temperature. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator test as described in Subclause E.7.2.1.
- 5) Connect the fuel cartridge to a micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator test as described in Subclause E.7.2.1. See Figure E.3.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

E.7.3.5 Drop test

Subclause E.7.3.5 replaces Subclause 7.3.5 for micro fuel cell power systems, units and fuel cartridges covered by this Annex E.

- a) **Test sample:** an unused fuel cartridge, a used fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an inadvertent drop and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure E.2 for the fuel cartridge and Figure E.4 for the micro fuel cell power system or unit.
 - 2) The test sample shall be dropped on a horizontal surface that consists of hardwood at least 13 mm thick, mounted on two layers of plywood each 18 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor from a predetermined height.
 - 3) The height of the drop shall be:
 - i) $1\ 200\text{ mm} \pm 10\text{ mm}$: in the case of a micro fuel cell power unit and/or a micro fuel cell power system.
 - ii) $1\ 500\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge of more than 200 ml.
 - iii) $1\ 800\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge of up to 200 g of solid fuel or up to 200 ml of liquid fuel component.

- 4) For the fuel cartridge tests, the drop test shall be carried out in four drop orientations with the same sample.
 - 5) For the micro fuel cell power unit or the micro fuel cell power system, one micro fuel cell power system or unit may be used for all four drop orientations, or more than one micro fuel cell power system or unit may be used in subsequent drops, at the discretion of the manufacturer.
 - 6) For all tests, drop orientations shall be:
 - i) valve up;
 - ii) valve down;
 - iii) two other mutually perpendicular orientations.
 - 7) For the fuel cartridge, check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator test as described in Subclause E.7.2.1.
 - 8) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator as described in Subclause E.7.2.1. See Figure E.2.
 - 9) For micro fuel cell power system or micro fuel cell power unit tests, perform emission testing in accordance with E.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

E.7.3.6 Compressive loading test

Subclause E.7.3.6 replaces Subclause 7.3.6 for micro fuel cell power systems, units and fuel cartridges covered by this Annex E.

E.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the micro fuel cell power unit, or micro fuel cell power system.

c) **Test procedure:**

- 1) Perform these tests in accordance with Figure E.4 for the micro fuel cell power system or unit.
- 2) The micro fuel cell power system or unit test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $245 \text{ N} \pm 9,8 \text{ N}$.
- 3) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
- 4) A compressive force of $245 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
- 5) The test shall be carried out in three mutually perpendicular orientations as a rule. If the sample would not stand on its own, it does not need to be tested in that orientation.
- 6) Perform emission testing in accordance with E.7.3.12 following the compressive loading test.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

E.7.3.6.2 Fuel cartridge

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.

- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the fuel cartridge and ensure no leakage.

c) **Test procedure:**

- 1) Perform these tests in accordance with Figure E.2 for the fuel cartridge.
- 2) The fuel cartridge test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $981 \text{ N} \pm 9,8 \text{ N}$.
- 3) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
- 4) A compressive force of $981 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
- 5) Fuel cartridge orientations shall be selected on the basis of likely stable resting positions when accidentally dropped (e.g. those orientations having the lowest centres of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic fuel cartridge that is sufficiently cubic and the curved surface of a cylindrical fuel cartridge with a longitudinal axis length longer than twice the diameter. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte

and liquid fuel components using visual inspection with pH indicator as described in Subclause E.7.2.1.

- 6) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause E.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator as described in Subclause E.7.2.1. See Figure E.2.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

E.7.3.7 External short-circuit test

Subclause E.7.3.7 replaces Subclause 7.3.7 for micro fuel cell power systems and units covered by this Annex E.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an external short-circuit.
- c) **Test procedure:**
- 1) Perform these tests in accordance with Figure E.5 for the micro fuel cell power system or unit.
 - 2) External short-circuit testing shall be done separately on both operating [DEVICE ON] and non-operating [DEVICE OFF] micro fuel cell power systems or micro fuel cell power units respectively.
 - 3) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power system or unit with wire having a maximum resistance load of 0,1 Ω for at least 5 min.
 - 4) Following the short-circuit test, evaluate performance and perform leakage and emissions testing in accordance with Figure E.5.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed the temperatures shown in Table 2 during or after short circuit testing.

Emissions shall meet the passing criteria in E.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of E.7.3.12, the emission test is acceptable.

NOTE The external short circuit test can be done sequentially with the surface component and exhaust gas temperature test using the same sample.

E.7.3.9 Long-term storage test

Subclause E.7.3.9 replaces Subclause 7.3.9 for fuel cartridges covered by this Annex E.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure E.9 for fuel cartridges.
 - 2) Record initial mass M_0 and time t_0 and place sample in temperature chamber at $50 \text{ }^\circ\text{C} \pm 2 \text{ }^\circ\text{C}$ with a chamber relative humidity of at least 60 %.
 - 3) The temperature chamber shall be equipped with ventilation and measurement instruments capable of accurately measuring the concentration of hydrogen in the chamber similar to the configuration in Figure E.10.
 - 4) The ventilation flow rate and the hydrogen concentration of interest in the chamber shall be monitored continuously and recorded. See Table E.7. At no time during the test shall the hydrogen concentration in the chamber shall exceed 25 % LFL.
 - 5) The sample shall remain in the chamber at $50 \text{ }^\circ\text{C} \pm 2 \text{ }^\circ\text{C}$ with a chamber relative humidity of at least 60 % for at least 28 days.
 - 6) At the end of the 28 days, remove the fuel cartridge from the test chamber and record the time the fuel cartridge was removed from the test chamber, t_1 . Allow the fuel cartridge to stabilize at laboratory temperature and record the final mass, M_1 . Hydrogen gas loss is calculated as follows and shall not exceed 0,0032 g/h:
$$\frac{M_0 - M_1}{t_1 - t_0} < 0,0032 \text{ g/h}$$
 - 7) Perform fuel, fuel byproduct, electrolyte and liquid fuel component leakage testing in accordance with Subclause E.7.2.1 for the fuel cartridge. Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for fuel, fuel byproduct, electrolyte, or liquid fuel component leakage using visual inspection with pH indicator test as described in E.7.2.1. See Figure E.9.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause E.7.2.3 (less than 0,0032 g/h). The hydrogen concentration in the temperature test chamber shall not exceed 25 % LFL at any time during the test. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

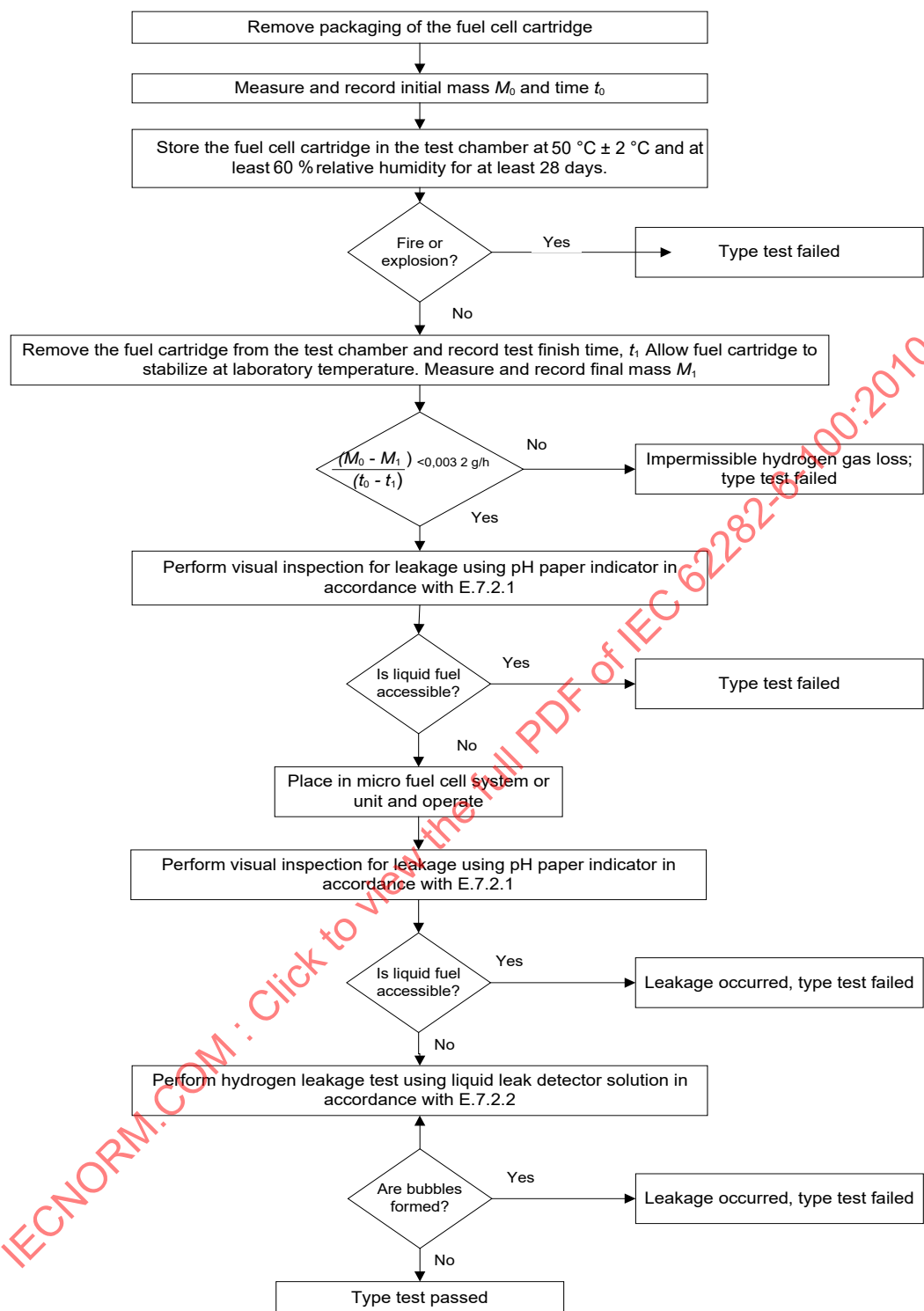


Figure E.9 – Fuel cartridge hydrogen leakage and mass loss test flowchart for long-term storage test – Replaces Figure 9

E.7.3.10 High-temperature connection test

Subclause E.7.3.10 replaces Subclause 7.3.10 for micro fuel cell power systems, units and fuel cartridges covered by this Annex E.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge and a micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure E.2 for fuel cartridges.
 - 2) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of $50\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for at least 4 h.
 - 3) The micro fuel cell power unit or test fixture with micro fuel cell power unit valve is kept at laboratory temperature.
 - 4) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or test fixture with micro fuel cell power unit valve within 5 min of removal from the chamber.
 - 5) Check for leakage upon connection and disconnection the fuel cartridge and the micro fuel cell power system or micro fuel cell power unit and perform leakage and hydrogen leakage measurement in accordance with E.7.2.1 and E.7.2.2.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods.

E.7.3.11 Connection cycling tests

Subclause E.7.3.11 replaces Subclause 7.3.11 for micro fuel cell power systems, units and fuel cartridges covered by this Annex E.

E.7.3.11.1 Fuel cartridge

E.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

- a) **Test sample:** an unused or a used insert cartridge, exterior cartridge or attached cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve and fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.

c) Test procedure:

- 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve. Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as in the leakage test and measurement procedure specified in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in E.7.2.1.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as in specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage specified in the leakage test and measurement procedure specified in Subclause E.7.2.1.
- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in E.7.2.1.
- 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure specified in Subclause E.7.2.1. Hydrogen leakage shall meet the criteria for no hydrogen leakage specified in the leakage test and measurement procedure in Subclause E.7.2.1. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as described in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage as specified in the leakage test and measurement procedure in Subclause E.7.2.1.
- 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure in Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the leakage test and measurement procedure in Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria

for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.

- 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 13) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure in Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage as specified in the leakage test and measurement procedure in Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
 - 14) Connect the fuel cartridge to the micro fuel cell power system or micro fuel cell power unit and perform emission testing in accordance with E.7.3.12 following the connection cycling test.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Hydrogen gas loss shall meet the requirements of Subclause E.7.2.3. Emissions must meet passing criteria of E.7.3.12 for operational and non-operating systems.

E.7.3.11.1.2 Satellite cartridge

- a) **Test sample:** an unused satellite fuel cartridge and an unused micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve. Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproduct, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1. Initiate or simulate fuel flow.

- 2) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 3) Repeat this twice more for a total of three connections and disconnections.
- 4) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 5) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 7) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 9) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and initiate or simulate fuel flow.
- 10) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria

for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.

- 11) Repeat steps 1 through 10 four more times for a total of 55 cycles, waiting 1 h between each set of 11 cycles.
 - 12) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform emissions testing as specified in Subclause E.7.3.12 following the cycling test.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Emissions must meet passing criteria of E.7.3.12 for operational and non-operating systems.

E.7.3.11.2 Micro fuel cell power unit

- a) **Test sample:** a minimum of two unused fuel cartridges and an additional 98 fuel cartridges or suitable test fixtures with fuel cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the fuel cartridge valve geometry and material and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage both at initial use and after suitable ageing of the micro fuel cell power unit connection.

First fuel cartridge (#1) and final fuel cartridge (#100) are inspected; the other 980 cycles are only to age the micro fuel cell power unit.

In the case of a micro fuel cell power unit using satellite cartridge, it shall be tested according to the following procedure by simulating fuel flow between the satellite cartridge and the micro fuel cell power unit.

c) **Test procedure:**

- 1) Connect the first fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and the fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.

- 4) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 7) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 9) Connect and disconnect the first fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 11) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system the internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test

and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.

- 12) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 13) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 14) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 15) In order to age the micro fuel cell power unit fuel cartridge connection, perform the following steps.
 - i) Using either fuel cartridges or a suitable test fixture with fuel cartridge valves, cycle the micro fuel cell power unit fuel cartridge connection for a total of 980 connections and disconnections.
 - ii) Simulate fuel flow after each set of 50 connection-disconnection cycles.
 - iii) Inversion of the micro fuel cell power unit or the fuel cartridges is not necessary, but, if leakage is found, the test fails.
 - iv) Following this ageing, a final unused fuel cartridge will be tested.
- 16) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and the fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 17) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 18) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 19) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 20) Repeat this twice more for a total of three connections and disconnections.

- 21) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 22) Connect and disconnect the final fuel cartridge four more times for a total of seven connections and disconnections.
- 23) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 24) Connect and disconnect the final fuel cartridge three more times for a total of ten connections and disconnections.
- 25) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 26) Connect the fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.
- 27) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 28) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 29) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge and fuel management system internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause E.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage

test and measurement procedure in Subclause E.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause E.7.2.1.

- 30) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform emissions testing as specified in Subclause E.7.3.12 following the cycling test.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator as specified in the leakage measurement and test procedure in Subclause E.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 for the fuel cartridge. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator specified in the leakage measurement and test procedure in Subclause E.7.2.1 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause E.7.2.2 after the fuel cartridge is installed in a micro fuel cell power system or unit and operated. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Emissions must meet passing criteria of E.7.3.12 for operational and non-operating systems.

E.7.3.12 Emission test

This Subclause E.7.3.12 shall replace Subclause 7.3.12 for Class 8 (corrosive) borohydride micro fuel cell power systems or units tested in accordance with Annex E. The included Table E.7, Emission limits, replaces Table 7 in Subclause 7.3.12. Figure E.10 replaces Figure 10 and is identical to Figure 10. Hydrogen emissions are evaluated separately. The procedure for hydrogen emission testing is detailed in Figure E.12, which is to be used as an additional figure when testing is done in accordance with Annex E.

- a) **Test sample:** A micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under normal operating conditions, indirect borohydride powered micro fuel cell power system may have emissions. The emissions may be comprised of water or hydrogen, both of which are known not to be toxic. Indirect borohydride micro fuel cell power systems do not normally emit CO, CO₂, formaldehyde or other volatile organic compounds. However, there is a remote possibility that indirect borohydride micro fuel cell power systems utilizing fuels or liquid fuel components containing organic additives may emit CO, CO₂, formaldehyde or other volatile organic compounds under abnormal circumstances. Because this possibility exists, emission limits for CO, CO₂, formaldehyde and volatile organic compounds for micro fuel cell power systems utilizing fuels or liquid fuel components containing organic compounds are imposed by this annex and are listed in Table E.7.

The possibility for hydrogen emissions exists for non-operating indirect borohydride micro fuel cell power systems. Hydrogen emissions testing shall therefore be performed with the micro fuel cell power system off ("DEVICE – OFF") as an additional test. Hydrogen emissions shall be below the allowable 0,0032 g/h with the "DEVICE – OFF" limit given to avoid harmful exposures.

Micro fuel cell power systems emit water vapour and under certain conditions this water vapour can condense. This condensation is not considered an emission or a leak if the pH of the condensate is between 3,5 pH and 10,5 pH.

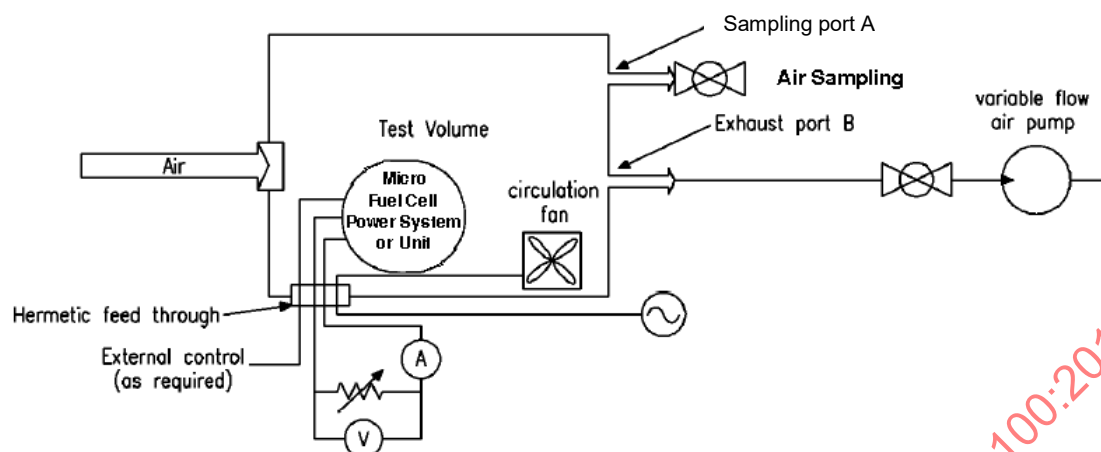


Figure E.10 – Operational emission rate testing apparatus – Replaces Figure 10

- c) **Test apparatus:** An example of the operational emission test apparatus is shown in Figure E.10. The configuration shown in Figure E.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex E. Emission rate testing in accordance with E.7.3.12 d) 1) is required for all types of micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex E.

To analyse the hydrogen emissions, a mass spectrometer, gas chromatograph, or other suitable instrument calibrated to measure hydrogen concentration shall be used and connected to sampling port A in Figure E.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

For micro fuel cell power systems or units that are intended to be used in close proximity to a consumer's mouth or nose (such as micro fuel cell power systems or units used to power cell phones, handheld games, etc.), additional testing in accordance with E.7.3.12 d) 3) and E.7.3.12 d) 4) is required to verify that emission concentrations in the vicinity of a user's mouth or nose are kept within appropriate limits. This emission concentration testing shall be done in a large open room using a different emission concentration testing apparatus. An example of the operational emission concentration testing apparatus is shown in Figure E.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell power system or unit to a consumer's mouth or nose when in use) for emissions concentration limit testing.

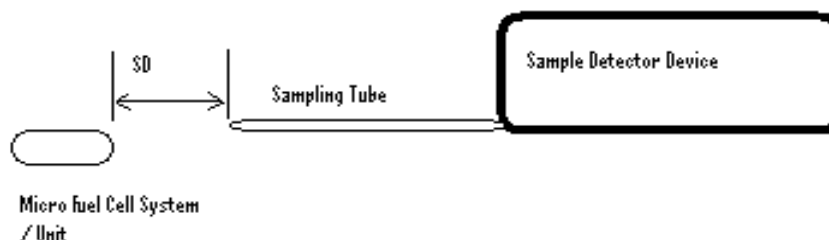


Figure E.11 – Operational emission concentration testing apparatus – Replaces Figure 11

Emission gases might be composed of toxic organic materials such as carbon dioxide, carbon monoxide and formaldehyde, which are potentially exhausted from a micro fuel cell power system or a micro fuel cell power unit.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) shall be used by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyzer through sampling port A in Figure E.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

A hydrogen detector calibrated for the zero-to-one-percent mass concentration hydrogen range can be used to measure the hydrogen concentration.

The concentration of CO and CO₂ gas can be measured by a non-dispersive infrared absorption analyzer. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) **Test procedure:**

Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure E.12, which is to be used as an additional figure when testing is done in accordance with Annex E.*

Emission rate sampling tests shall be performed with the micro fuel cell power system or unit on ("DEVICE – ON") follows.

- 1) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed with the micro fuel cell power system or unit on ("DEVICE – ON") as follows.
 - i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure E.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure E.10.
 - iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure E.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
 - vi) Record the concentrations of chemical compounds of interest. See Table E.7.
 - vii) Calculate the emission rate of chemical compounds being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:

$$ER = (F_P + F_S) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in litres per hour;

F_S is the sample flow rate in litres per hour;

C is the concentration in grams per litre.

- viii) Compare the maximum measured "DEVICE – ON" emission rate to Table E.7. If the emission rate is not less than the emission rate limit in Table E.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria E.7.3.12 e) 1) i) and E.7.3.12 e) 2) i).
 - ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 2) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emissions concentration sampling test shall be performed with the micro fuel cell power system or unit on "DEVICE – ON" as follows.
- i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling system do not contribute emissions (that is, contaminants) to the test. Prior to testing, a system check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results. Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - ii) Operate the micro fuel cell power system or micro fuel cell power unit at rated power in the large open room while sampling the emission concentrations using the operational emission concentration testing apparatus shown in Figure E.11. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission concentration test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "ON" position ("DEVICE – ON").
 - iii) Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - iv) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the operational emission concentration testing apparatus shown in Figure E.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - v) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - vi) Allow the sample flow rate to stabilise.
 - vii) Sample and record the fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - viii) Record the concentrations of the chemical compounds of interest. See Table E.7.
 - ix) Compare the maximum measured concentrations to Table E.7. If the emission concentrations are not less than the emission concentration limits in Table E.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria E.7.3.12 e) 2) ii).

- x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 3) Upon completion of the emissions measurements with both "DEVICE – ON" in accordance with Table E.7, "DEVICE – ON" hydrogen emissions are evaluated as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure E.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber at air sampling port A shown in Figure E.10.
 - iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure E.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
 - vi) Record the hydrogen concentration.
 - vii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:

$$ER = (F_P + F_S) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in litres per hour;

F_S is the sample flow rate in litres per hour;

C is the concentration in grams per litre.

- viii) Compare the maximum measured "DEVICE – ON" hydrogen emission rate to Table E.7.

NOTE This is a stabilised concentration measurement.

- ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

- 4) Upon completion of the hydrogen emissions measurements with "DEVICE – ON", hydrogen emissions with ("DEVICE – OFF") are evaluated as follows.
- Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure E.10 for 10 min or until 10 % of the fuel capacity of a full fuel cartridge is used up, whichever is less.
 - Turn the micro fuel cell power system or unit off ("DEVICE – OFF") and measure the emission rates with the micro fuel cell power system or unit off ("DEVICE – OFF") inside the small test chamber shown in Figure E.10.
 - The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown on Figure E.10.
 - Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure E.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
 - Record the hydrogen concentration.
 - Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:
- $$ER = (F_P + F_S) \times C$$
- where
- ER is the emission rate in grams per hour;
- F_P is the variable flow air pump flow rate in litres per hour;
- F_S is the sample flow rate in litres per hour;
- C is the concentration in grams per litre.
- Compare the maximum measured "DEVICE – OFF" hydrogen emission rate to Table E.7.
- NOTE This is a stabilised concentration measurement.
- Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 5) Evaluate the hydrogen emission rate as follows.
- If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and below the allowable 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or unit passes the test and no further testing is necessary.
 - If the hydrogen emission rate measurement is not below the allowable 0,0032 g/h with the "DEVICE – OFF" and not below the total allowable 0,8 g/h with the "DEVICE – ON", the system or unit fails the test and no further testing is necessary.

- iii) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and is below the total allowable 0,8 g/h with the "DEVICE – ON" but is not below 0,016 g/h with the "DEVICE – ON", then proceed with E.7.3.13, hydrogen point source gas loss detection test to verify that no single source of hydrogen exceeds 0,016 g/h.

e) **Passing criteria:**

- 1) For micro fuel cell power systems and micro fuel cell power units not intended to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table E.7 shall be less than the emission rate limit value in Table E.7 when tested in accordance with E.7.3.12 d) 1) for "DEVICE – ON" and E.7.3.12 d) 2) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 2) For micro fuel cell power systems and micro fuel cell power units to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table E.7 shall be less than the emission rate limit value in Table E.7 when tested in accordance with E.7.3.12 d) 1) for "DEVICE – ON" and E.7.3.12 d) 2) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
 - ii) For micro fuel cell power systems and micro fuel cell power units intended to be used in close proximity to a consumer's mouth or nose; in addition to meeting the emission rate limit above, the maximum emission concentration for each of the constituents of interest shall not exceed the emission concentration limit in Table E.7 when tested in accordance with E.7.3.12 d) 3) "DEVICE – ON" and E.7.3.12 d) 4) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 3) Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure E.12, which is to be used as an additional figure when testing is done in accordance with Annex E.* Upon completion of the hydrogen emissions measurements with both "DEVICE – ON" and "DEVICE – OFF" in accordance with Table E.7, hydrogen emissions are evaluated as follows.
 - i) **Passing criteria for non-operating systems:** The hydrogen emission rate shall be less than 0,0032 g/h with the "DEVICE – OFF".
 - ii) **Passing criteria for operational systems:** If the total hydrogen emission rate is less than 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or micro fuel cell power unit passes the emission test and no further testing is required. If the total hydrogen emission rate is not less than 0,8 g/h with the "DEVICE – ON", the micro fuel cell power system or unit fails the emission test and no further testing is required. If the Hydrogen emission rate is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON", E.7.3.13, hydrogen point source gas loss detection test must be performed with acceptable results to show no more than 0,016 g/h hydrogen leakage from any single point leak.

NOTE 1 The allowable flammable hydrogen emission level that will not support a standing flame is 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). The non-flammable hydrogen emissions limit is based on the criteria that hydrogen emission does not build up to more than 25 % of LFL in the reference volume.

NOTE 2 Hydrogen is defined as a simple asphyxiant but for this risk to exist, oxygen levels have to fall less than 18 % at normal atmospheric pressure. Hydrogen related flammability risk arises at hydrogen-in-air concentrations greater than 4 %, while the asphyxiant risk arises at hydrogen-in-air concentrations greater than 12 %. Therefore, the flammability limits are used in defining the limits for hydrogen emissions.

NOTE 3 Carbon dioxide and carbon monoxide vapour emission level limits are based on toxicity effects on humans while the hydrogen emissions level limit is based on the risk of creating a flammable atmosphere in confined spaces and the risk of a potential standing hydrogen flame.

Table E.7 – Emission limits – Replaces Table 7

Emissions	"DEVICE – ON" Concentration limit ^a based on TWA values for "DEVICE – ON" test condition	"DEVICE – ON" Permissible emissions rate in 10 m³ ACH volume ^b
Water	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5
Hydrogen	0,8 g/m ³	0,8 g/h total 0,016 g/h from single point leak
Formaldehyde^d	0,000 1 g/m ³	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Volatile organic carbon compounds^e	0,000 1 g/m ³	0,000 6 g/h

Table E.7 replaces Table 7.

^a The concentration limits for CO and CO₂ in this table are the mg/m³ equivalent of the TWA and STEL exposure limits.

^b The "DEVICE – ON" emission rate limit was based on 10 m³ ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is over 20 m³, so a product of 10 is conservative.

^c A seated human adult has a CO₂ emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO₂ concentration does not reach the WHO eight-hour concentration limit of 9 g/m³. In an environment with 10 m³ ACH, this limits the contribution from the fuel cell to 60 g/h.

^d WHO guideline limit is 0,000 1 g/m³. Background levels are 0,000 03 g/m³. The emission limit cannot push the background level above the guideline limit.

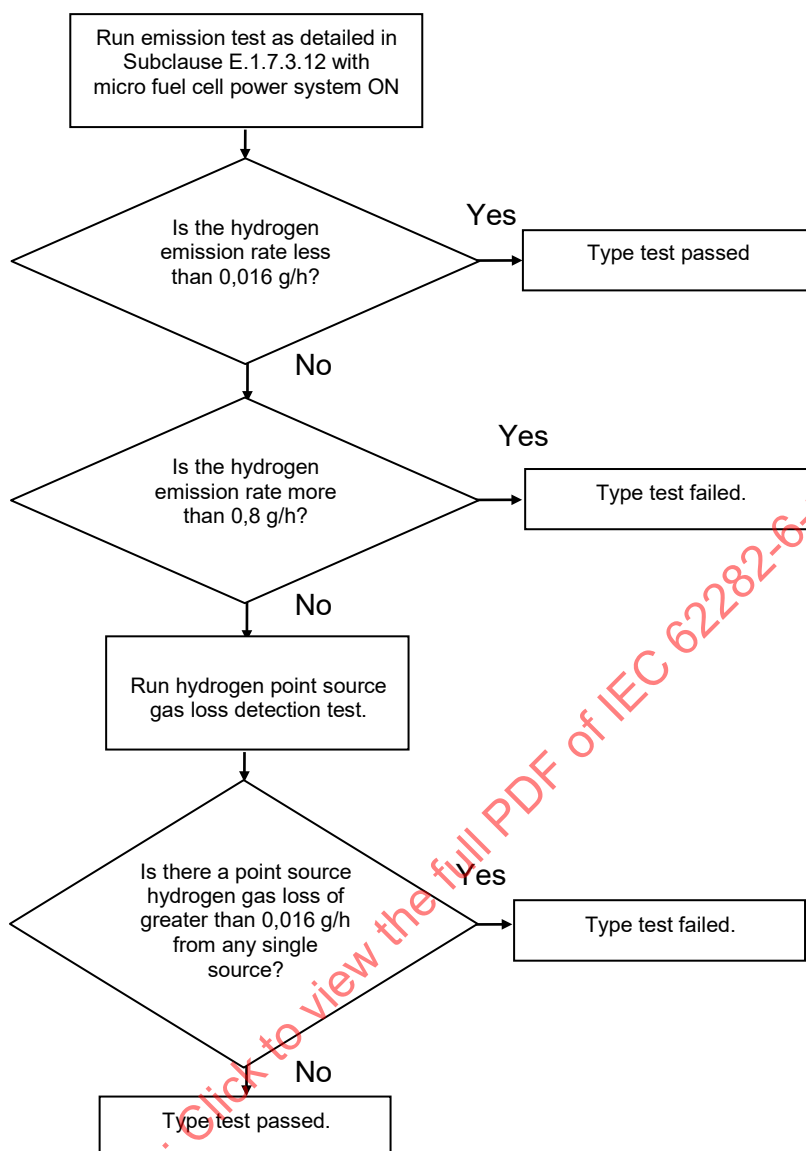


Figure E.12 – Hydrogen emission test procedure for operating micro fuel cell power system – Replaces Figure 12

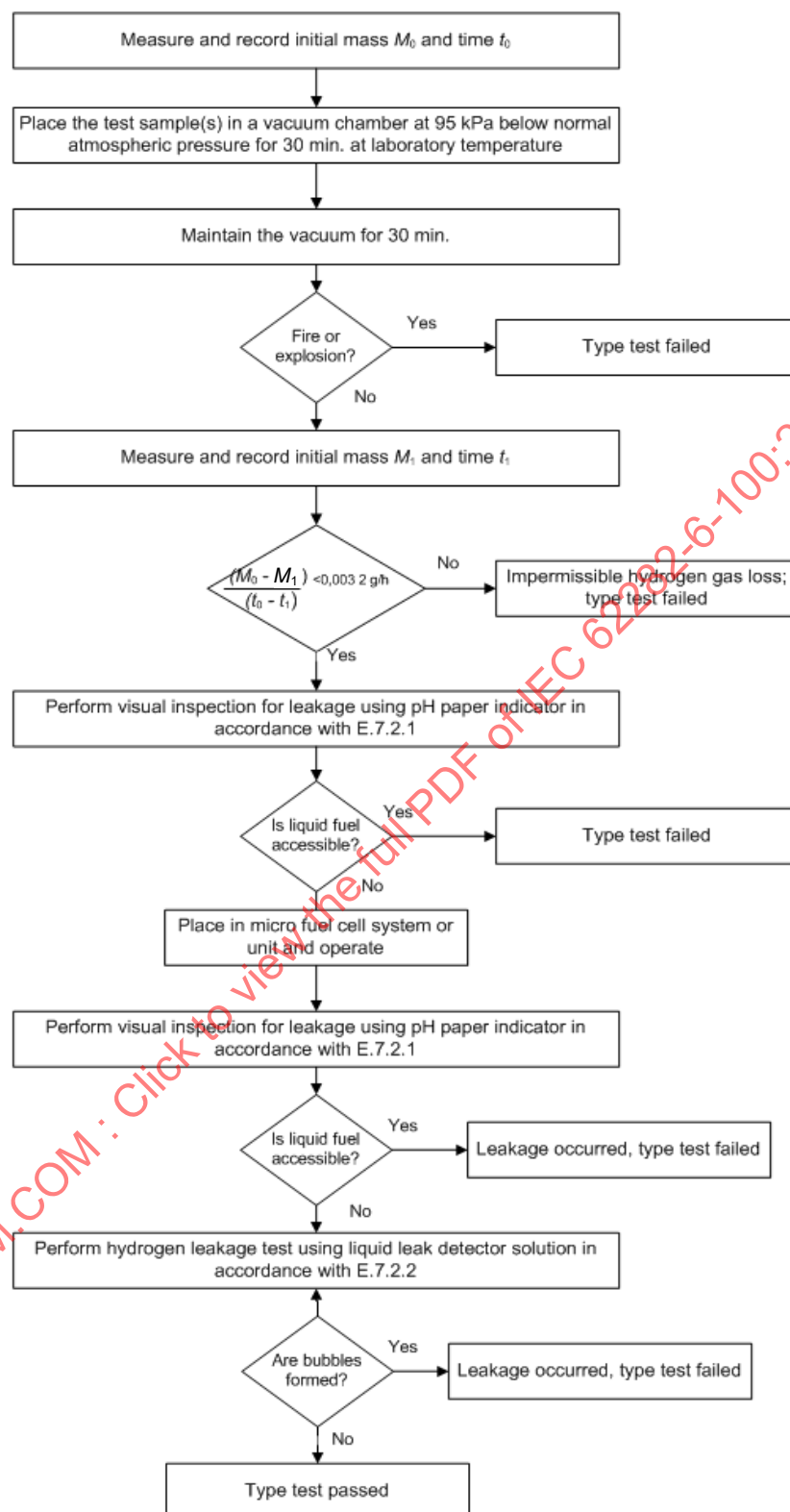


Figure E.16 – Fuel cartridge leakage test flow chart for external pressure test

E.7.3.13 Hydrogen point source gas loss detection test

The procedure for hydrogen emission testing is detailed in Figure E.12, which is to be used as an additional figure when testing is done in accordance with Annex E. This subclause is additional to the requirements in Clause 7.

This subclause shall be used if required by Subclause E.7.3.12 d) 5) iii) to show compliance with Table F.7, for Class 8 (corrosive) borohydride micro fuel cell power systems and Class 4.3 (water reactive) borohydride micro fuel cell power units. This subclause is required to be performed to meet the passing criteria of Subclause E.7.3.12 e) 3) ii) if the total hydrogen emission rate from an operational Class 8 (corrosive) borohydride micro fuel cell power system or unit is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON".

- a) **Test sample:** A micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or a micro fuel cell power unit within the scope of this Annex A, emission of hydrogen shall be maintained at less than the specified values in Table E.7. The hydrogen point source gas loss detection test shall be performed to determine that no single source on the micro fuel cell power system or unit can support a flame in all cases where such compliance cannot be definitively determined by the emission test. Maintaining these limits ensures that, in addition to not permitting a flammable concentration to build up in the reference volume, there is no gas loss of hydrogen from the specimen that could support a flame and ensures an adequate supply of oxygen is maintained in the operating environment
- c) **Test apparatus:** The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, a hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL. The response of the aforementioned hydrogen detectors is commonly slow, with a response time of many seconds, thus high sweep speeds may cause underestimation of the hydrogen concentration. It is important that the sweep speed shall be slow enough to accurately measure the hydrogen concentration.
- d) **Test procedure:**
 - 1) The micro fuel cell power system or micro fuel cell power unit shall remain turned on ("DEVICE – ON") throughout the duration of the hydrogen point source gas loss detection test.
 - 2) The testing shall be conducted in a space with no substantial air movement. The measured wind speed 10 cm above the micro fuel cell power system or unit shall not exceed 0,02 m/s. The local concentration of hydrogen diffusion measured in this test is very susceptible to the effect of wind. It is desirable that wind speed anywhere in the test space is as close to zero as possible. Testing in a closed space, such as a glove box or equivalent chamber, is one available method to achieve this requirement.
 - 3) The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL.
 - 4) The sensor of the hydrogen detector shall sweep the micro fuel cell power system or unit at a distance no more than 3 mm normal to the surface of the micro fuel cell power system or unit. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the micro fuel cell power system or unit. The entire surface of the micro fuel cell power system or unit shall be swept in this manner.

- 5) An effective method for completing these sweeps would be to attach a stand off to the sensor that ensures that a spacing of 3 mm from the micro fuel cell power system or unit is maintained at all times. A pen or other marking utensil attached to the stand off could be used to identify swept areas and ensure that the distance between sweeps does not exceed 8 mm.
 - 6) The sensor should always face directly downward, and the micro fuel cell power system or unit should be moved beneath it such that the surface directly below the sensor is always horizontal.
 - 7) If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the micro fuel cell power system or unit shall be considered to have passed.
 - 8) When some point source sweeps show a large region of 25 % LFL or greater in the initial linear sweeps, recording the measured concentration values will assist in determining the starting point of secondary spiral sweeps. Point sources are supposed to be where local maximum values exist in the distribution of measured concentration values.
 - 9) If any points are detected to have a hydrogen concentration of 25 % LFL or greater, a second test shall be conducted to ensure that the emission does not exceed 0,016 g/h of pure hydrogen from any single source.
 - 10) The second test shall be performed with the sensor height adjusted to 6,5 mm above the micro fuel cell power system or unit.
 - 11) A spiral sweep shall then be made, originating from the point where the detection of 25 % LFL or greater of hydrogen occurred during the initial linear sweep. The spiral sweep shall have a spacing of 1 mm or less between sweeps, and shall spiral out to a radial distance of at least 4 mm and far enough to detect the maximum hydrogen level from the particular hydrogen source.
 - 12) If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the micro fuel cell power system or unit passes the test.
- e) **Passing criteria:** No gas loss of hydrogen from any single source at greater than 0,016 g/h as indicated by sweep testing. No indications of hydrogen that is 25 % of LFL during the primary sweep testing or no indications of hydrogen that is 25 % of LFL during the secondary sweep testing at 6,5 mm above the micro fuel cell power system or unit. If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. See Table E.7.

Annex F

(normative)

Borohydride micro fuel cell power systems: Class 4.3 (water reactive) compounds in indirect borohydride fuel cells

F.1 Scope

F.1.2 Fuels and technologies covered by this annex

Annex F covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges using hydrogen produced from Class 4.3 (water reactive) borohydride compounds as fuel. These systems and units use proton exchange membrane fuel cell technologies. The designs may include fuel processing subsystems to derive hydrogen gas from the borohydride compound fuel.

Figure F.1 replaces Figure 1 and Figure F.12 is an additional figure for this annex showing micro fuel cell power system block diagrams for use with this annex.

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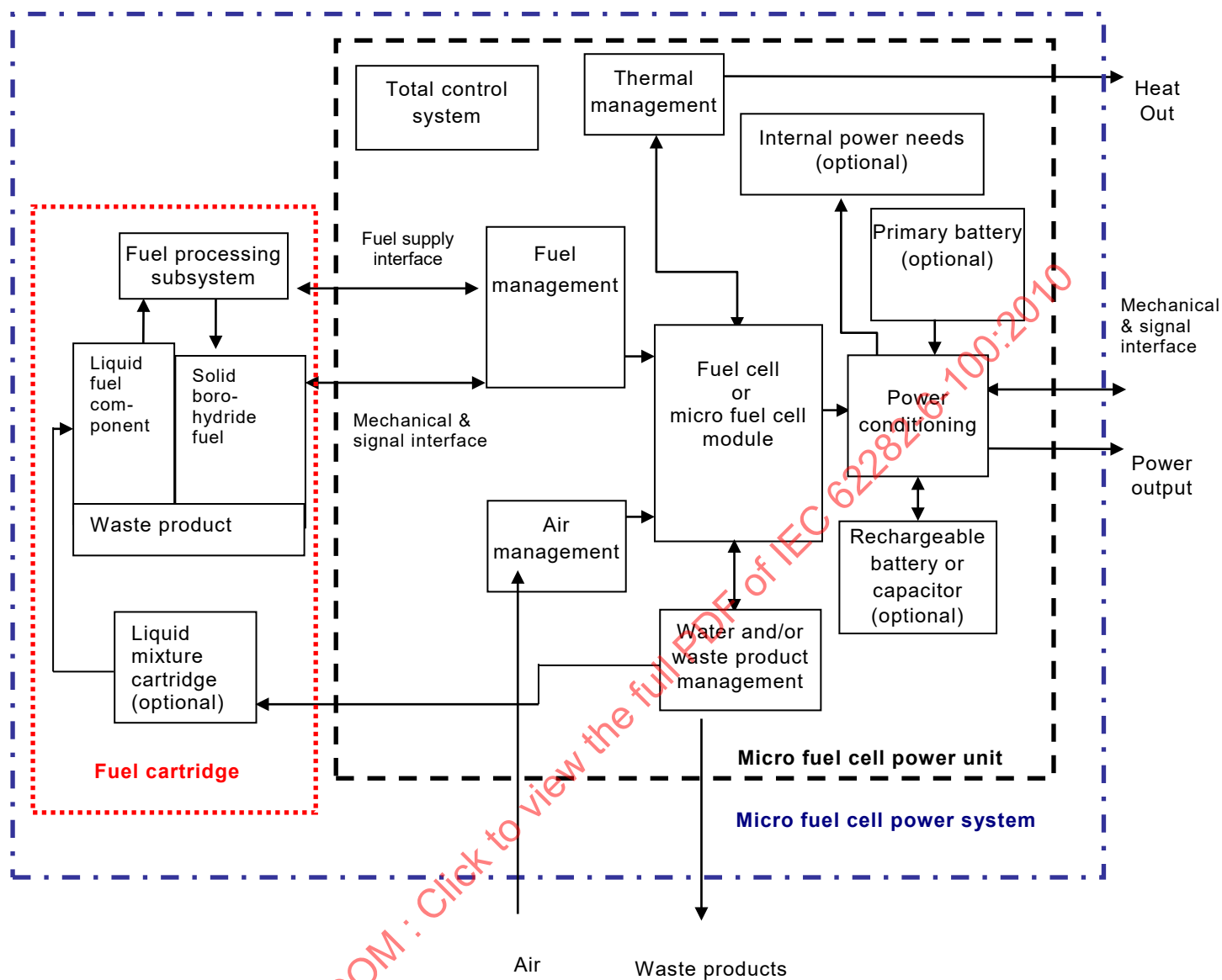


Figure F.1 – Borohydride micro fuel cell power system block diagram for Class 4.3 (water reactive) compound fuel in indirect borohydride fuel cell system; fuel management in micro fuel cell power unit – Replaces Figure 1

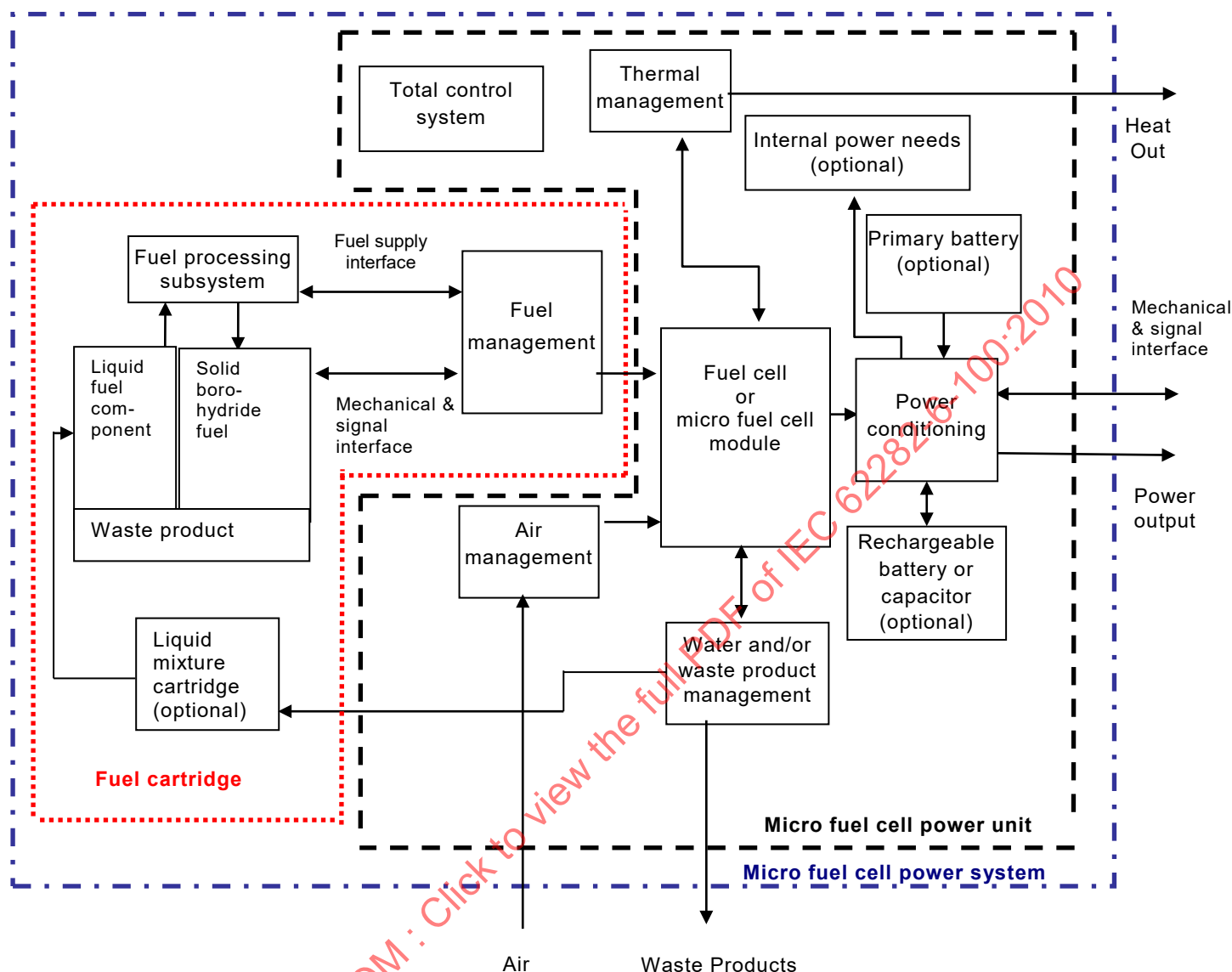


Figure F.12 – Borohydride micro fuel cell power system block diagram for Class 4.3 (water reactive) compound fuel in indirect borohydride fuel cell system; fuel management in fuel cartridge

F.2 Normative references

In addition to the normative references specified in Clause 2, 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 16111:2008, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

F.3 Terms and definitions

The terms and definitions below replace those corresponding terms and definitions in Clause 3 for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex F. All terms and definitions in Clause 3 not specifically mentioned here also apply.

F.3.5

fuel

Class 4.3 (water reactive) formulation of borohydride compounds used to produce electricity indirectly in a micro fuel cell power system

F.3.8

liquid fuel component

Class 8 (corrosive), or non-hazardous, water solutions containing acids or metal salts as activators, or alcohols as freezing point suppressors

NOTE The water solutions are used to produce hydrogen within the fuel processing subsystem.

F.3.11

leakage

accessible fuel, fuel byproducts, electrolyte or liquid fuel components outside the micro fuel cell power system or fuel cartridge; hydrogen leakage or impermissible hydrogen gas loss

The additional terms and their definitions below are needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex F in addition to those given in Clause F.3 and in Clause 3.

F.3.37

solid fuel, water reactive

solid formulation of borohydride compounds used as fuel for an indirect borohydride micro fuel cell power system

The formulation contains at least 70 % borohydride compound and may contain up to 30 % of a non-hazardous activator to facilitate the production of hydrogen.

F.3.38

indirect borohydride fuel cell power system

micro fuel cell power system in which a solid or liquid formulation of borohydride compounds is processed to produce hydrogen which reacts at the anode of a fuel cell to produce electricity in a micro fuel cell power system

F.3.39

borohydride compounds

sodium or potassium borohydride, or a mixture thereof

F.3.40

electrolyte

ion conducting membrane used to complete an electric circuit within a fuel cell

F.3.41

fuel byproducts

Class 8 (corrosive), or non-hazardous compounds produced after hydrogen and/or electricity is produced from fuel

F.3.42

impermissible hydrogen gas loss

hydrogen gas escaping non-operating micro fuel cell power system or micro fuel cell power unit greater than or equal 0,0032 g/h

F.3.43

accessible fuel, fuel byproducts, electrolyte or liquid fuel components

fuel, fuel byproducts, electrolyte or liquid fuel components that the consumer may come into physical contact with during normal use, reasonably foreseeable misuse, and consumer transportation; or, water reactive components within the fuel cartridge capable of releasing hydrogen if the fuel cartridge is immersed

F.3.44

fuel processing subsystem

subsystem within the micro fuel cell power unit or fuel cartridge used to produce hydrogen from formulations of borohydride compounds

F.3.45

incompatible materials

materials which are likely to cause a dangerous evolution of heat, or flammable or poisonous gas or vapours if allowed to mix in ways other than those specifically provided for by the micro fuel cell power system design

F.3.46

uncontrolled mixing

mixing of incompatible materials that occurs in ways not specifically provided for by the micro fuel cell power system design

F.3.47

Class 4.3 (water reactive)

materials which are classified as Class 4.3: Water Reactive substances under the guidelines of the 15th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

F.3.48

non-hazardous

materials which are not subject to guidelines of the 15th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

F.3.49

activator

a substance such as a metal salt or acid that facilitates the production of hydrogen from water-reactive borohydride fuel

F.3.50

used fuel cartridge

fuel cartridge that that has been put into operation such that at least 45 % of the initial fuel has been utilized and that the operation of the micro fuel cell power system has been halted for at least 1 h

F.3.51

hydrogen leakage

hydrogen gas outside fuel containment system, including fuel cartridge and fuel management components (see Subclause F.7.2.2)

F.4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges

F.4.4 Selection of materials

These requirements replace the corresponding requirements of Subclause 4.4.

These requirements of Subclause F.4.4 apply below to micro fuel cell power systems, units and fuel cartridges covered by this Annex F.

F.4.4.1 Micro fuel cell power systems and units are expected to be exposed to a number of environmental conditions over the manufacturer-defined life span of the product such as vibration, shock, varying humidity levels and corrosive environments. Materials employed in the micro fuel cell power system or unit shall be resistant to these environmental conditions. If a micro fuel cell power system or unit is to be used in service where specific environmental conditions are beyond those accounted for in the required tests of this standard, then additional testing shall be performed to verify safety under those environmental conditions.

F.4.4.2 Metallic and non-metallic materials used to construct internal or external parts of the micro fuel cell power system or unit, in particular those exposed directly or indirectly to moisture, fuel and/or byproducts in either a gas or liquid form as well as all parts and materials used to seal or interconnect the same, e.g. welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable under the normal transportation and normal usage conditions within the manufacturer-defined life span of the product and for all test conditions; in particular, they shall be designed to retain their mechanical stability under normal use;

- they shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation;
- the chemical and physical properties necessary for operational safety shall not be significantly affected within the manufacturer-defined life span of the product; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, ageing resistance, the effects of temperature variations, the effects arising when materials are put together (e.g. galvanic corrosion), and the effects of ultraviolet radiation;
- where conditions of erosion, abrasion, corrosion or other chemical attack may arise, adequate measures shall be taken to
 - minimize that effect by appropriate design, e.g. additional thickness, or by appropriate protection, e.g. use of liners, cladding materials or surface coatings, taking due account of normal use;
 - permit replacement of parts which are most affected;
 - and draw attention, in the manual referred to in Clause 6, to type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement.

F.4.4.3 Elastomeric materials such as gaskets and tubing in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperatures that they are exposed to during normal use. Compliance shall be determined by the following: ISO 188 and ISO 1817.

F.4.4.4 Polymeric materials in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperature they are exposed to during normal use. Compliance shall be determined by ISO 175.

F.4.4.5 Piping systems exposed to hydrogen shall employ materials suitable for exposure to hydrogen, as defined in Annex A of ISO 16111.

F.4.7 Materials and construction – system

F.4.7.1 *These requirements of Subclause F.4.7 apply to micro fuel cell power systems and units covered by this Annex F. These requirements replace the corresponding requirements of Subclause 4.7. The maximum quantity of liquid fuel or liquid fuel components stored in the micro fuel cell power unit shall not be more than 1 l. Solid fuel shall not be present in the micro fuel cell power unit.*

F.4.7.2 The micro fuel cell power system or unit shall be designed such that an explosion cannot occur even if fuel or hydrogen leaks from or inside the micro fuel cell power system or unit. The design criteria for such means (for example, required ventilation rate) shall be provided by the micro fuel cell power system or unit manufacturer. The means shall be provided either by the micro fuel cell power system or unit manufacturer or by the manufacturer of the device powered by the micro fuel cell power system or unit.

F.4.7.3 Components and materials inside the micro fuel cell power system or unit shall be constructed or shall make use of such materials that propagation of fire and ignition is mitigated. The material flammability shall be such that a sustained fire will not be supported after electrical power and the fuel and oxidant supply have been terminated. This may be demonstrated through the selection of materials meeting FV 0, FV 1 or FV 2 in accordance with IEC 60695-1-1 and IEC 60695-11-10.

F.4.7.4 Micro fuel cell stack membranes are not required to have flammability ratings.

F.4.7.5 Other materials within the micro fuel cell stack which comprise less than 30 % of the total micro fuel cell stack mass are considered to be of limited quantity and are permissible without flammability ratings.

F.4.12 Fuel supply construction

F.4.12.1 Fuel cartridge construction

These requirements of Subclause F.4.12.1 apply to micro fuel cell power systems and units covered by this Annex F. These requirements replace the corresponding requirements of Subclause 4.12.1.

Fuel cartridges shall conform to the following requirements:

F.4.12.1.1 There shall be no leakage from the fuel cartridge in the temperature range of –40 °C to +70 °C. Compliance shall be determined by type testing in accordance with Subclause F.7.3.3 and Subclause F.7.3.4.

F.4.12.1.2 There shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Compliance shall be determined by type testing in accordance with F.7.3.1.

F.4.12.1.3 The maximum fuel charge is limited to 1 l for liquid fuel components, and 200 g for solid fuel.

F.4.12.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a micro fuel cell power unit by a consumer, means to prevent fuel or hydrogen leakage prior to, during, and after connection or transfer of fuel to the micro fuel cell power unit shall be provided. Compliance is checked by Subclause F.7.3.11.

F.4.12.1.5 A fuel cartridge shall be resistant to corrosion in its usage environment.

F.4.12.1.6 A fuel cartridge shall be provided with a means to prevent mis-connection that would result in leakage of fuel or hydrogen when it is installed in a micro fuel cell power system. Compliance is checked by the connection cycling test, Subclause F.7.3.11.

F.4.12.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel or hydrogen when not attached to a micro fuel cell power unit during normal usage, reasonably foreseeable misuse, and consumer transportation. Compliance is checked by the drop test, Subclause F.7.3.5, and the connection cycling test, subclause F.7.3.11.

F.4.12.1.8 In the case where a pressure release valve or similar means is provided, such pressure release valve shall satisfy the performance requirement for each type test. This valve shall pass all type tests with no leakage.

F.4.12.1.9 The structure at the connection to the fuel cartridge shall not allow fuel or hydrogen to leak.

F.4.12.1.10 A fuel cartridge, including the fuel cartridge interface to the micro fuel cell power unit, including the valve, shall have a construction sufficient to withstand normal use and reasonably foreseeable misuse generated by vibration, heat, pressure, being dropped or otherwise subject to a mechanical shock etc. Compliance is checked by:

- pressure differential tests, F.7.3.1;
- vibration test, F.7.3.2;
- temperature cycling test, F.7.3.3;
- high temperature exposure test, F.7.3.4;
- drop test, F.7.3.5;
- compressive loading test, F.7.3.6;
- long-term storage test, F.7.3.9;
- high-temperature connection test, F.7.3.10;
- connection cycling tests, F.7.3.11.

F.4.12.1.11 The fuel cartridge valves shall operate as intended without the use of tools and without excessive force needed to connect or disconnect.

F.4.12.1.12 In cases where materials (either solid or liquid) are present that are incompatible with either the borohydride fuel or liquid fuel component, the design of the fuel cartridge and micro fuel cell power system shall provide a means for preventing inadvertent or uncontrolled mixing of these materials.

Two independent means for preventing inadvertent or uncontrolled mixing of these materials shall be provided during transportation and storage prior to use. Illustrative examples of these means include but are not limited to: positive activation by the control system; physical removal of an impermeable barrier preventing contact; opening of a normally closed manually controlled valve preventing contact. For at least one of these means for preventing uncontrolled mixing, it shall be necessary for the user to take positive action to remove or deactivate it prior to use.

At least one means for preventing uncontrolled mixing of these materials shall be provided during use and storage after use. This means may include active control by system electronics, subject to the FMEA analysis of Subclause 4.2.

F.6 Instructions and warnings for fuel cartridges, micro fuel cell power units, and micro fuel cell power systems

F.6.2 Minimum markings required on the fuel cartridge

These markings replace the markings required by Subclause 6.2.

As a minimum, the following shall be marked on the fuel cartridge.

- a) CONTENTS ARE WATER-REACTIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) KEEP AWAY FROM CHILDREN.
- d) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- e) DO NOT EXPOSE TO ACIDS, OXIDIZERS, ALCOHOL OR HOUSEHOLD CLEANING PRODUCTS.
- f) DO NOT IMMERSE IN WATER OR OTHER LIQUIDS.
- g) FOLLOW USAGE INSTRUCTIONS.
- h) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- i) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- j) COMPOSITION AND AMOUNT OF FUEL.
- k) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.
- l) MAY CONTAIN FLAMMABLE GAS.

In the case that the contents of the fuel cartridge are corrosive, the marking required under "a" above shall be changed as follows:

- a) CONTENTS ARE WATER-REACTIVE, CORROSIVE AND TOXIC. DO NOT DISASSEMBLE.

In the case that the contents of the fuel cartridge are flammable, the marking required under "a" above shall be changed as follows:

- a) CONTENTS ARE WATER-REACTIVE, CORROSIVE, TOXIC AND FLAMMABLE. DO NOT DISASSEMBLE.

F.6.3 Minimum markings required on the micro fuel cell power system

These markings replace the markings required by Subclause 6.3.

In addition, as a minimum, the following shall also be marked on the micro fuel cell power system to show:

- a) CONTENTS ARE WATER-REACTIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.

- c) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- d) DO NOT IMMERSE IN WATER OR OTHER LIQUIDS.
- e) FOLLOW USAGE INSTRUCTIONS.
- f) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- g) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- h) COMPOSITION OF FUEL.
- i) MAXIMUM CAPACITY OF FUEL IN THE FUEL CARTRIDGE
- j) TEXT OR MARKING THAT INDICATES THAT THE MICRO FUEL CELL POWER SYSTEM COMPLIES WITH IEC 62282-6-100.
- k) MAY CONTAIN FLAMMABLE GAS.
- l) ELECTRICAL OUTPUT (VOLTAGE, CURRENT, RATED POWER).

In the case that the contents of the fuel cartridge are corrosive, the marking required under “a” above shall be changed as follows:

- a) CONTENTS ARE WATER-REACTIVE, CORROSIVE AND TOXIC. DO NOT DISASSEMBLE.

In the case that the contents of the fuel cartridge are flammable, the marking required under “a” above shall be changed as follows:

- a) CONTENTS ARE WATER-REACTIVE, CORROSIVE, TOXIC AND FLAMMABLE. DO NOT DISASSEMBLE.

F.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

F.7.1 General

This Subclause F.7.1 replaces Subclause 7.1 for this annex when testing borohydride micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use Class 4.3 (water reactive) borohydride as fuel.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table F.5 lists the type tests that must be performed. *Table F.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table F.6. *Table F.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of 22 °C ± 5 °C for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table F.5 – List of type tests – Replaces Table 5

	Test item	Test sample
F.7.3.1	Pressure differential tests	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
F.7.3.2	Vibration test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
F.7.3.3	Temperature cycling test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
F.7.3.4	High temperature exposure test	Fuel cartridge Used fuel cartridge
F.7.3.5	Drop test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
F.7.3.6	Compressive loading test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
F.7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
F.7.3.9	Long-term storage test	Fuel cartridge Used fuel cartridge
F.7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
F.7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
F.7.3.12	Emission test	Micro fuel cell power system or power unit
F.7.3.13	Hydrogen point source gas loss detection test	Micro fuel cell power system or power unit
Table F.5 replaces Table 5. Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or used, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test. Test sequence: Tests F.7.3.2 and F.7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests F.7.3.1, F.7.3.2, and F.7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or power units. Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.		

Table F.6 – Laboratory standard conditions – Replaces Table 6

Item	Condition
Laboratory temperature	Laboratory temperature is “room temperature” (standard temperature condition, 22 °C ± 5 °C)
Laboratory atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen. The laboratory atmosphere contains not more than 0,008 % hydrogen
Table F.6 replaces Table 6.	

F.7.2 Leakage, hydrogen leakage, and hydrogen gas loss, and hydrogen emission measurement and the measuring procedure

This Subclause F.7.2 replaces Subclause 7.2 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use Class 4.3 (water reactive) borohydride as fuel.

The leakage measurements shall be executed in principle in accordance with the procedures shown in Figures F.2 through F.5. These figures and their procedures, replace the corresponding figures in Subclause 7.2.

Compliance with the “no leakage”, “no hydrogen leakage” and “no impermissible hydrogen gas loss” requirement for all type tests specified in Subclause F.7.3 shall be determined by the leakage test and measurement procedure of Subclause F.7.2.1, the hydrogen leakage measurement procedure of Subclause F.7.2.2 and the hydrogen gas loss measuring procedure of Subclause F.7.2.3 in conjunction with the definition of “leakage” in Subclause F.3.11, “hydrogen leakage” in Subclause F.3.51, and the definition of “impermissible hydrogen gas loss” in Subclause F.3.42, unless otherwise specified.

F.7.2.1 Leakage test and measurement procedure

- a) For micro fuel cell power systems, micro fuel cell power units and fuel cartridges containing Class 4.3 (water reactive) borohydride fuel, the leakage measurement of fuel, fuel byproducts, electrolyte or liquid fuel components shall be done following each type test by performing visual inspection of all possible leak locations. Any drops of fuel, fuel byproducts, electrolyte or liquid fuel component and/or white crystals on the exterior of the micro fuel cell power system or unit or fuel cartridge are indications of leakage. If crystals are accessible, the micro fuel cell power system or unit or fuel cartridge fails the leakage test. As an additional tool for finding fuel, fuel byproducts, electrolyte or liquid fuel component leaks, pH paper, attached to the possible leak areas of the micro fuel cell power system, shall be used to aid in the visual check for leakage. This is an additional requirement in Annex F for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel components. Any existence of a substance with a pH lower than 3,5 or greater than 10,5 is an indication of leakage. See Figure F.2 and Figure F.3. For operational tests, reactant air passages into the micro fuel cell power system and exhaust ports should not be blocked with pH paper.
- b) For fuel cell cartridges containing solid, water reactive borohydride fuel, a water immersion test shall be performed following each type test. The entire fuel cartridge containing solid borohydride fuel is immersed in at least one meter of laboratory temperature water for 30 min. If bubbles are observed, the fuel cartridge fails the leakage test. See Figure F.2 and Figure F.3.

F.7.2.2 Hydrogen leakage measurement from fuel cartridges and/or fuel management systems and measuring procedures

- a) For fuel cartridges containing Class 4.3 (water reactive) borohydride, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector

(bubble forming) solution or other equivalent means on all possible leak locations of the fuel cartridge. See Figure F.2 and Figure F.3.

- b) If the fuel cartridge is of the type that is refillable by the manufacturer (automated or by trained technicians), it shall be filled to its rated capacity prior to testing. If the fuel cartridge is not refillable, it shall be tested in the condition in which it completed the type test in question. The fuel cartridge shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel cartridge.
- c) For micro fuel cell power systems or micro fuel cell power units with a fuel management system that contains hydrogen gas above ambient pressure, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the fuel management system. The fuel management system shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel management system.
- d) Both for fuel cartridges containing Class 4.3 (water reactive) borohydride, and for fuel management systems containing hydrogen, no hydrogen leakage is allowed. Testing for hydrogen leakage with a liquid leak detector (bubble forming) solution is acceptable only if no bubbles are found.

NOTE The "no leakage" criteria for fuel cartridges containing Class 4.3 (water reactive) borohydride has been chosen to be consistent with the 15th Edition of the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations; Special Provision 339 for UN 3479, Fuel Cell Cartridge *containing hydrogen in metal hydride*.

F.7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures

For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure F.4 as follows:

- a) Perform hydrogen emission testing in accordance with F.7.3.12 with the exception that the micro fuel cell power system or unit shall be off ("DEVICE – OFF"). Hydrogen point source testing in accordance with Subclause F.7.3.13 is not applicable. Hydrogen gas loss shall be less than 0,0032 g/h. See Table F.7.
- b) Perform hydrogen emission testing in accordance with Subclause F.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h and hydrogen leakage from any single point leak shall be less than 0,016 g/h. See Table F.7.

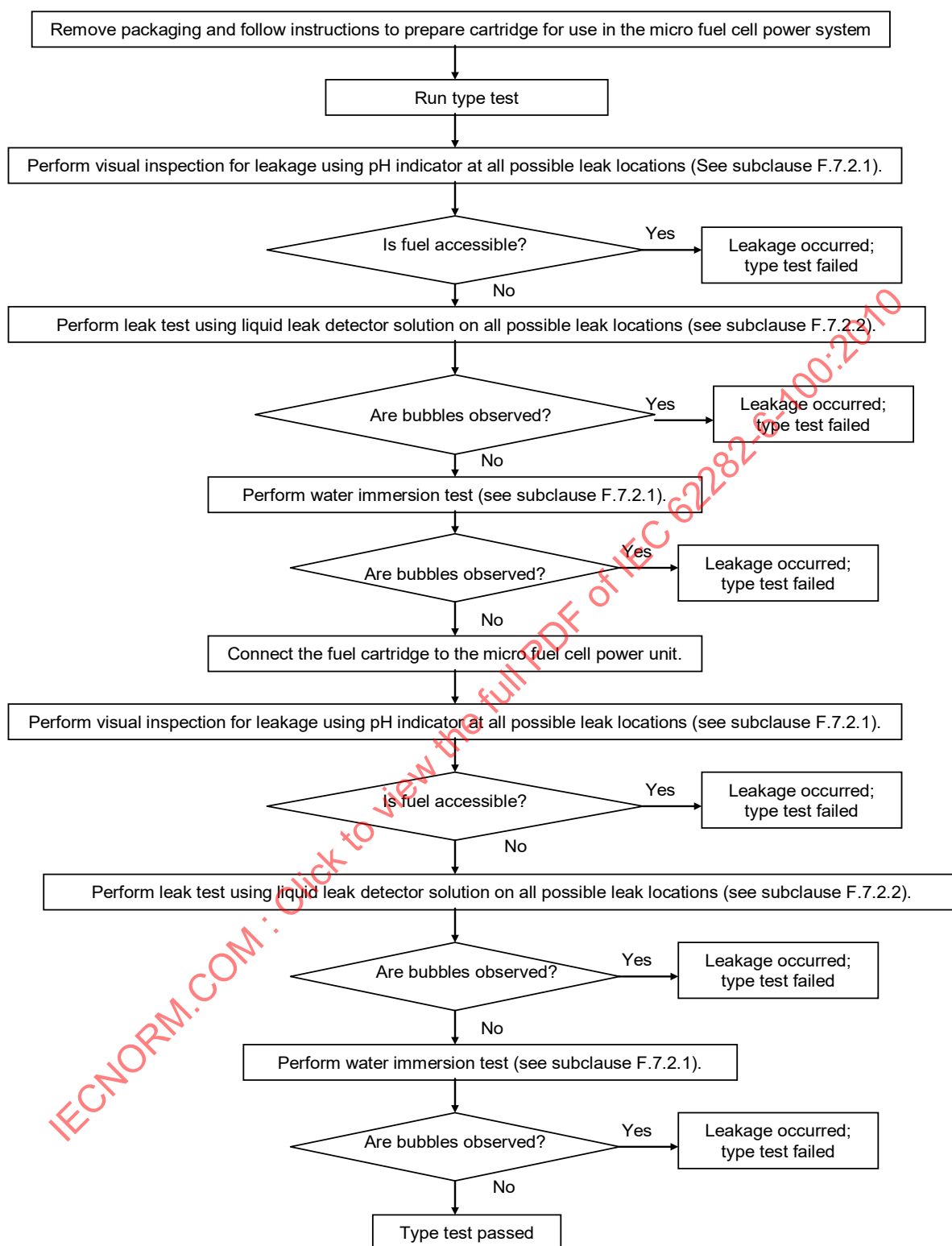


Figure F.2 – Fuel cartridge leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

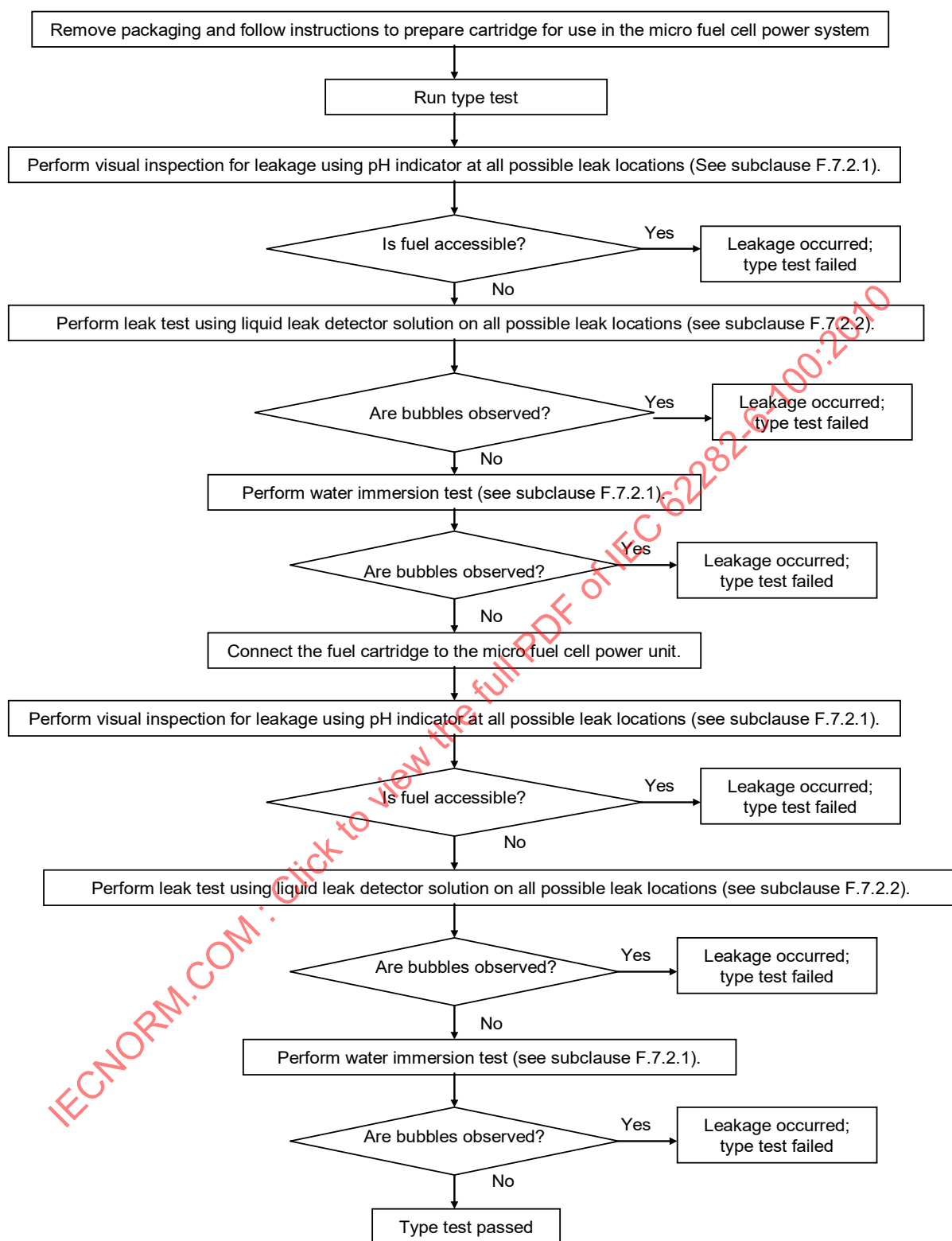


Figure F.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

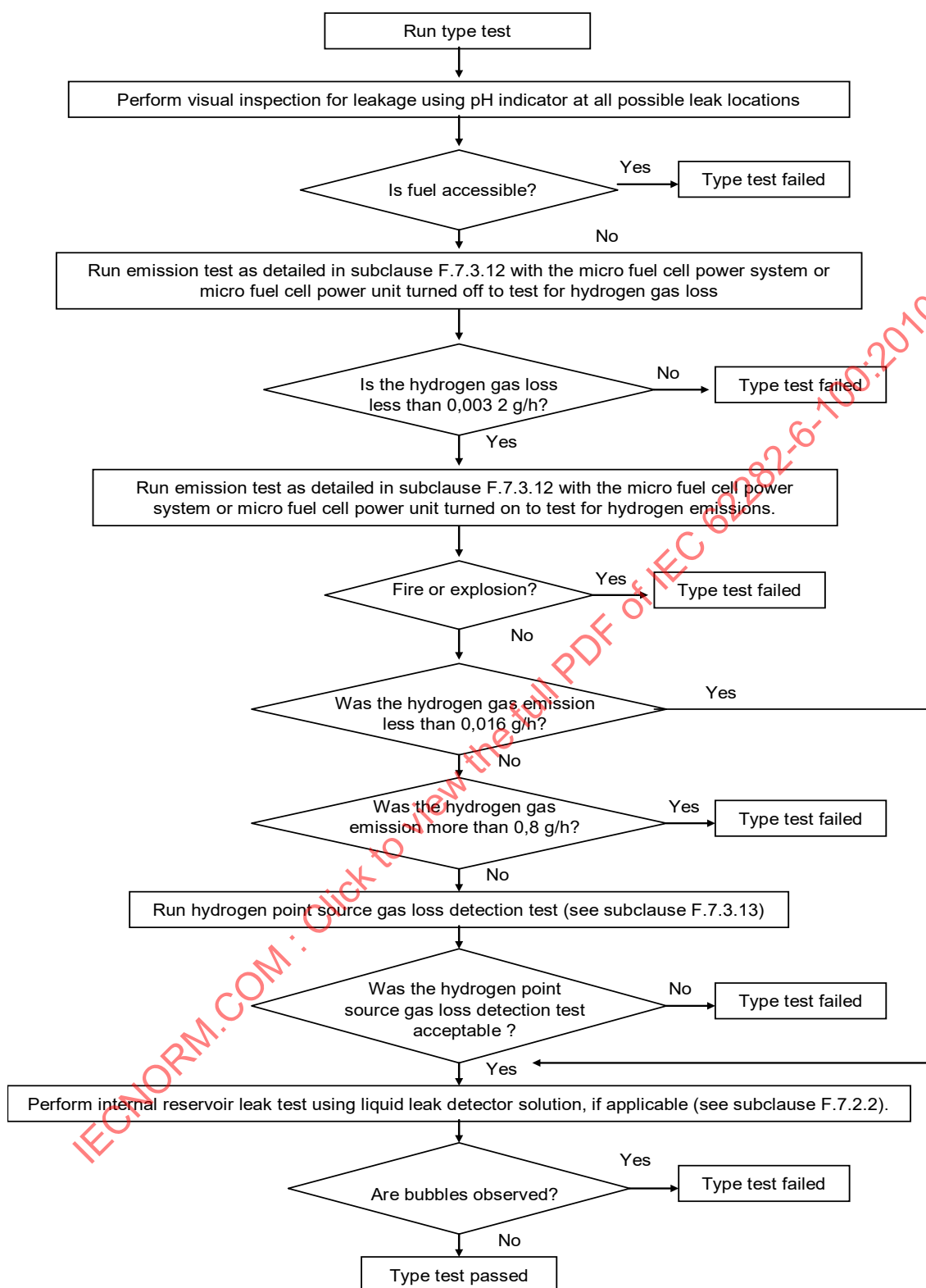


Figure F.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

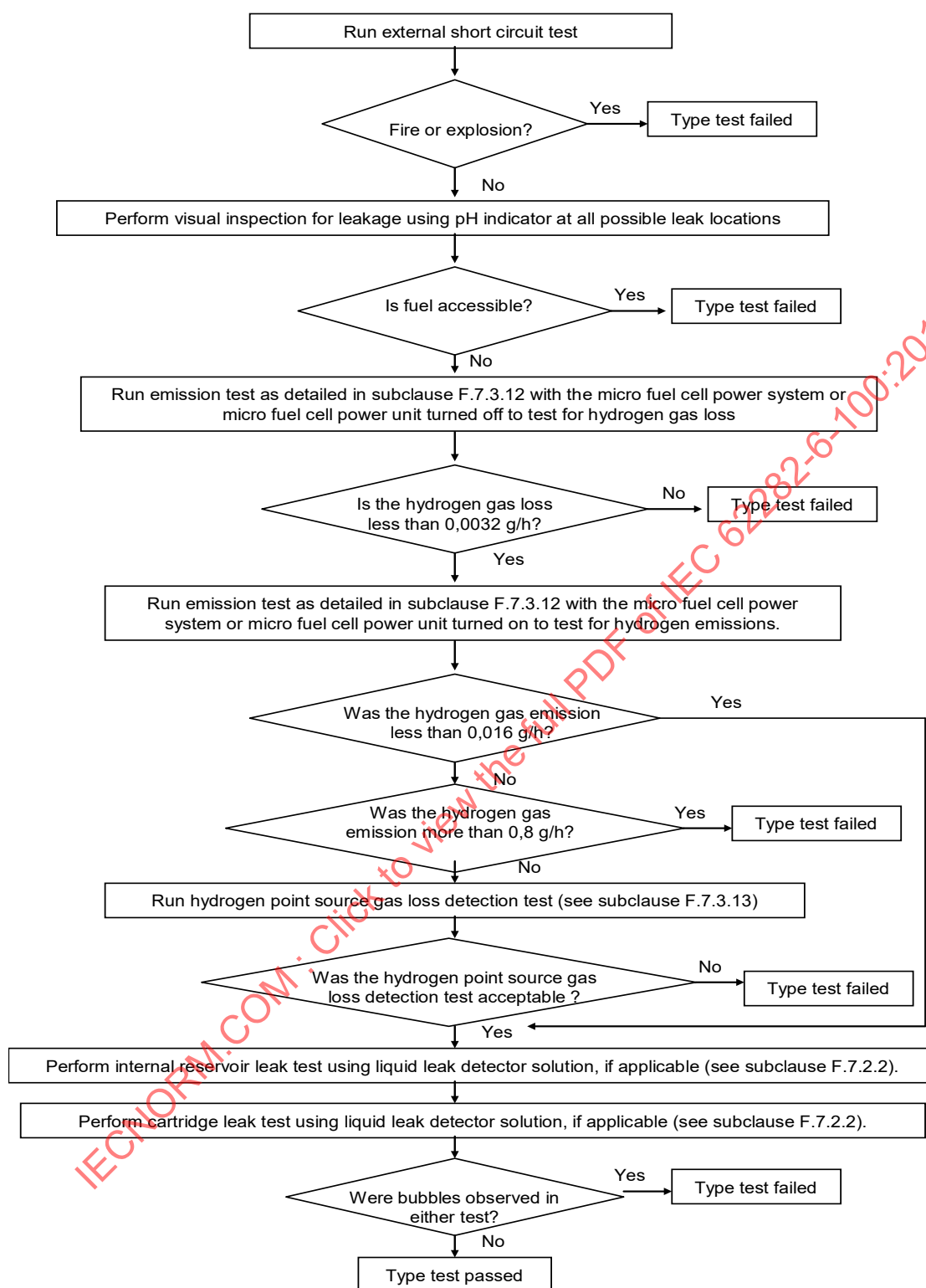


Figure F.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

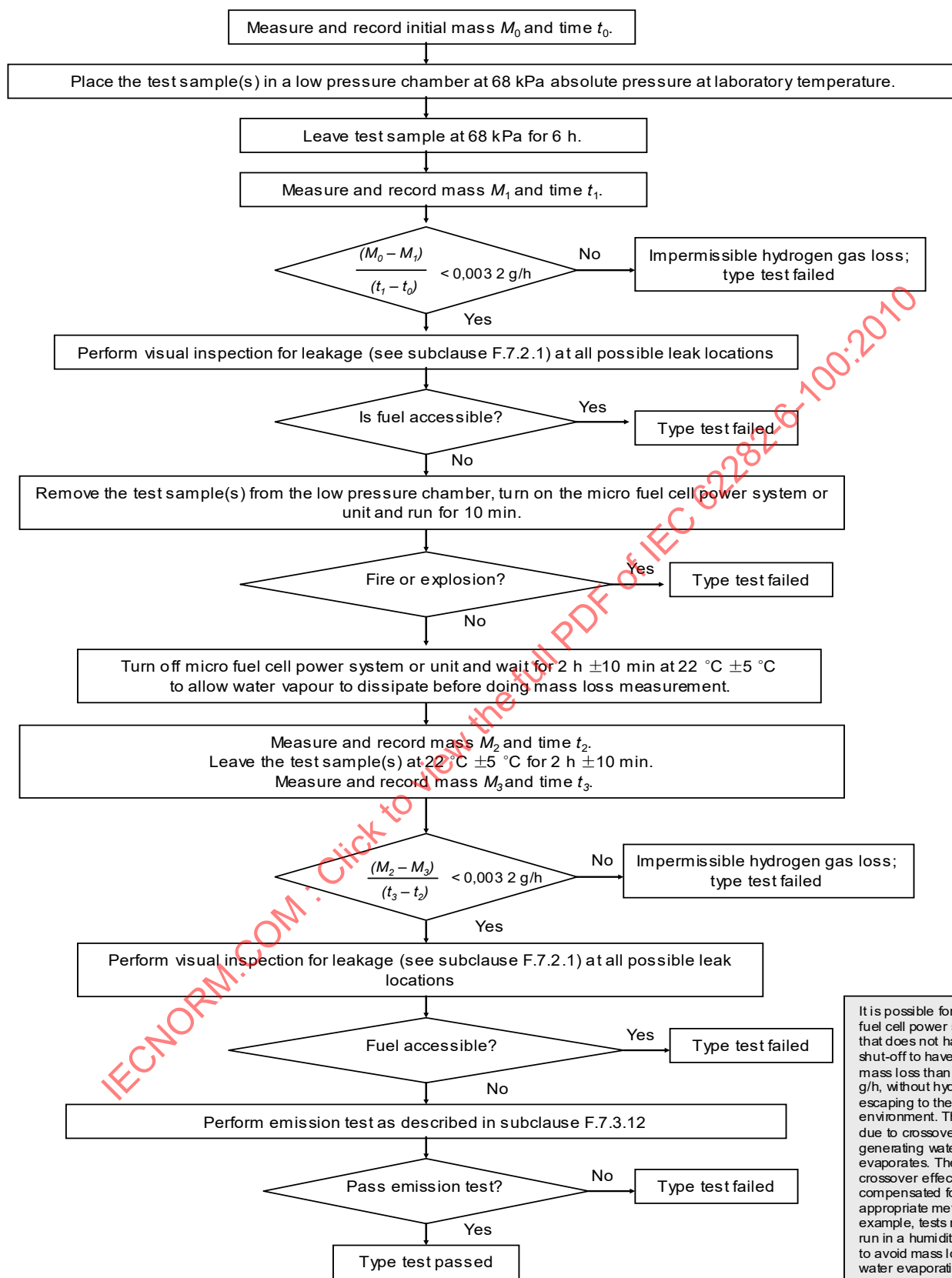


Figure F.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

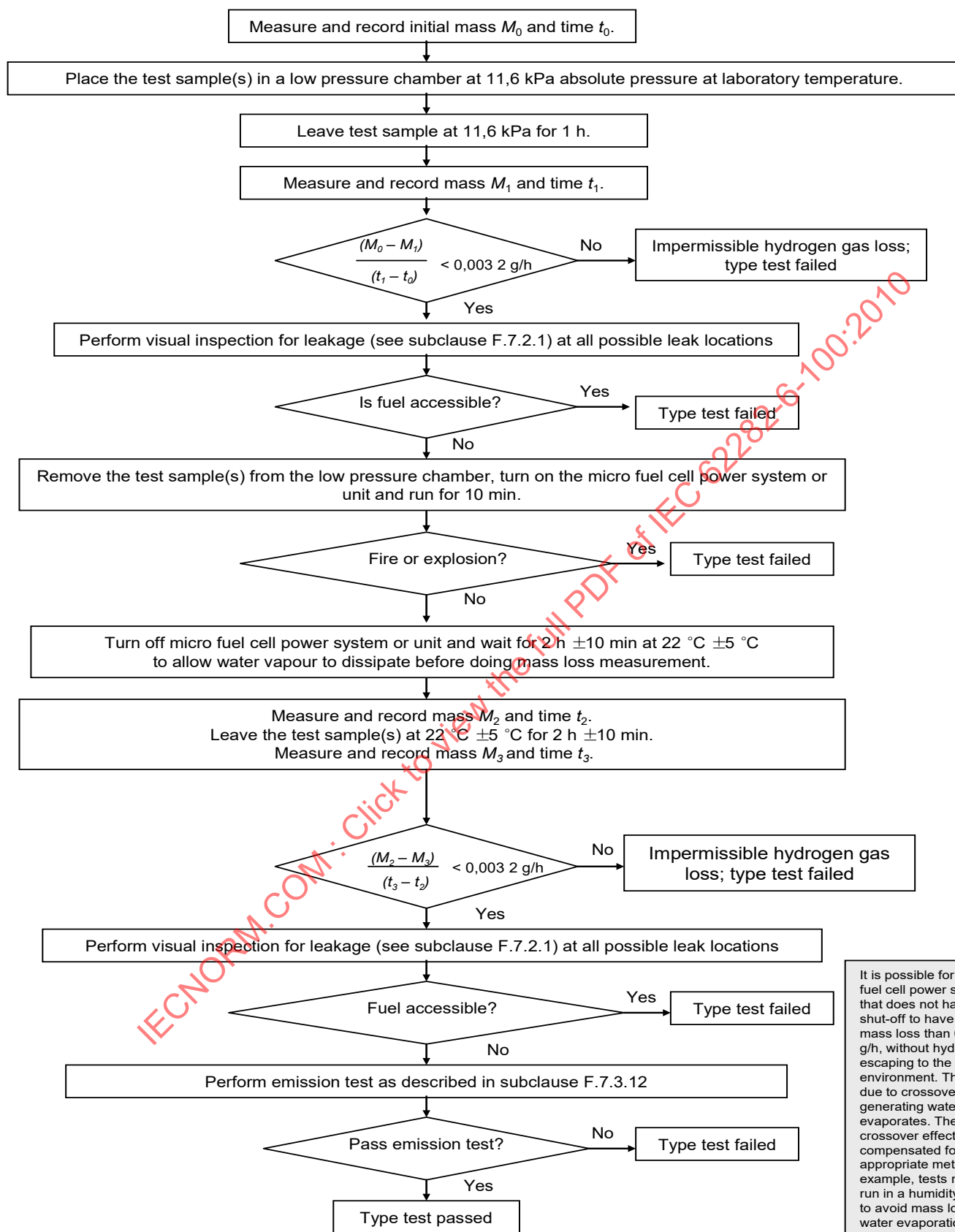


Figure F.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

F.7.3 Type tests

F.7.3.1 Pressure differential tests

F.7.3.1.1 General

Subclause F.7.3.1 replaces Subclause 7.3.1.

Portions of this test check compliance with Subclause 4.12.1.2 to verify that there shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Depending upon which of the two limiting pressure conditions is greater, two options for testing are provided.

- a) If 95 kPa internal gauge pressure plus normal working pressure of the fuel cartridge at 22 °C is greater than two times the gauge pressure of the fuel cartridge at 55 °C, either Subclause F.7.3.1.2 or subclause F.7.3.1.3 may be used to verify compliance with Subclause 4.12.1.2.
- b) If two times the gauge pressure of the fuel cartridge at 55 °C is greater than 95 kPa internal gauge pressure plus normal working pressure at 22 °C, Subclause F.7.3.1.2 must be used to verify compliance with Subclause 4.12.1.2.

F.7.3.1.2 Fuel cartridge internal pressurization test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.

- c) **Test procedure:**

For the internal pressurization test, the fuel cartridge body and the fuel cartridge valve shall be tested separately.

- 1) Using a suitable fluid medium such as mineral oil, pressurize the fuel cartridge body to an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater.
 - 2) The pressure rise shall not exceed a rate of 60 kPa/s.
 - 3) Maintain the maximum pressure for 30 min at laboratory temperature.
 - 4) Using a suitable fluid medium such as mineral oil, pressurize the closed fuel cartridge valve to 95 kPa gauge pressure plus the normal working pressure of the cartridge at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater.
 - 5) The pressure rise shall not exceed a rate of 60 kPa/s.
 - 6) Maintain the maximum pressure for 30 min at laboratory temperature.
 - 7) Perform visual check for leakage of test fluid medium.
- d) **Passing criteria:** no accessible liquid test medium leakage and no sudden drop of pressure during the course of the test. Leakage shall be checked visually. Invert the fuel cartridge and the fuel cartridge valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails.

NOTE Class 4.3 (water reactive) borohydride fuel will chemically react with water, therefore, water or water-containing substances should not be used as the fluid test medium. Class 4.3 (water reactive) borohydride fuels have the potential to react with substances other than water, therefore, the chemical reactivity and stability of the particular Class 4.3 (water reactive) borohydride fuel being tested should be used to guide the selection of a suitable liquid test medium.

F.7.3.1.3 Fuel cartridge low external pressure test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.

c) **Test procedure:**

Perform this test in accordance with Figure F.14. Figure F.14 is a new figure.

- 1) Record the initial mass of the test sample M_0 and starting time t_0 . Place the sample in a vacuum chamber and reduce the pressure in the vacuum chamber to 95 kPa below normal atmospheric pressure.
 - 2) Maintain the vacuum for 30 min.
 - 3) Remove the sample from the vacuum chamber and record the final mass M_1 and time t_1 . Determine hydrogen gas loss and check for leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel components using visual inspection with pH indicator and water immersion test as described in Subclause F.7.2.1.
 - 4) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1. See Figure F.14.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss, no hydrogen leakage and no Class 4.3 (water reactive) fuel or liquid fuel component leakage. See Figure F.14. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3 (less than 0,0032 g/h). Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator and with the water immersion test as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.1.4 Micro fuel cell power system or micro fuel cell power unit pressure differential tests

F.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

This test is required for all Class 4.3 (water reactive) borohydride micro fuel cell power systems and all Class 4.3 (water reactive) borohydride micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.

c) **Test procedure:**

- 1) Perform this test in accordance with Figure F.6.
 - 2) Test samples shall be stored at a low external pressure of 68 kPa absolute pressure for 6 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure F.6.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with Subclause F.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel components liquid leakage. See Figure F.6. Remove the fuel

cartridge, if present, from the micro fuel cell power system. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Hydrogen gas loss shall be determined by the mass loss measurement as shown in Figure F.6. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of F.7.3.12, the emission test result is acceptable.

F.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

This test is required for all Class 4.3 (water reactive) borohydride micro fuel cell power systems and all Class 4.3 (water reactive) borohydride micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure F.7.
 - 2) Test samples shall be stored at a low external pressure of 11,6 kPa absolute pressure for 1 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure F.7.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with F.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel components liquid leakage. See Figure F.7. Remove the fuel cartridge, if present, from the micro fuel cell power system. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Hydrogen gas loss shall be determined by the mass loss measurement as shown in Figure F.7. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of F.7.3.12, the emission test result is acceptable.

F.7.3.2 Vibration test

Subclause F.7.3.2 replaces Subclause 7.3.2.

- a) **Test sample:** an unused fuel cartridge, a used fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in Subclause F.7.3.1 or a micro fuel cell power system used in used in Subclause F.7.3.1.
- b) **Purpose:** to simulate the effects of normal transportation vibration and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure F.2 for the fuel cartridge and Figure F.4 for the micro fuel cell power system or unit.
 - 2) The test sample shall be firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.
 - 3) The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min.

- 4) This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions of the test samples.
- 5) The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of $1 g_n$ is maintained until 18 Hz is reached. The amplitude is then maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of $8 g_n$ occurs (approximately 50 Hz). A peak acceleration of $8 g_n$ is then maintained until the frequency is increased to 200 Hz.
- 6) For the micro fuel cell power system or unit, perform emission testing in accordance with F.7.3.12.
- 7) For the fuel cartridge, check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1.
- 8) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.3 Temperature cycling test

Subclause F.7.3.3 replaces Subclause 7.3.3.

- a) **Test sample:** a fuel cartridge used in Subclause F.7.3.2, a used fuel cartridge used in Subclause F.7.3.2, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in Subclause F.7.3.2 or a micro fuel cell power system used in Subclause F.7.3.2.
- b) **Purpose:** to simulate the effects of low-temperature and high temperature exposure and the effects of extreme temperature change.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure F.3 for the fuel cartridge and Figure F.4 for the micro fuel cell power system or unit.
 - 2) For a fuel cartridge, two fuel cartridge orientations shall be tested – valve up and valve down. For a micro fuel cell power system or a micro fuel cell power unit, only one orientation needs to be tested.
 - 3) See Figure F.8 for the temperature profile to be used.
 - 4) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from laboratory temperature to $55\text{ °C} \pm 2\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $55\text{ °C} \pm 2\text{ °C}$ for a minimum of 4 h.
 - 5) Decrease the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$ then decrease the chamber temperature to $-40\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $-40\text{ °C} \pm 5\text{ °C}$ for a minimum of 4 h.

- 6) Increase the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$.
 - 7) The above process is to be done twice.
 - 8) After 1 h at $22\text{ °C} \pm 5\text{ °C}$, leakage shall be measured based upon the procedure described in Figure F.3 (for fuel cartridge) and Figure F.4 (for micro fuel cell power system or unit).
 - 9) For the micro fuel cell power system or micro fuel cell power unit, perform emission testing in accordance with F.7.3.12.
 - 10) For the fuel cartridge, connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

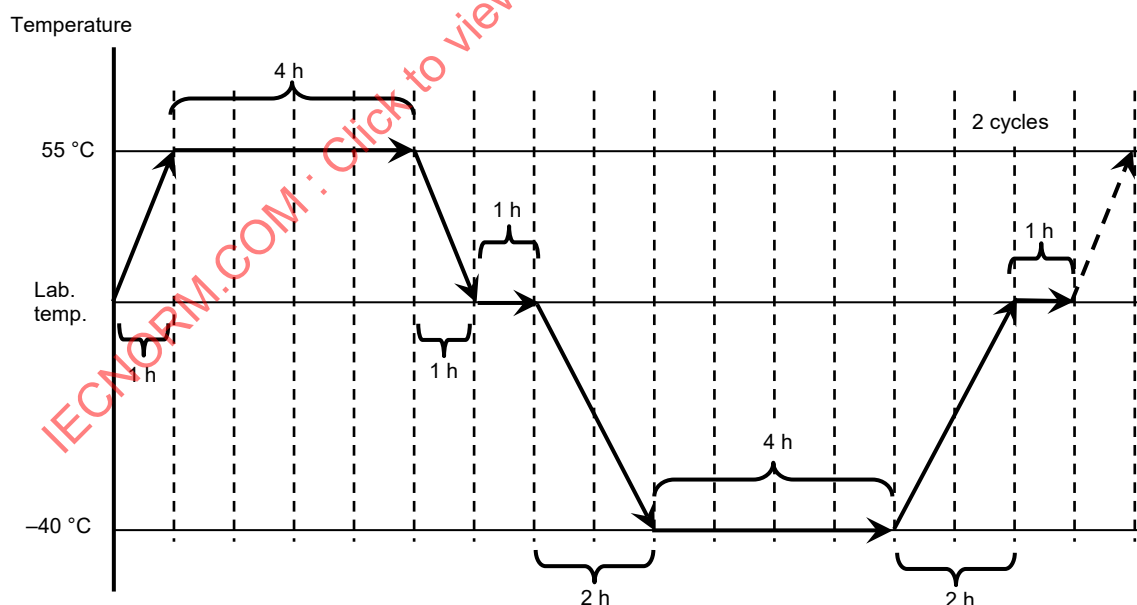


Figure F.8 – Temperature cycling – Replaces Figure 8

F.7.3.4 High temperature exposure test

Subclause F.7.3.4 replaces Subclause 7.3.4.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of a fuel cartridge left in high temperature environments.
- c) **Test procedure:**
 - 1) Two orientations shall be tested – valve up and valve down.
 - 2) Place the test sample in a temperature controlled test chamber that is at a temperature of $70\text{ °C} \pm 2\text{ °C}$ and allow chamber temperature to recover to $70\text{ °C} \pm 2\text{ °C}$ and maintain that temperature for at least 4 h with the sample in the chamber.
 - 3) Remove the test sample to laboratory temperature. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1.
 - 4) Connect the fuel cartridge to a micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1. See Figure F.3.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

F.7.3.5 Drop test

Subclause F.7.3.5 replaces Subclause 7.3.5.

- a) **Test sample:** an unused fuel cartridge, a used fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an inadvertent drop and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure F.2 for the fuel cartridge and Figure F.4 for the micro fuel cell power system or unit. The test sample shall be dropped on a horizontal surface that consists of hardwood at least 13 mm thick, mounted on two layers of plywood each 18 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor from a predetermined height.
 - 2) The height of the drop shall be:
 - i) $1\,200\text{ mm} \pm 10\text{ mm}$: in the case of a micro fuel cell power unit and/or a micro fuel cell power system.
 - ii) $1\,500\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge of more than 200 g solid fuel or more than 200 ml of liquid fuel component.
 - iii) $1\,800\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge of up to 200 g of solid fuel or up to 200 ml of liquid fuel component.

- 3) For the fuel cartridge tests, the drop test shall be carried out in four drop orientations with the same sample.
- 4) For the micro fuel cell power unit or the micro fuel cell power system, one micro fuel cell power system or unit may be used for all four drop orientations, or more than one micro fuel cell power system or unit may be used in subsequent drops, at the discretion of the manufacturer.
- 5) For all tests, drop orientations shall be:
 - i) valve up;
 - ii) valve down;
 - iii) two other mutually perpendicular orientations.
- 6) For the fuel cartridge, check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1.
- 7) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in subclause F.7.2.1. See Figure F.2.
- 8) For micro fuel cell power system or micro fuel cell power unit tests, perform emission testing in accordance with Subclause F.7.3.12. See Figure F.4.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

F.7.3.6 Compressive loading test

Subclause F.7.3.6 replaces Subclause 7.3.6.

F.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the micro fuel cell power unit, or micro fuel cell power system.
- c) **Test procedure:**
 - 1) The micro fuel cell power system or unit test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $245 \text{ N} \pm 9,8 \text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $245 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.

- 4) The test shall be carried out in three mutually perpendicular orientations as a rule. If the sample would not stand on its own, it does not need to be tested in that orientation.
- 5) Perform emission testing in accordance with Subclause F.7.3.12 following the compressive loading test. See Figure F.4.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in Subclause F.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emission test is acceptable.

F.7.3.6.2 Fuel cartridge

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the fuel cartridge.
- c) **Test procedure:**
 - 1) The fuel cartridge test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $981 \text{ N} \pm 9,8 \text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $981 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) Fuel cartridge orientations shall be selected on the basis of likely stable resting positions when accidentally dropped (e.g. those orientations having the lowest centres of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic fuel cartridge that is sufficiently cubic and the curved surface of a cylindrical fuel cartridge with a longitudinal axis length longer than twice the diameter.
 - 5) Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1.
 - 6) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for hydrogen leakage using liquid leak detector (bubble-forming) solution as described in Subclause F.7.2.2. Check for leakage of fuel, fuel byproducts, electrolyte and liquid fuel components using visual inspection with pH indicator and the water immersion test as described in Subclause F.7.2.1. See Figure F.2.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

F.7.3.7 External short-circuit test

Subclause F.7.3.7 replaces Subclause 7.3.7.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an external short-circuit.
- c) **Test procedure:**
 - 1) External short-circuit testing shall be done separately on both operating [DEVICE ON] and non-operating [DEVICE OFF] micro fuel cell power systems or micro fuel cell power units respectively.
 - 2) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power system or unit with wire having a maximum resistance load of 0,1 Ω for at least 5 min.
 - 3) Perform emission testing in accordance with Subclause F.7.3.12 after each short-circuit test. See Figure F.5.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed temperatures in Table 2 during or after short circuit testing.

Emissions shall meet the passing criteria in subclause F.7.3.12. If the micro fuel cell power system or unit does not operate but emissions do not exceed the limits of Subclause F.7.3.12, the emissions test is acceptable.

NOTE The external short-circuit test can be done sequentially with the surface, component and exhaust gas temperature test using the same sample.

F.7.3.9 Long-term storage test

Subclause F.7.3.9 replaces Subclause 7.3.9 for micro fuel cell power systems, units and fuel cartridges covered by this Annex F.

- a) **Test sample:** An unused or a used fuel cartridge
- b) **Purpose:** to simulate the effects of long term storage at elevated temperature and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure F.9 for fuel cartridges.
 - 2) Record initial mass M_0 and time t_0 and place sample in temperature chamber at 50 °C $\pm$ 2°C with a chamber relative humidity of at least 60 %.
 - 3) The temperature chamber shall be equipped with ventilation and measurement instruments capable of accurately measuring the concentration of hydrogen in the chamber similar to the configuration in Figure F.10.
 - 4) The ventilation flow rate and the hydrogen concentration of interest in the chamber shall be monitored continuously and recorded. See Table F.7. At no time during the test shall the hydrogen concentration in the chamber shall exceed 25 % LFL.

- 5) The sample shall remain in the chamber at $50\text{ °C} \pm 2\text{ °C}$ with a chamber relative humidity of at least 60 % for at least 28 days.
- 6) At the end of the 28 days, remove the fuel cartridge from the test chamber and record the time the fuel cartridge was removed from the test chamber, t_1 . Allow the fuel cartridge to stabilize at laboratory temperature and record the final mass, M_1 . Hydrogen gas loss is calculated as follows and shall not exceed 0,0032 g/h:

$$\frac{M_0 - M_1}{t_1 - t_0} < 0,0032 \text{ g/h}$$

- 7) Perform fuel, fuel byproduct, electrolyte and liquid fuel component leakage testing using visual inspection with pH indicator and water immersion test in accordance with Subclause F.7.2.1 for the fuel cartridge.
 - 8) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for fuel, fuel byproduct, electrolyte, or liquid fuel component leakage using visual inspection with pH indicator and water immersion test as described in F.7.2.1. See Figure F.9.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, or liquid fuel components. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. The hydrogen concentration in the chamber shall not exceed 25 % LFL at any time during the test. The hydrogen gas loss rate from the cartridge shall not exceed 0,0032 g/h at any time during the test. Fire, flame and explosion shall be checked using cheesecloth, infrared camera, or other suitable methods.

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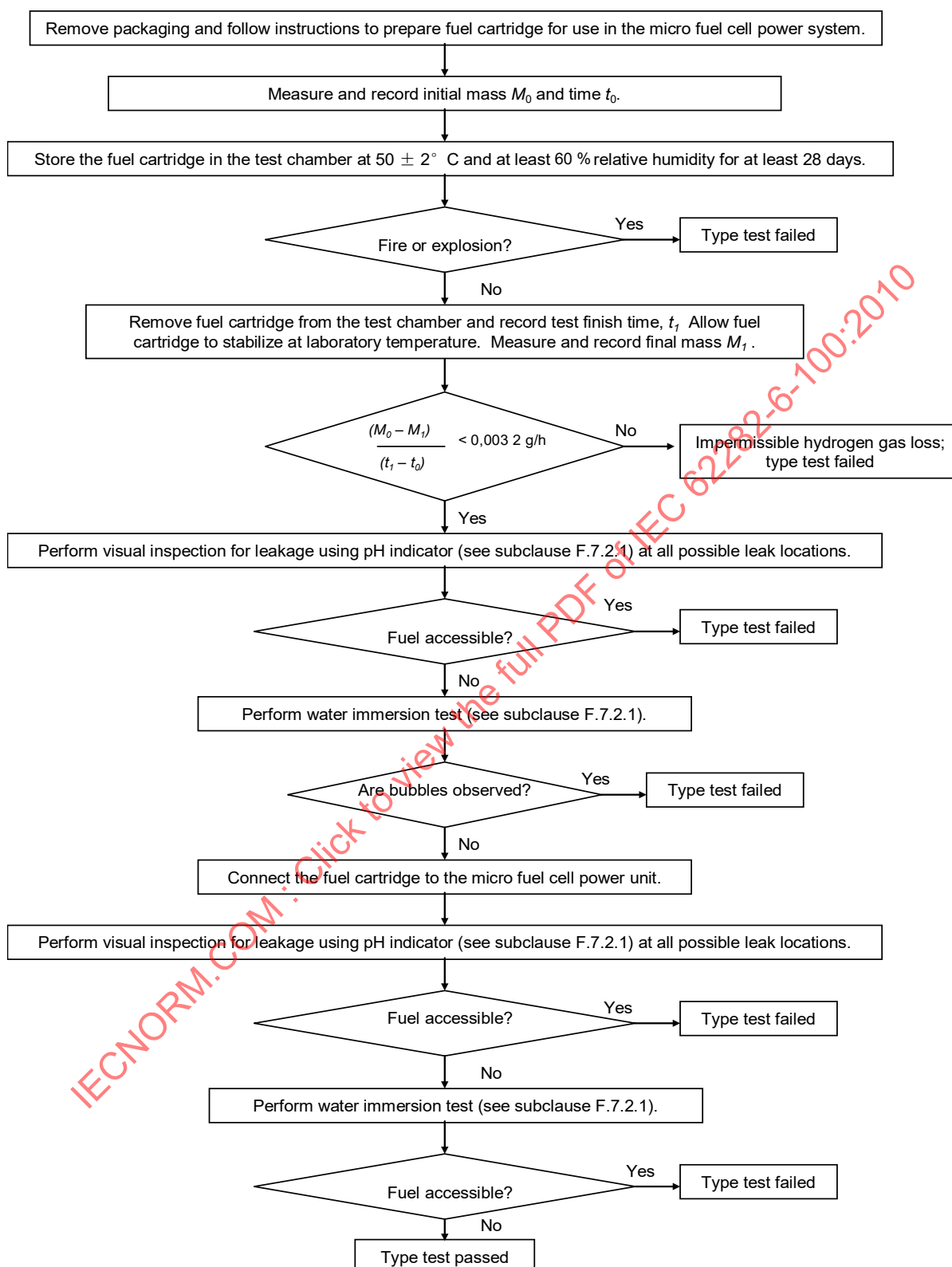


Figure F.9 – Fuel cartridge leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

F.7.3.10 High-temperature connection test

Subclause F.7.3.10 replaces Subclause 7.3.10.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge and a micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage, no fire, no explosion.
- c) **Test procedure:**
 - 1) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of $50\text{ °C} \pm 2\text{ °C}$ for at least 4 h.
 - 2) The micro fuel cell power unit or test fixture with micro fuel cell power unit valve is kept at laboratory temperature.
 - 3) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or test fixture with micro fuel cell power unit valve within 5 min of removal from the chamber.
 - 4) Check for leakage upon connection. Perform fuel, fuel byproduct, electrolyte and liquid fuel component leakage testing by visual inspection with pH indicator and water immersion test in accordance with Subclause F.7.2.1. Perform hydrogen leakage testing using a liquid leak detector (bubble-forming) in accordance with Subclause F.7.2.2 for the fuel cartridge.
 - 5) Disconnect the fuel cartridge. Perform fuel, fuel byproduct, electrolyte and liquid fuel component leakage testing by visual inspection with pH indicator and water immersion test in accordance with Subclause F.7.2.1. Perform hydrogen leakage testing using a liquid leak detector (bubble-forming) in accordance with Subclause F.7.2.2 for the fuel cartridge.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage. No leakage of Class 4.3 (water reactive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, this is acceptable. Leakage of Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause F.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

F.7.3.11 Connection cycling tests

Subclause F.7.3.11 replaces Subclause 7.3.11 for micro fuel cell power systems, units and fuel cartridges covered by this Annex F.

F.7.3.11.1 Fuel cartridge

F.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

- a) **Test sample:** an unused or a used insert cartridge, exterior cartridge or attached cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve and fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.

c) Test procedure:

- 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve. Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as in the leakage test and measurement procedure specified in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in Subclause F.7.2.1.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage as specified in the leakage test and measurement procedure in Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as in specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage specified in the leakage test and measurement procedure specified in Subclause F.7.2.1.
- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in Subclause F.7.2.1.
- 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure specified in Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen specified in the leakage test and measurement procedure in Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as described in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage as specified in the leakage test and measurement procedure in Subclause F.7.2.1.
- 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure in Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the leakage test and measurement procedure in Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water

reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.

- 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 13) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure in Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage as specified in the leakage test and measurement procedure in Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator and water immersion test as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
 - 14) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform emissions testing as specified in Subclause F.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of the hydrogen leakage measurement procedure (no bubbles) of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3. Emissions must meet passing criteria of Subclause F.7.3.12 for operational and non-operating systems.

F.7.3.11.1.2 Satellite cartridge

- a) **Test sample:** an unused satellite fuel cartridge and an unused micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve. Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproduct, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1. Initiate or simulate fuel flow.
 - 2) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive)

borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.

- 3) Repeat this twice more for a total of three connections and disconnections.
- 4) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 5) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 7) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 9) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and initiate or simulate fuel flow.
- 10) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 11) Repeat steps 1 through 10 four more times for a total of 55 cycles, waiting 1 h between each set of 11 cycles.

- 12) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform emissions testing as specified in Subclause F.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of the hydrogen leakage measurement procedure (no bubbles) of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3. Emissions must meet passing criteria of Subclause F.7.3.12 for operational and non-operating systems.

F.7.3.11.2 Micro fuel cell power unit

- a) **Test sample:** a minimum of two unused fuel cartridges and an additional 98 fuel cartridges or suitable test fixtures with fuel cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the fuel cartridge valve geometry and material and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage both at initial use and after suitable ageing of the micro fuel cell power unit connection.

First fuel cartridge (#1) and final fuel cartridge (#100) are inspected; the other 98 cycles are only to age the micro fuel cell power unit.

In the case of a micro fuel cell power unit using satellite cartridge, it shall be tested according to the following procedure by simulating fuel flow between the satellite cartridge and the micro fuel cell power unit.

c) **Test procedure:**

- 1) Connect the first fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and the fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall

meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.

- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 7) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 9) Connect and disconnect the first fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 11) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 12) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 13) Turn off the micro fuel cell power unit or stop simulated fuel flow.

- 14) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 15) In order to age the micro fuel cell power unit fuel cartridge connection, perform the following steps.
 - i) Using either fuel cartridges or a suitable test fixture with fuel cartridge valves, cycle the micro fuel cell power unit fuel cartridge connection for a total of 980 connections and disconnections.
 - ii) Simulate fuel flow after each set of 50 connection-disconnection cycles.
 - iii) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. If leakage is found, the test fails.
 - iv) Following this ageing, a final unused fuel cartridge will be tested.
- 16) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and the fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 17) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 18) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 19) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 20) Repeat this twice more for a total of three connections and disconnections.
- 21) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive)

borohydride and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.

- 22) Connect and disconnect the final fuel cartridge four more times for a total of seven connections and disconnections.
- 23) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 24) Connect and disconnect the final fuel cartridge three more times for a total of ten connections and disconnections.
- 25) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 26) Connect the fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.
- 27) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 28) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 29) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause F.7.2.2 for the fuel cartridge and fuel management system, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause F.7.2.2. Check for Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause F.7.2.1.

- 30) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and perform emissions testing as specified in Subclause F.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of the hydrogen leakage measurement procedure (no bubbles) of Subclause F.7.2.2 for the fuel cartridge. Class 4.3 (water reactive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause F.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause F.7.2.3. Emissions must meet passing criteria of F.7.3.12 for operational and non-operating systems.

F.7.3.12 Emission test

This Subclause F.7.3.12 shall replace Subclause 7.3.12 for Class 4.3 (water reactive) borohydride micro fuel cell power systems or units tested in accordance with Annex F. The included Table F.7, Emission limits, replaces Table 7 in Subclause 7.3.12. Figure F.10 replaces Figure 10 and is identical to Figure 10. Hydrogen emissions are evaluated separately. The procedure for hydrogen emission testing is detailed in Figure F.13, which is to be used as an additional figure when testing is done in accordance with Annex F.

- a) **Test sample:** A micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under normal operating conditions, indirect borohydride powered micro fuel cell power systems may have emissions. The emissions may be comprised of water or hydrogen, both of which are known not to be toxic. Indirect borohydride micro fuel cell power systems do not normally emit CO, CO₂, formaldehyde or other volatile organic compounds. However, there is a remote possibility that indirect borohydride micro fuel cell power systems utilizing fuels or liquid fuel components containing organic additives may emit CO, CO₂, formaldehyde, or other volatile organic compounds under abnormal circumstances. Because this possibility exists, emission limits for CO, CO₂, formaldehyde, and volatile organic compounds for micro fuel cell power systems utilizing fuels or liquid fuel components containing organic compounds are imposed by this annex and are listed in Table F.7.

The possibility for hydrogen emissions exists for non-operating indirect borohydride micro fuel cell power systems. Hydrogen emissions testing shall therefore be performed with the micro fuel cell power system off ("DEVICE – OFF") as an additional test. Hydrogen emissions shall be below the allowable 0,0032 g/h with the "DEVICE – OFF" limit given to avoid harmful exposures.

Micro fuel cell power systems emit water vapour and under certain conditions this water vapour can condense. This condensation is not considered an emission or a leak if the pH of the condensate is between 3,5 and 10,5 pH.

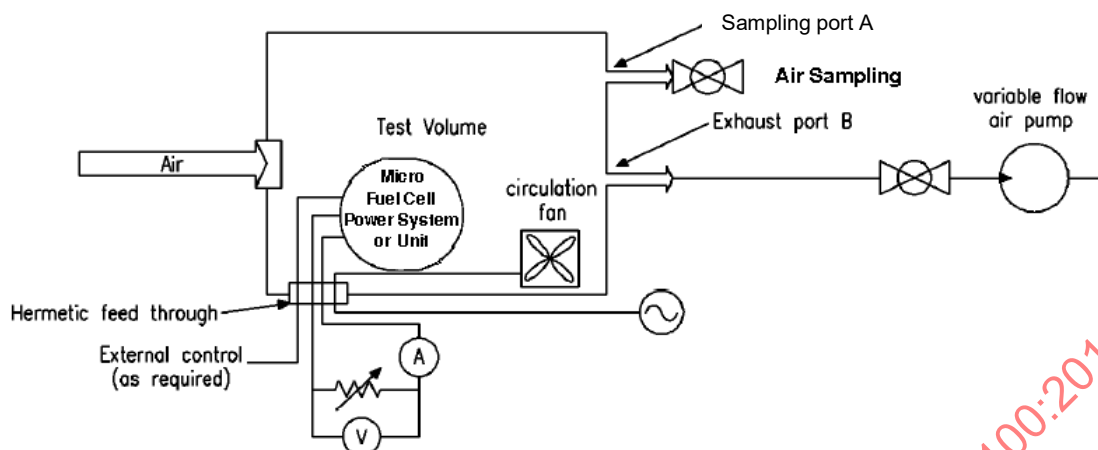


Figure F.10 – Operational emission rate testing apparatus – Replaces Figure 10

- c) **Test apparatus:** An example of the operational emission test apparatus is shown in Figure F.10. The configuration shown in Figure F.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex F. Emission rate testing in accordance with Subclause F.7.3.12 d) 1) is required for all types of micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex F.

To analyse the hydrogen emissions, a mass spectrometer, gas chromatograph, or other suitable instrument calibrated to measure hydrogen concentration shall be used and connected to sampling port A in Figure F.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

For micro fuel cell power systems or units that are intended to be used in close proximity to a consumer's mouth or nose (such as micro fuel cell power systems or units used to power cell phones, handheld games, etc.), additional testing in accordance with Subclause F.7.3.12 d) 1) and Subclause F.7.3.12 d) 2) is required to verify that emission concentrations in the vicinity of a user's mouth or nose are kept within appropriate limits. This emission concentration testing shall be done in a large open room using a different emission concentration testing apparatus. An example of the operational emission concentration testing apparatus is shown in Figure F.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell power system or unit to a consumer's mouth or nose when in use) for emissions concentration limit testing.

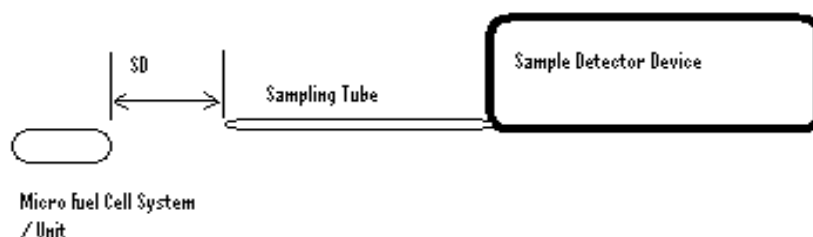


Figure F.11 – Operational emission concentration testing apparatus – Replaces Figure 11

Emission gases might be composed of toxic organic materials such as carbon dioxide, carbon monoxide and formaldehyde, which are potentially exhausted from a micro fuel cell power system or a micro fuel cell power unit.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) shall be used by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyzer through sampling port A in Figure F.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

A hydrogen detector calibrated for the zero-to-one-percent mass concentration hydrogen range can be used to measure the hydrogen concentration.

The concentration of CO and CO₂ gas can be measured by a non-dispersive infrared absorption analyzer. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) **Test procedure:**

Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure F.13, which is to be used as an additional figure when testing is done in accordance with Annex F.*

- 1) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed with the micro fuel cell power system or unit on ("DEVICE – ON") as follows.
 - i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure F.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure F.10.
 - iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure F.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
 - vi) Record the concentrations of chemical compounds of interest. See Table F.7.
 - vii) Calculate the emission rate of chemical compounds being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:

$$ER = (F_P + F_S) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

C is the concentration in grams per standard litre.

- viii) Compare the maximum measured "DEVICE – ON" emission rate to Table F.7. If the emission rate is not less than the emission rate limit in Table F.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria in Subclause F.7.3.12 e) 1) i) and Subclause F.7.3.12 e) 2) i).
 - ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 2) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emissions concentration sampling test shall be performed with the micro fuel cell power system or unit on "DEVICE – ON" as follows.
- i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling system do not contribute emissions (that is, contaminants) to the test. Prior to testing, a system check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results. Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - ii) Operate the micro fuel cell power system or micro fuel cell power unit at rated power in the large open room while sampling the emission concentrations using the operational emission concentration testing apparatus shown in Figure F.11. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission concentration test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "ON" position ("DEVICE – ON").
 - iii) Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - iv) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the operational emission concentration testing apparatus shown in Figure F.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - v) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - vi) Allow the sample flow rate to stabilise.
 - vii) Sample and record the fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - viii) Record the concentrations of the chemical compounds of interest. See Table F.7.

- ix) Compare the maximum measured concentrations to Table F.7. If the emission concentrations are not less than the emission concentration limits in Table F.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria in Subclause F.7.3.12 e) 2) ii).
 - x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 3) Upon completion of the emissions measurements with both "DEVICE – ON" in accordance with Table F.7, "DEVICE – ON" hydrogen emissions are evaluated as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure F.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure F.10.
 - iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure F.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
 - vi) Record the hydrogen concentration.
 - vii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:
- $$ER = (F_P + F_S) \times C$$
- where
- ER is the emission rate in grams per hour;
 - F_P is the variable flow air pump flow rate in standard litres per hour;
 - F_S is the sample flow rate in standard litres per hour;
 - C is the concentration in grams per standard litre.
- viii) Compare the maximum measured "DEVICE – ON" hydrogen emission rate to Table F.7.

NOTE This is a stabilised concentration measurement.

- ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 4) Upon completion of the hydrogen emissions measurements with "DEVICE – ON", hydrogen emissions with ("DEVICE – OFF") are evaluated as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure F.10 for 10 min or until 10 % of the fuel capacity of a full fuel cartridge is used up, whichever is less.
 - ii) Turn the micro fuel cell power system or unit off ("DEVICE – OFF") and measure the emission rates with the micro fuel cell power system or unit off ("DEVICE – OFF") inside the small test chamber shown in Figure F.10.
 - iii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iv) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown on Figure F.10.
 - v) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - vi) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure F.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
 - vii) Record the hydrogen concentration.
 - viii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:
- $$ER = (F_P + F_S) \times C$$
- where
- ER is the emission rate in grams per hour;
 - F_P is the variable flow air pump flow rate in standard litres per hour;
 - F_S is the sample flow rate in standard litres per hour;
 - C is the concentration in grams per standard litre.
- ix) Compare the maximum measured "DEVICE – OFF" hydrogen emission rate to Table F.7.
- NOTE This is a stabilised concentration measurement.
- x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

5) Evaluate the hydrogen emission rate as follows.

- i) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and below the allowable 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or unit passes the test and no further testing is necessary.
- ii) If the hydrogen emission rate measurement is not below the allowable 0,0032 g/h with the "DEVICE – OFF" and not below the total allowable 0,8 g/h with the "DEVICE – ON", the system or unit fails the test and no further testing is necessary.
- iii) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and is below the total allowable 0,8 g/h with the "DEVICE – ON" but is not below 0,016 g/h with the "DEVICE – ON", then proceed with Subclause F.7.3.13, hydrogen point source gas loss detection test to verify that no single source of hydrogen exceeds 0,016 g/h.

e) **Passing criteria:**

- 1) For micro fuel cell power systems and micro fuel cell power units not intended to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table F.7 shall be less than the emission rate limit value in Table F.7 when tested in accordance with Subclause F.7.3.12 d) 1) for "DEVICE – ON" and Subclause F.7.3.12 d) 2) for "DEVICE – ON" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 2) For micro fuel cell power systems and micro fuel cell power units to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table F.7 shall be less than the emission rate limit value in Table F.7 when tested in accordance with Subclause F.7.3.12 d) 1) for "DEVICE – ON" and Subclause F.7.3.12 d) 2) for "DEVICE – ON" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
 - ii) For micro fuel cell power systems and micro fuel cell power units intended to be used in close proximity to a consumer's mouth or nose; in addition to meeting the emission rate limit above, the maximum emission concentration for each of the constituents of interest shall not exceed the emission concentration limit in Table A.7 when tested in accordance with Subclause F.7.3.12 d) 3) "DEVICE – ON" and Subclause F.7.3.12 d) 4) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 3) Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure F.13, which is to be used as an additional figure when testing is done in accordance with Annex F.* Upon completion of the hydrogen emissions measurements with both "DEVICE – ON" and "DEVICE – OFF" in accordance with Table F.7, hydrogen emissions are evaluated as follows.
 - i) **Passing criteria for non-operating systems:** The hydrogen emission rate shall be less than 0,0032 g/h with the "DEVICE – OFF".
 - ii) **Passing criteria for operational systems:** If the total hydrogen emission rate is less than 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or micro fuel cell power unit passes the emission test and no further testing is required. If the total hydrogen emission rate is not less than 0,8 g/h with the "DEVICE – ON", the micro fuel cell power system or unit fails the emission test and no further testing is required. If the hydrogen emission rate is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON", F.7.3.13, hydrogen point source gas loss detection test must be performed with acceptable results to show no more than 0,016 g/h hydrogen leakage from any single point leak.

NOTE 1 The allowable flammable hydrogen emission level that will not support a standing flame is 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). The non-flammable hydrogen emissions limit is based on the criteria that hydrogen emission does not build up to more than 25 % of LFL in the reference volume.

NOTE 2 Hydrogen is defined as a simple asphyxiant but for this risk to exist, oxygen levels have to fall less than 18 % at normal atmospheric pressure. Hydrogen related flammability risk arises at hydrogen-in-air concentrations greater than 4 %, while the asphyxiant risk arises at hydrogen-in-air concentrations greater than 12 %. Therefore, the flammability limits are used in defining the limits for hydrogen emissions.

NOTE 3 Carbon dioxide and carbon monoxide vapour emission level limits are based on toxicity effects on humans while the hydrogen emissions level limit is based on the risk of creating a flammable atmosphere in confined spaces and the risk of a potential standing hydrogen flame.

Table F.7 – Emission limits – Replaces Table 7

Emissions	"DEVICE – ON" Concentration limit ^a based on TWA values for "DEVICE – ON" test condition	"DEVICE – ON" Permissible emissions rate in 10 m³ ACH volume ^b
Water	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5
Hydrogen	0,8 g/m ³	0,8 g/h total 0,016 g/h from single point leak
Formaldehyde^d	0,000 1 g/m ³	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Volatile organic carbon compounds^e	0,000 1 g/m ³	0,000 6 g/h
Table F.7 replaces Table 7. ^a The concentration limits for CO and CO₂ in this table are the mg/m³ equivalent of the TWA and STEL exposure limits. ^b The "DEVICE – ON" emission rate limit was based on 10 m³ ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is over 20 m³, so a product of 10 is conservative. ^c A seated human adult has a CO₂ emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO₂ concentration does not reach the WHO eight-hour concentration limit of 9 g/m³. In an environment with 10 m³ ACH, this limits the contribution from the fuel cell to 60 g/h. ^d WHO guideline limit is 0,000 1 g/m³. Background levels are 0,000 03 g/m³. The emission limit cannot push the background level above the guideline limit.		

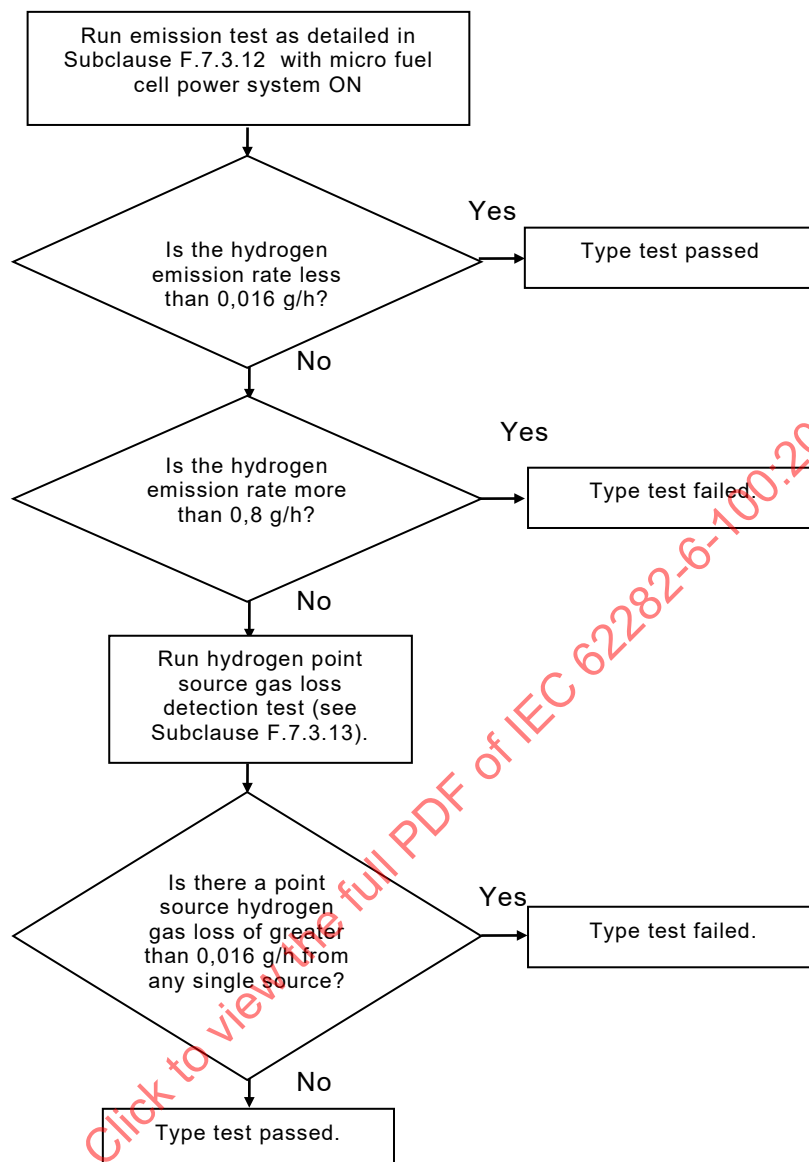


Figure F.13 – Hydrogen emission test procedure for operating micro fuel cell power system

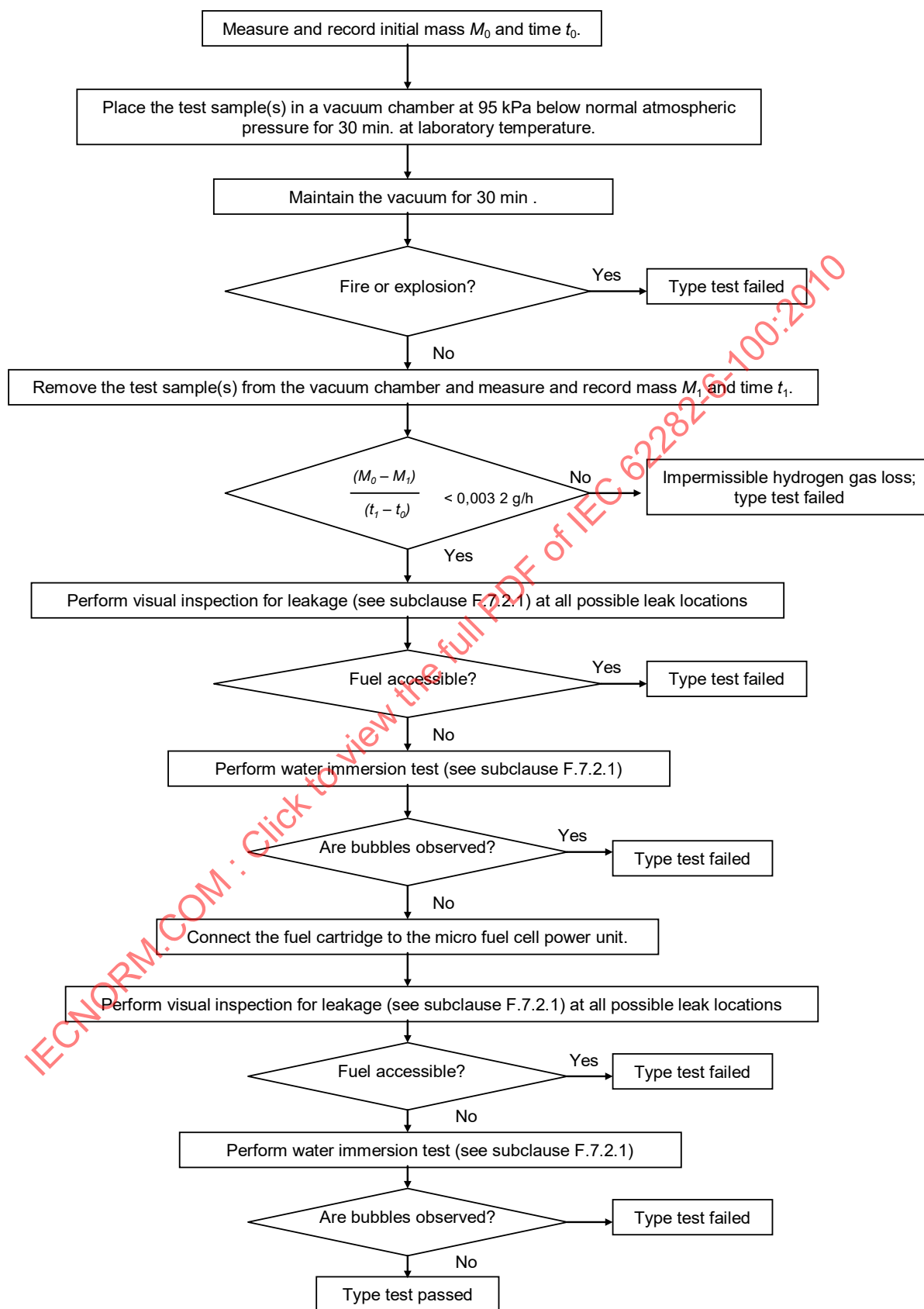


Figure F.14 – Fuel cartridge leakage test flow chart for low external pressure test

F.7.3.13 Hydrogen point source gas loss detection test

The procedure for hydrogen emission testing is detailed in Figure F.13, which is to be used as an additional figure when testing is done in accordance with Annex F. This subclause is additional to the requirements in Clause 7.

This subclause shall be used if required by Subclause F.7.3.12 d) 5) iii) to show compliance with Table F.7, for Class 4.3 (water reactive) borohydride micro fuel cell power systems and Class 4.3 (water reactive) borohydride micro fuel cell power units. This subclause is required to be performed to meet the passing criteria of Subclause F.7.3.12 e) 3) ii) if the total hydrogen emission rate from an operational Class 4.3 (water reactive) borohydride micro fuel cell power system or unit is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON".

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or a micro fuel cell power unit that is fuelled with Class 4.3 (water reactive) borohydride emission of hydrogen shall be maintained at less than the specified values in Table F.7. The hydrogen point source gas loss detection test shall be performed to determine that no single source on the micro fuel cell power system or unit can support a flame in all cases where such compliance cannot be definitively determined by the hydrogen emission test. Maintaining these limits ensures that, in addition to not permitting a flammable concentration to build up in the reference volume, there is no gas loss of hydrogen from the specimen that could support a flame and along with the other emissions testing ensures an adequate supply of oxygen is maintained in the operating environment
- c) **Test apparatus:** The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, a hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL. The response of the aforementioned hydrogen detectors is commonly slow, with a response time of many seconds, thus high sweep speeds may cause underestimation of the hydrogen concentration. It is important that the sweep speed shall be slow enough to accurately measure the hydrogen concentration.
- d) **Test procedure:**
 - 1) The micro fuel cell power system or micro fuel cell power unit shall remain turned on ("DEVICE – ON") throughout the duration of the hydrogen point source gas loss detection test.
 - 2) The testing shall be conducted in a space with no substantial air movement. The measured wind speed 10 cm above the micro fuel cell power system or unit shall not exceed 0,02 m/s. The local concentration of hydrogen diffusion measured in this test is very susceptible to the effect of wind. It is desirable that wind speed anywhere in the test space is as close to zero as possible. Testing in a closed space, such as a glove box or equivalent chamber, is one available method to achieve this requirement.
 - 3) The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL.
 - 4) The sensor of the hydrogen detector shall sweep the micro fuel cell power system or unit at a distance no more than 3 mm normal to the surface of the micro fuel cell power system or unit. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the micro fuel cell power system or unit. The entire surface of the micro fuel cell power system or unit shall be swept in this manner.

- 5) An effective method for completing these sweeps would be to attach a stand off to the sensor that ensures that a spacing of 3 mm from the micro fuel cell power system or unit is maintained at all times. A pen or other marking utensil attached to the stand off could be used to identify swept areas and ensure that the distance between sweeps does not exceed 8 mm.
 - 6) The sensor should always face directly downward, and the micro fuel cell power system or unit should be moved beneath it such that the surface directly below the sensor is always horizontal.
 - 7) If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the micro fuel cell power system or unit shall be considered to have passed.
 - 8) When some point source sweeps show a large region of 25 % LFL or greater in the initial linear sweeps, recording the measured concentration values will assist in determining the starting point of secondary spiral sweeps. Point sources are supposed to be where local maximum values exist in the distribution of measured concentration values.
 - 9) If any points are detected to have a hydrogen concentration of 25 % LFL or greater, a second test shall be conducted to ensure that the emission does not exceed 0,016 g/h of pure hydrogen from any single source.
 - 10) The second test shall be performed with the sensor height adjusted to 6,5 mm above the micro fuel cell power system or unit.
 - 11) A spiral sweep shall then be made, originating from the point where the detection of 25 % LFL or greater of hydrogen occurred during the initial linear sweep. The spiral sweep shall have a spacing of 1 mm or less between sweeps, and shall spiral out to a radial distance of at least 4 mm and far enough to detect the maximum hydrogen level from the particular hydrogen source.
 - 12) If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the micro fuel cell power system or unit passes the test.
- e) **Passing criteria:** No gas loss of hydrogen from any single source at greater than 0,016 g/h as indicated by sweep testing. No indications of hydrogen that is 25 % of LFL during the primary sweep testing or no indications of hydrogen that is 25 % of LFL during the secondary sweep testing at 6,5 mm above the micro fuel cell power system or unit. If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. See Table F.7.

Annex G (normative)

Borohydride micro fuel cell power systems: Class 8 (corrosive) compounds in direct borohydride fuel cells

G.1 Scope

G.1.2 Fuel and technology covered by this annex

Annex G covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges using Class 8 (corrosive) borohydride compound fuels directly.

Figure G.1 replaces Figure 1 showing a direct borohydride micro fuel cell power system block diagram for use with this annex.

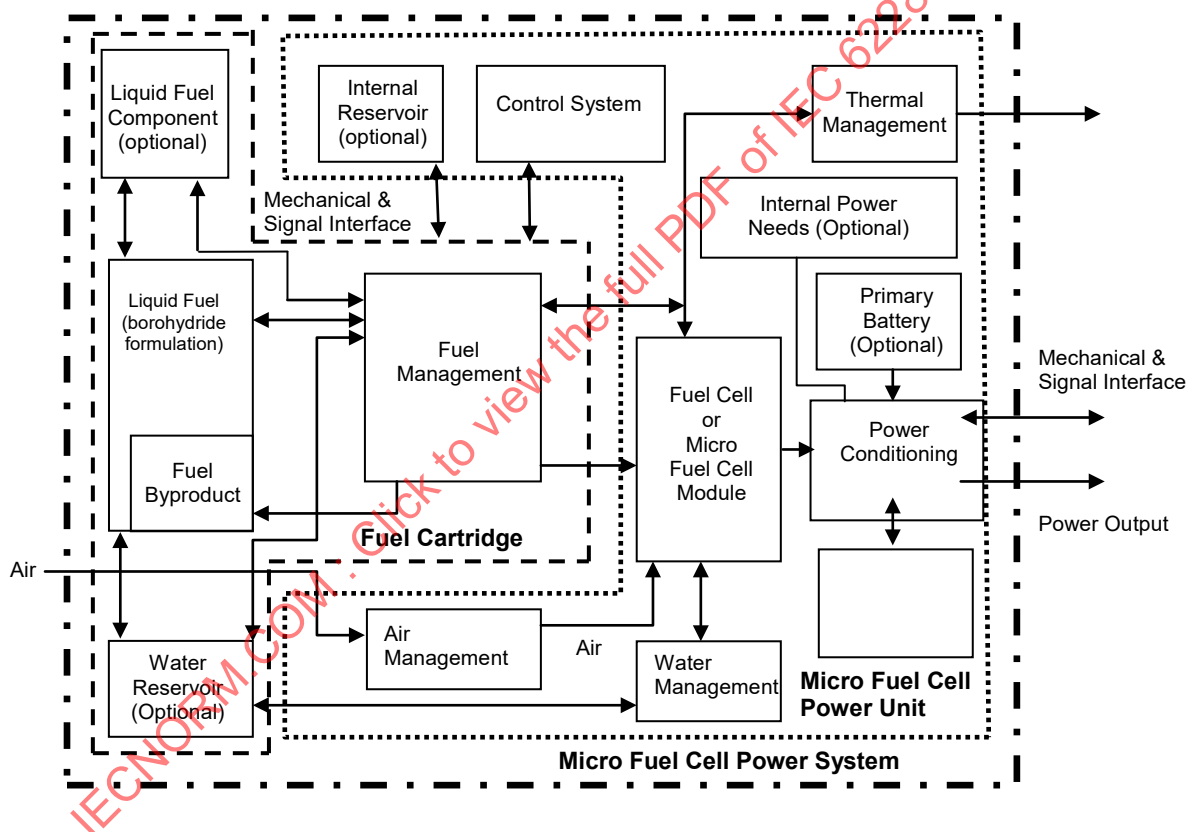


Figure G.1 – Direct borohydride micro fuel cell power system block diagram –
Replaces Figure 1

G.1.3 Equivalent level of safety

This subclause replaces Subclause 1.3.

- The requirements of this standard are not intended to constrain innovation. The manufacturer may consider fuels, materials, designs or constructions not specifically dealt with in this standard. These alternatives should be evaluated as to their ability to yield levels of safety equivalent to those prescribed by this standard.

- b) It is understood that all micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall comply with applicable country and local requirements including, but not limited to, those concerning transportation, child-resistance, and storage, where required.
- c) The following similarities between methanol and direct borohydride micro fuel cell power systems are provided to enhance understanding of why the direct borohydride requirements mimic methanol requirements with minimal changes.
- 1) The similarity in micro fuel cell power system components (see Figure 1 and Figure G.1).
 - 2) Both types of micro fuel cell power systems use liquid fuels and both micro fuel cell power systems have the "no accessible liquid" criteria for no leakage (see definitions in Clause G.3).
 - 3) Both types of micro fuel cell power systems may have similar gaseous emissions components and thus shall have similar criteria for measurement and analysis of the emissions, and the same considerations shall be made for emission risk levels.
 - 4) Formaldehyde and methyl formate emissions seen in methanol micro fuel cell power systems are not present in direct borohydride micro fuel cell power systems.
 - 5) Hydrogen emissions are possible when sodium or potassium borohydride is in contact with decomposition catalysts with no load on the fuel cell. Properly functioning non-operating micro fuel cell power systems shall have fail-safe mechanisms to prevent fuel flow to the catalysts. Failure modes and effects analysis and related testing shall ensure protection against such failure modes and ensure existence of relevant design mitigations.
 - 6) Since even with the micro fuel cell power system off, hydrogen may be produced from a direct borohydride fuel cartridge and a micro fuel cell power system, the emission test shall be performed with the micro fuel cell power system off "DEVICE – OFF" as an additional test.
 - 7) Hydrogen and water vapour are possible emissions from an operational "DEVICE – ON" micro fuel cell power system.
 - 8) Sodium and potassium borohydride fuels are non-flammable; thus warning statements for the product related to fuel flammability do not apply to direct borohydride micro fuel cell power system products.

G.2 Normative references

In addition to the normative references specified in Clause 2, the following normative documents are indispensable for the application of this document.

ISO 16111, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

G.3 Terms and definitions

The terms and definitions below replace those corresponding terms and definitions in Clause 3 for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex G. All terms and conditions in Clause 3 not specifically mentioned here also apply.

G.3.5

fuel

Class 8 (corrosive) formulation of borohydride compounds used to produce electricity directly in a micro fuel cell power system

G.3.7

direct borohydride micro fuel cell power system

micro fuel cell power system in which a liquid formulation of borohydride compounds chemically reacts on an anode of a fuel cell to produce electricity in a micro fuel cell power system

G.3.8

liquid fuel, corrosive

materials which are classified as Class 8: corrosive substances under the guidelines of the 15th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

Liquid formulation of borohydride compounds used as fuel for a direct borohydride micro fuel cell power system.

G.3.11

leakage

accessible fuel, fuel by-products, electrolyte or liquid fuel components outside the micro fuel cell power system or fuel cartridge; hydrogen leakage or impermissible hydrogen gas loss

The additional terms and their definitions below are needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex G in addition to those given in Clause 3.

G.3.37

borohydride compounds

sodium or potassium borohydride, or a mixture thereof

G.3.38

liquid fuel component

Class 8 (corrosive), or non-hazardous, water solutions used to produce hydrogen within the fuel processing subsystem

G.3.39

electrolyte

corrosive (alkaline) compound solution or ion conducting membrane used to complete an electric circuit within a fuel cell

G.3.40

fuel byproducts

Class 8 (corrosive), or non-hazardous compounds produced after hydrogen and/or electricity is produced from fuel

G.3.41

impermissible hydrogen gas loss

hydrogen gas escaping non-operating micro fuel cell power system or micro fuel cell power unit greater than or equal to 0,0032 g/h

G.3.42

accessible fuel, fuel byproducts, electrolyte or liquid fuel components

fuel, fuel byproducts, electrolyte or liquid fuel components that the consumer may come into physical contact with during normal use, reasonably foreseeable misuse, and consumer transportation

G.3.43

Class 8 (corrosive)

materials which are classified as Class 8: Corrosive Substance under the guidelines of the 15th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

G.3.44**non-hazardous**

materials which are not subject to guidelines of the 15th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

G.3.45**alkali metal hydroxide**

hydroxides of sodium, potassium and lithium used in Class 8 (corrosive) liquid fuels

G.3.46**used fuel cartridge**

fuel cartridge that has been put into operation such that at least 45 % of the initial fuel has been utilized and that the operation of the micro fuel cell power system has been halted for at least 1 h

G.3.47**hydrogen leakage**

hydrogen gas outside fuel containment system, including fuel cartridge, fuel management and internal reservoir, if applicable (see G.7.2.2)

G.4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges**G.4.4 Selection of materials**

These requirements replace the corresponding requirements of Subclause 4.4.

These requirements of Subclause G.4.4, below, apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

G.4.4.1 Micro fuel cell power systems and units are expected to be exposed to a number of environmental conditions over the manufacturer-defined life span of the product such as vibration, shock, varying humidity levels and corrosive environments. Materials employed in the micro fuel cell power system or unit shall be resistant to these environmental conditions. If a micro fuel cell power system or unit is to be used in service where specific environmental conditions are beyond those accounted for in the required tests of this standard, then additional testing shall be performed to verify safety under those environmental conditions.

G.4.4.2 Metallic and non-metallic materials used to construct internal or external parts of the micro fuel cell power system or unit, in particular those exposed directly or indirectly to moisture, fuel and/or byproducts in either a gas or liquid form as well as all parts and materials used to seal or interconnect the same, e.g. welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable under the normal transportation and normal usage conditions within the manufacturer-defined life span of the product and for all test conditions; in particular, they shall be designed to retain their mechanical stability under normal use;

- they shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation;
- the chemical and physical properties necessary for operational safety shall not be significantly affected within the manufacturer-defined life span of the product; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, ageing resistance, the effects of temperature variations, the effects arising when materials are put together (e.g. galvanic corrosion), and the effects of ultraviolet radiation;
- where conditions of erosion, abrasion, corrosion or other chemical attack may arise, adequate measures shall be taken to

- minimize that effect by appropriate design, e.g. additional thickness, or by appropriate protection, e.g. use of liners, cladding materials or surface coatings, taking due account of normal use;
 - permit replacement of parts which are most affected;
 - and draw attention, in the manual referred to in Clause 6, to type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement.
- Fuel containing parts, such as piping systems, shall employ materials suitable for exposure to hydrogen, as defined in 5.2 of ISO 16111. Annex A of ISO 16111 details material compatibility for hydrogen service.

G.4.4.3 Elastomeric materials such as gaskets and tubing in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperatures that they are exposed to during normal use. Compliance shall be determined by the following: ISO 188.

G.4.4.4 Polymeric materials in contact with fuels shall be resistant to deterioration when in contact with those fuels and shall be suitable for the temperature they are exposed to during normal use. Compliance shall be determined by ISO 175.

G.4.4.5 Piping systems exposed to hydrogen shall employ materials suitable for exposure to hydrogen, as defined in Annex A of ISO 16111.

G.4.7 Materials and construction – system

These requirements of Subclause G.4.7 apply to micro fuel cell power systems and units covered by this Annex G. These requirements replace the corresponding requirements of Subclause 4.7.

G.4.7.1 The maximum quantity of liquid fuel or liquid fuel components stored in the micro fuel cell power unit shall not exceed 1 l.

G.4.7.2 The micro fuel cell power system or unit shall be designed such that an explosion cannot occur even if fuel leaks from or inside the micro fuel cell power system or unit. The design criteria for such means (for example, required ventilation rate) shall be provided by the micro fuel cell power system or unit manufacturer. The means shall be provided either by the micro fuel cell power system or unit manufacturer or by the manufacturer of the device powered by the micro fuel cell power system or unit.

G.4.7.3 Components and materials inside the micro fuel cell power system or unit shall be constructed or shall make use of such materials that propagation of fire and ignition is mitigated. The material flammability shall be such that a sustained fire will not be supported after electrical power and the fuel and oxidant supply have been terminated. This may be demonstrated through the selection of materials meeting FV 0, FV 1 or FV 2 in accordance with IEC 60695-1-1 and IEC 60695-11-10.

G.4.7.4 Micro fuel cell stack membranes are not required to have flammability ratings.

G.4.7.5 Other materials within the micro fuel cell stack which comprise less than 30 % of the total micro fuel cell stack mass are considered to be of limited quantity and are permissible without flammability ratings.

G.4.12 Fuel supply construction

G.4.12.1 Fuel cartridge construction

These requirements replace the corresponding requirements of Subclause 4.12.1. Fuel cartridges shall conform to the following requirements.

These requirements apply to micro fuel cell power systems and units covered by this Annex G.

G.4.12.1.1 There shall be no leakage from the fuel cartridge in the temperature range of –40 °C to +70 °C. Compliance shall be determined by type testing in accordance with 7.3.3 and 7.3.4.

G.4.12.1.2 There shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Compliance shall be determined by type testing in accordance with 7.3.1.

G.4.12.1.3 The maximum quantity of fuel charge is limited to 1 l for either liquid fuel or liquid fuel components.

G.4.12.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a micro fuel cell power unit by a consumer, means to prevent fuel leakage prior to, during, and after connection or transfer of fuel to the micro fuel cell power unit shall be provided. Compliance is checked by 7.3.11.

G.4.12.1.5 A fuel cartridge shall be resistant to corrosion in its usage environment.

G.4.12.1.6 A fuel cartridge shall be provided with a means to prevent mis-connection that would result in leakage of fuel when it is installed in a micro fuel cell power system. Compliance is checked by the connection cycling test, 7.3.11.

G.4.12.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel when not attached to a micro fuel cell power unit during normal usage, reasonably foreseeable misuse, and consumer transportation. Compliance is checked by the drop test, 7.3.5, and the connection cycling test, 7.3.11.

G.4.12.1.8 In the case where a pressure release valve or similar means is provided, such pressure release valve shall satisfy the performance requirement for each type test. This valve shall pass all type tests with no leakage.

G.4.12.1.9 The structure at the connection to the fuel cartridge shall not allow fuel to leak.

G.4.12.1.10 A fuel cartridge, including the fuel cartridge interface to the micro fuel cell power unit, including the valve, shall have a construction sufficient to withstand normal use and reasonably foreseeable misuse generated by vibration, heat, pressure, being dropped or otherwise subject to a mechanical shock etc. Compliance is checked by:

- pressure differential tests, G.7.3.1;
- vibration test, G.7.3.2;
- temperature cycling test, G.7.3.3;
- high temperature exposure test, G.7.3.4;
- drop test, G.7.3.5;

- compressive loading test, G.7.3.6;
- long-term storage test, G.7.3.9;
- high-temperature connection test, G.7.3.10;
- connection cycling tests, G.7.3.11.

G.4.12.1.11 The fuel cartridge valves shall operate as intended without the use of tools and without excessive force needed to connect or disconnect.

G.4.12.2 Fuel cartridge fill requirement

This requirement replaces the corresponding requirement of Subclause 4.12.2:

This requirement applies to micro fuel cell power systems and units covered by this Annex G.

The fuel cartridge design and fuel fill amount shall allow fuel expansion without leakage to a fuel cartridge temperature of 70 °C in the case of the fuel cartridge alone and when the fuel cartridge is constrained by the micro fuel cell power system or a comparable test fixture.

G.6 Instructions and warnings for fuel cartridges, micro fuel cell power units, and micro fuel cell power systems

These markings replace the markings required by Subclause 6.2.

G.6.1 Minimum markings required on the fuel cartridge

As a minimum, the following shall be marked on the fuel cartridge.

- a) CONTENTS ARE CORROSIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) KEEP AWAY FROM CHILDREN.
- d) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- e) DO NOT EXPOSE TO ACIDS, OXIDIZERS, ALCOHOL OR HOUSEHOLD CLEANING PRODUCTS.
- f) FOLLOW USAGE INSTRUCTIONS.
- g) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- h) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- i) COMPOSITION AND AMOUNT OF FUEL.
- j) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.

In the case that the contents of the fuel cartridge may be flammable, the marking required under “a)” above shall be changed as follows:

- a) CONTENTS ARE FLAMMABLE, CORROSIVE AND TOXIC. DO NOT DISASSEMBLE.

G.6.2 Minimum markings on the micro fuel cell power system

In addition, as a minimum, the following shall also be marked on the micro fuel cell power system to show:

- a) CONTENTS ARE CORROSIVE AND TOXIC, DO NOT DISASSEMBLE.
- b) AVOID CONTACT WITH CONTENTS.
- c) KEEP AWAY FROM CHILDREN.
- d) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES.
- e) DO NOT EXPOSE FUEL CARTRIDGE TO ACIDS, OXIDIZERS, ALCOHOL OR HOUSEHOLD CLEANING PRODUCTS.
- f) FOLLOW USAGE INSTRUCTIONS.
- g) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
- h) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- i) COMPOSITION OF FUEL.
- j) MAXIMUM CAPACITY OF FUEL IN THE INTERNAL RESERVOIR, IF APPLICABLE.
- k) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.
- l) ELECTRICAL OUTPUT (VOLTAGE, CURRENT, RATED POWER)

In the case that the contents of the fuel cartridge may be flammable, the marking required under “a)” above shall be changed as follows:

- a) CONTENTS ARE FLAMMABLE, CORROSIVE AND TOXIC. DO NOT DISASSEMBLE.

G.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

G.7.1 General

This Subclause G.7.1 replaces Subclause 7.1 for this annex when testing borohydride micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use Class 8 (corrosive) borohydride as fuel.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table G.5 lists the type tests that must be performed. *Table G.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table G.6. *Table G.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of 22 °C ± 5 °C for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table G.5 – List of type tests – Replaces Table 5

	Test item	Test sample
G.7.3.1	Pressure differential tests	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
G.7.3.2	Vibration test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
G.7.3.3	Temperature cycling test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
G.7.3.4	High temperature exposure test	Fuel cartridge Used fuel cartridge
G.7.3.5	Drop test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
G.7.3.6	Compressive loading test	Fuel cartridge Used fuel cartridge Micro fuel cell power system or power unit
G.7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
G.7.3.9	Long-term storage test	Fuel cartridge Used fuel cartridge
G. 7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
G.7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit Used fuel cartridge and micro fuel cell power unit
G.7.3.12	Emission test	Micro fuel cell power system or power unit
G.7.3.13	Hydrogen point source gas loss detection test	Micro fuel cell power system or power unit
Table G.5 replaces Table 5. Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or used, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test. Test sequence: Tests G.7.3.2 and G.7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests G.7.3.1, G.7.3.2, and G.7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or power units. Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.		

Table G.6 – Laboratory standard conditions – Replaces Table 6

Item	Condition
Laboratory temperature	Laboratory temperature is "room temperature" (standard temperature condition, 22 °C ± 5 °C)
Laboratory atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen. The laboratory atmosphere contains not more than 0,008 % hydrogen
Table G.6 replaces Table 6.	

G.7.2 Leakage, hydrogen leakage, and hydrogen gas loss, and hydrogen emission measurement and the measuring procedure

This Subclause G.7.2 replaces Subclause 7.2 for this annex when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use Class 8 (corrosive) borohydride as fuel.

The leakage measurements shall be executed in principle in accordance with the procedures shown in Figures G.2 through G.5. These figures and their procedures, replace the corresponding figures in Subclause 7.2.

Compliance with the "no leakage", "no hydrogen leakage" and "no impermissible hydrogen gas loss" requirement for all type tests specified in Subclause G.7.3 shall be determined by the leakage test and measurement procedure of subclause G.7.2.1, the hydrogen leakage measurement procedure of Subclause G.7.2.2 and the hydrogen gas loss measuring procedure of Subclause G.7.2.3 in conjunction with the definitions of "leakage" in Subclause G.3.11, "hydrogen leakage" in Subclause G.3.47, and the definition of "impermissible hydrogen gas loss" in Subclause G.3.41, unless otherwise specified.

G.7.2.1 Leakage test and measurement procedure

- a) For micro fuel cell power systems, micro fuel cell power units and fuel cartridges containing Class 8 (corrosive) borohydride fuel, the leakage measurement of fuel, fuel byproducts, electrolyte or liquid fuel components shall be done following each type test by performing visual inspection of all possible leak locations. Any drops of fuel, fuel byproducts, electrolyte or liquid fuel component and/or white crystals on the exterior of the micro fuel cell power system or unit or fuel cartridge are indications of leakage. If crystals are accessible, the micro fuel cell power system or unit or fuel cartridge fails the leakage test. As an additional tool for finding fuel, fuel byproducts, electrolyte or liquid fuel component leaks, pH paper, attached to the possible leak areas of the micro fuel cell power system, shall be used to aid in the visual check for leakage. This is an additional requirement in Annex G for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel components. Any existence of a substance with a pH lower than 3,5 or greater than 10,5 is an indication of leakage. See Figure G.2 and Figure G.3. For operational tests, reactant air passages into the micro fuel cell power system and exhaust ports should not be blocked with pH paper.
- b) For fuel cell cartridges containing solid, corrosive borohydride fuel, a water immersion test shall be performed following each type test. The entire fuel cartridge containing solid borohydride fuel is immersed in at least one meter of laboratory temperature water for 30 min. If bubbles are observed, the fuel cartridge fails the leakage test. See Figure G.2 and Figure G.3.

G.7.2.2 Hydrogen leakage measurement from fuel cartridges, fuel management systems and internal reservoirs, if applicable, and measuring procedures

- a) For fuel cartridges containing Class 8 (corrosive) borohydride, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the fuel cartridge. See Figure G.2 and Figure G.3.
- b) If the fuel cartridge is of the type that is refillable by the manufacturer (automated or by trained technicians), it shall be filled to its rated capacity prior to testing. If the fuel cartridge is not refillable, it shall be tested in the condition in which it completed the type test in question. The fuel cartridge shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel cartridge.
- c) For micro fuel cell power systems or micro fuel cell power units with an internal reservoir, if applicable, a fuel management system that contains hydrogen gas above ambient pressure, the measurement of hydrogen leakage shall be done following each type test using a liquid leak detector (bubble forming) solution or other equivalent means on all possible leak locations of the fuel management system and internal reservoir, if applicable. The fuel management system and internal reservoir, if applicable shall be tested for leaks at laboratory temperature. There shall be no leakage from any point on the fuel management system and internal reservoir, if applicable
- d) Both for fuel cartridges containing Class 8 (corrosive) borohydride, and for fuel management systems containing hydrogen, no hydrogen leakage is allowed. Testing for hydrogen leakage with a liquid leak detector (bubble forming) solution is acceptable only if no bubbles are found.

NOTE The "no leakage" criteria for fuel cartridges containing Class 8 (corrosive) borohydride has been chosen to be consistent with the 15th Edition of the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations; Special Provision 339 for UN 3479, Fuel Cell Cartridge containing hydrogen in metal hydride.

G.7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures

For micro fuel cell power systems, or micro fuel cell power units, following the completion of each type test, the micro fuel cell power system or unit shall be tested for hydrogen gas loss according to Figure G.4 as follows:

- a) Perform hydrogen emission testing in accordance with G.7.3.12 with the exception that the micro fuel cell power system or unit shall be off ("DEVICE – OFF"). Hydrogen point source testing in accordance with G.7.3.13 is not applicable. Hydrogen gas loss shall be less than 0,0032 g/h.
- b) Perform hydrogen emission testing in accordance with G.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") to test for hydrogen emissions whether or not the micro fuel cell power system or unit is operational. Hydrogen emissions shall be less than 0,8 g/h.
- c) If hydrogen emissions in accordance with G.7.3.12 with the micro fuel cell power system or unit turned on ("DEVICE – ON") in step G.7.3.12.e) 3) ii) were greater than 0,016 g/h, perform the hydrogen point source gas loss detection test in accordance with G.7.3.13. If the micro fuel cell power system or unit fails the hydrogen point source gas loss detection test in accordance with G.7.3.13, the micro fuel cell power system or unit fails the type test and no further testing is necessary.
- d) Perform leak testing on the fuel management system and internal reservoir, if applicable, using a liquid leak detector (bubble forming) solution, if a fuel management system or internal reservoir containing hydrogen is used. No leakage is allowed from the fuel management system and internal reservoir, if applicable.
- e) Total hydrogen emissions from an operational system shall be less than 0,8 g/h and hydrogen leakage from any single point leak shall be less than 0,016 g/h. See Table G.7.
- f) Total hydrogen gas loss from a non-operating system shall be less than 0,0032 g/h. See Table G.7.

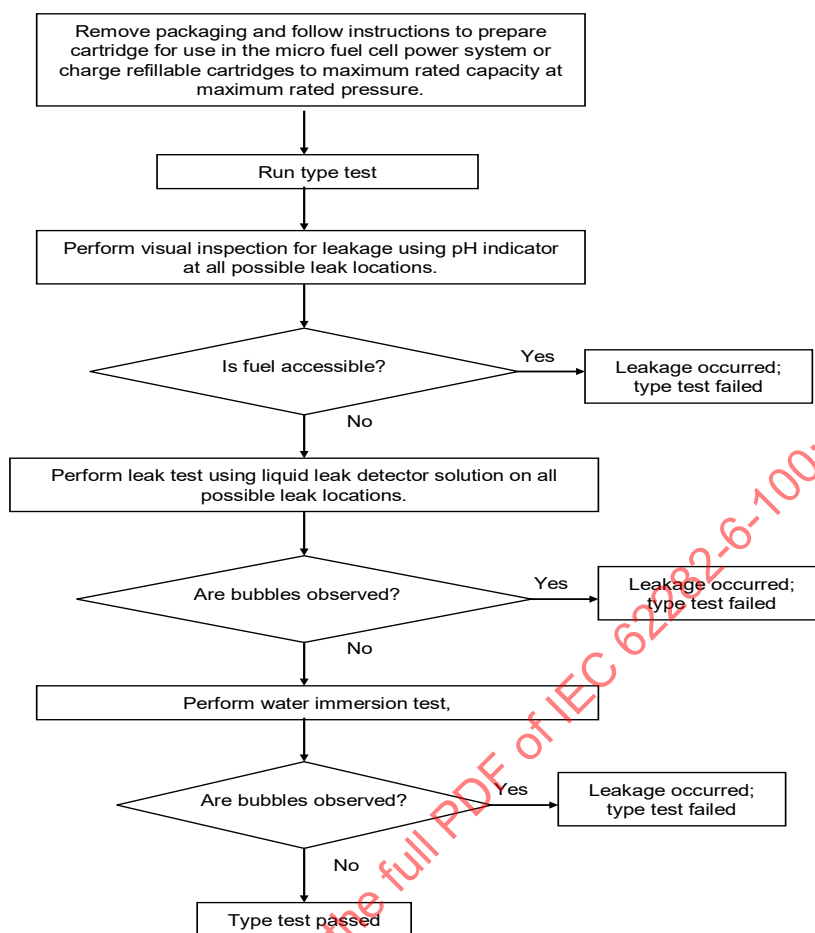


Figure G.2 – Fuel cartridge leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests – Replaces Figure 2

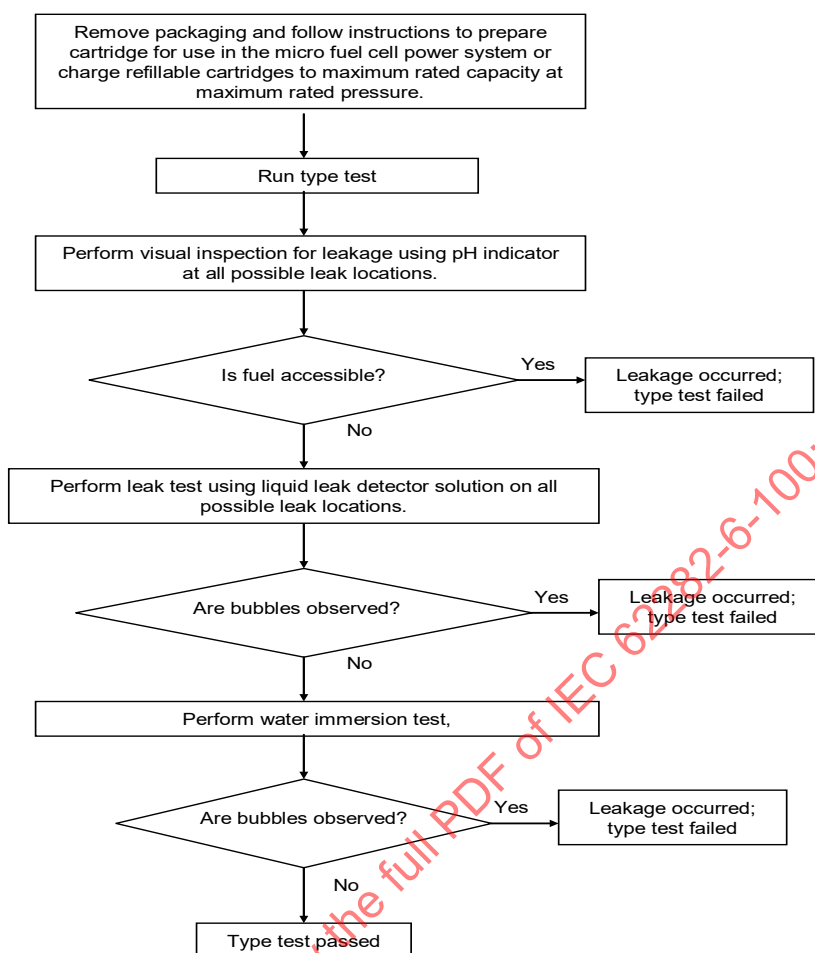


Figure G.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

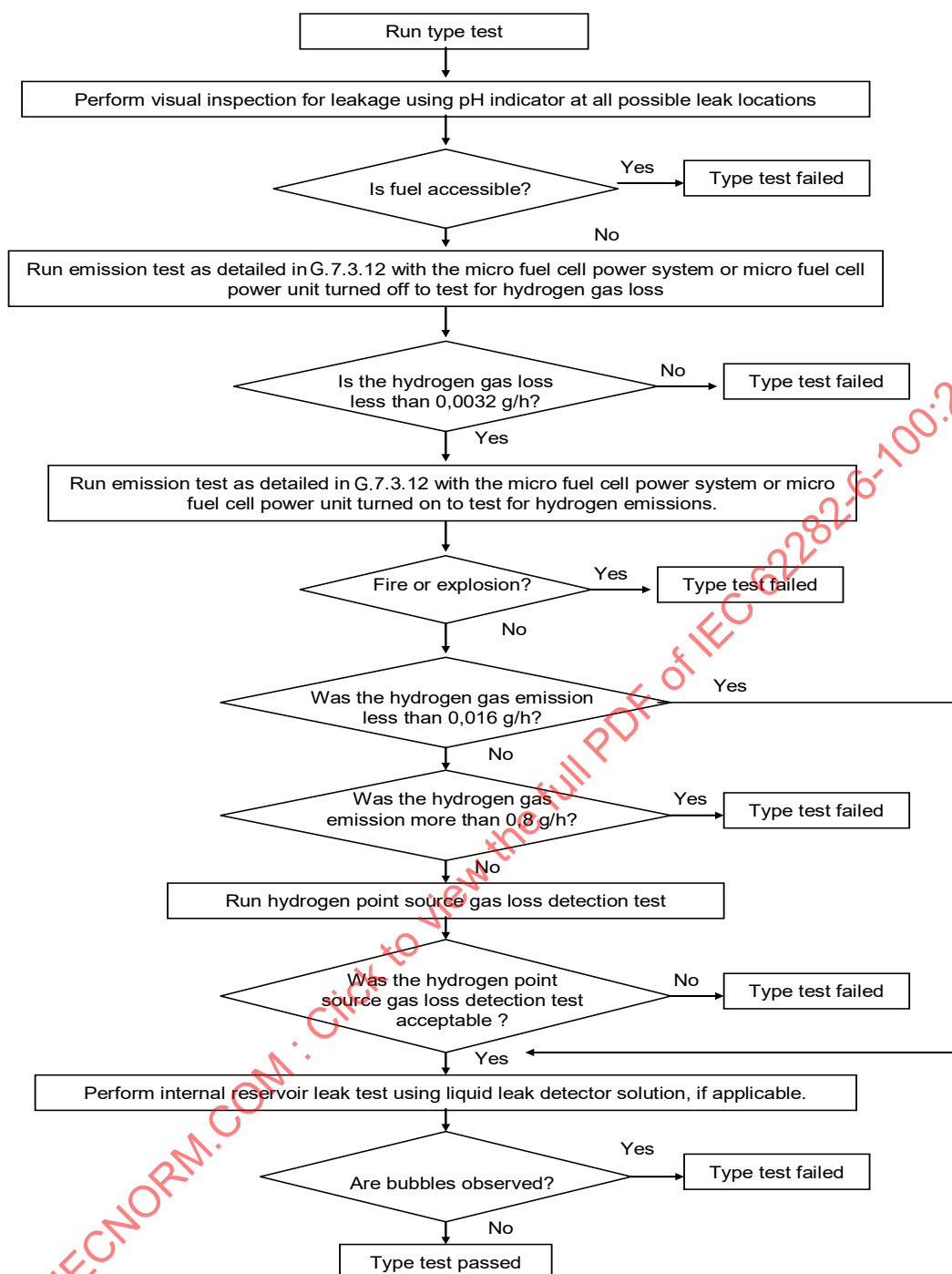


Figure G.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss flow chart for pressure differential, vibration, temperature cycling, drop, and compressive loading tests – Replaces Figure 4

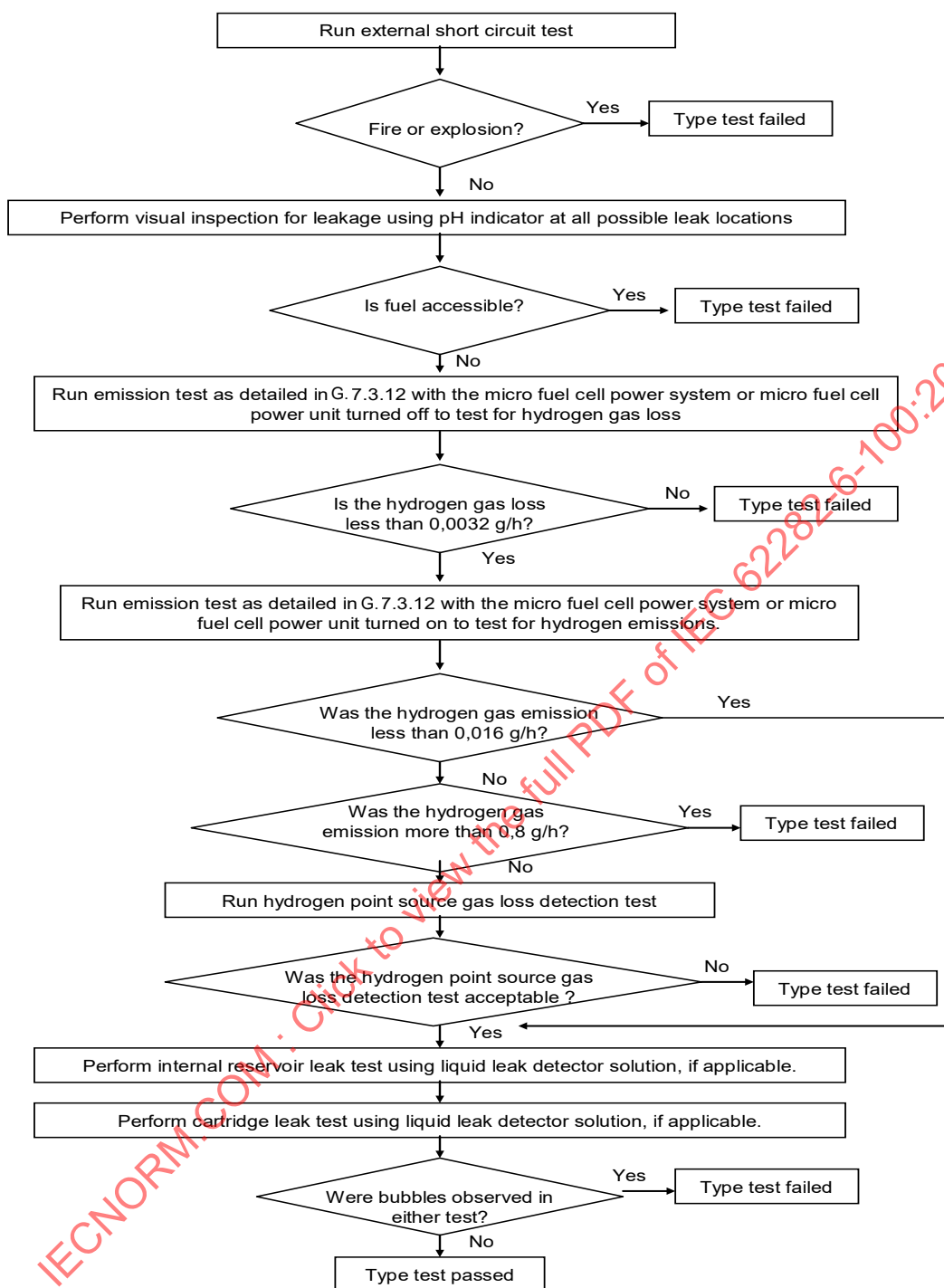


Figure G.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

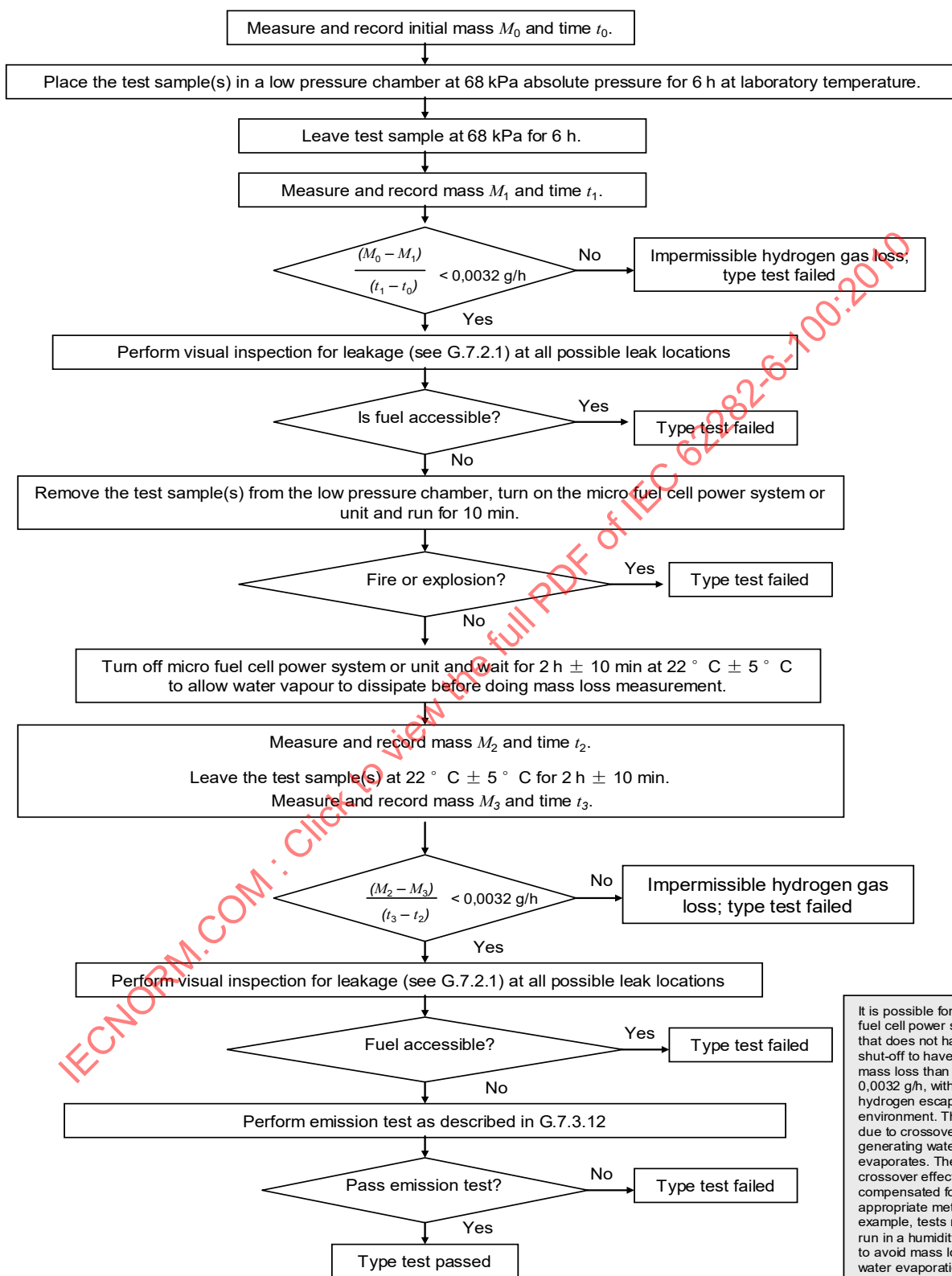


Figure G.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

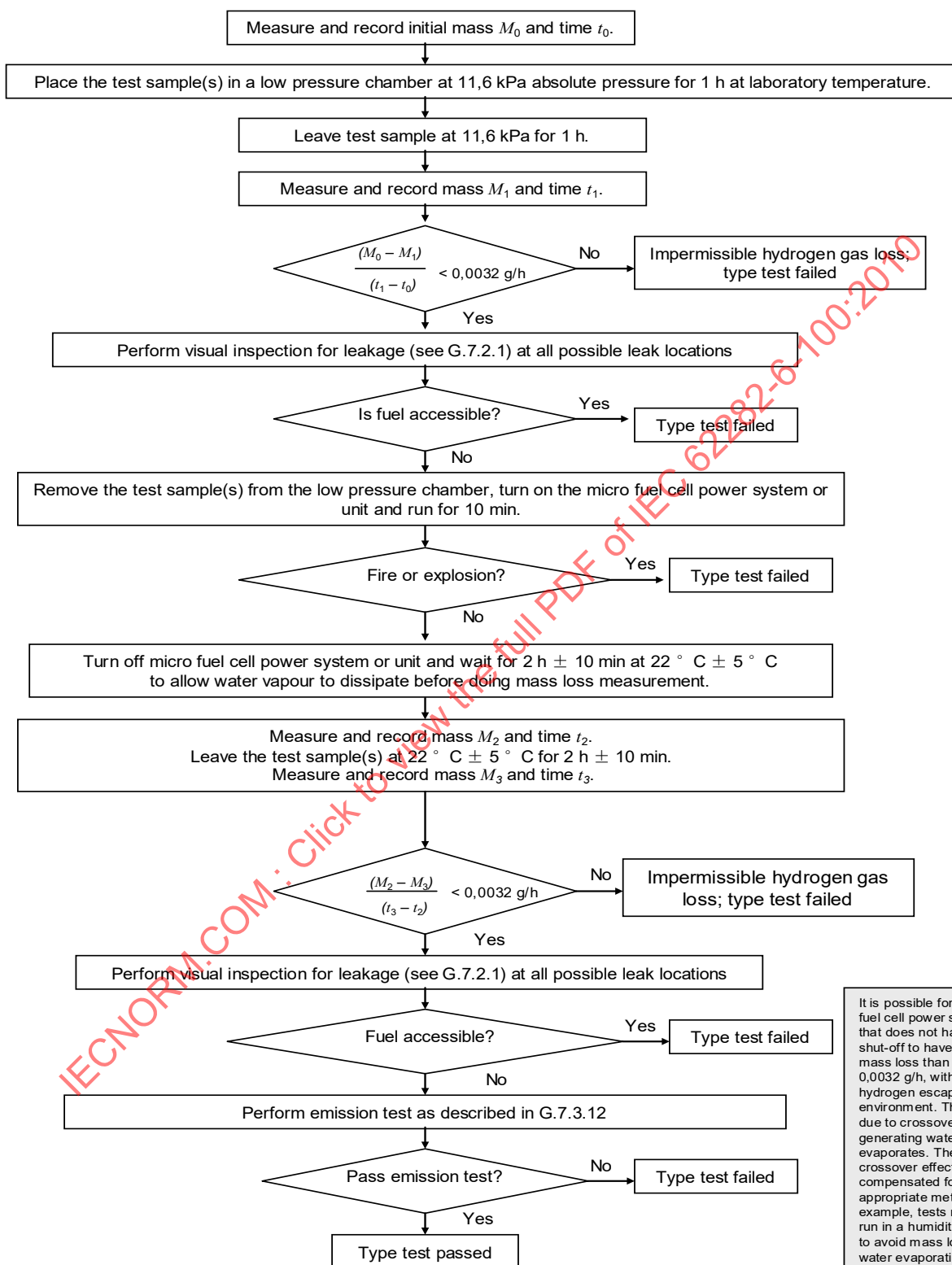


Figure G.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

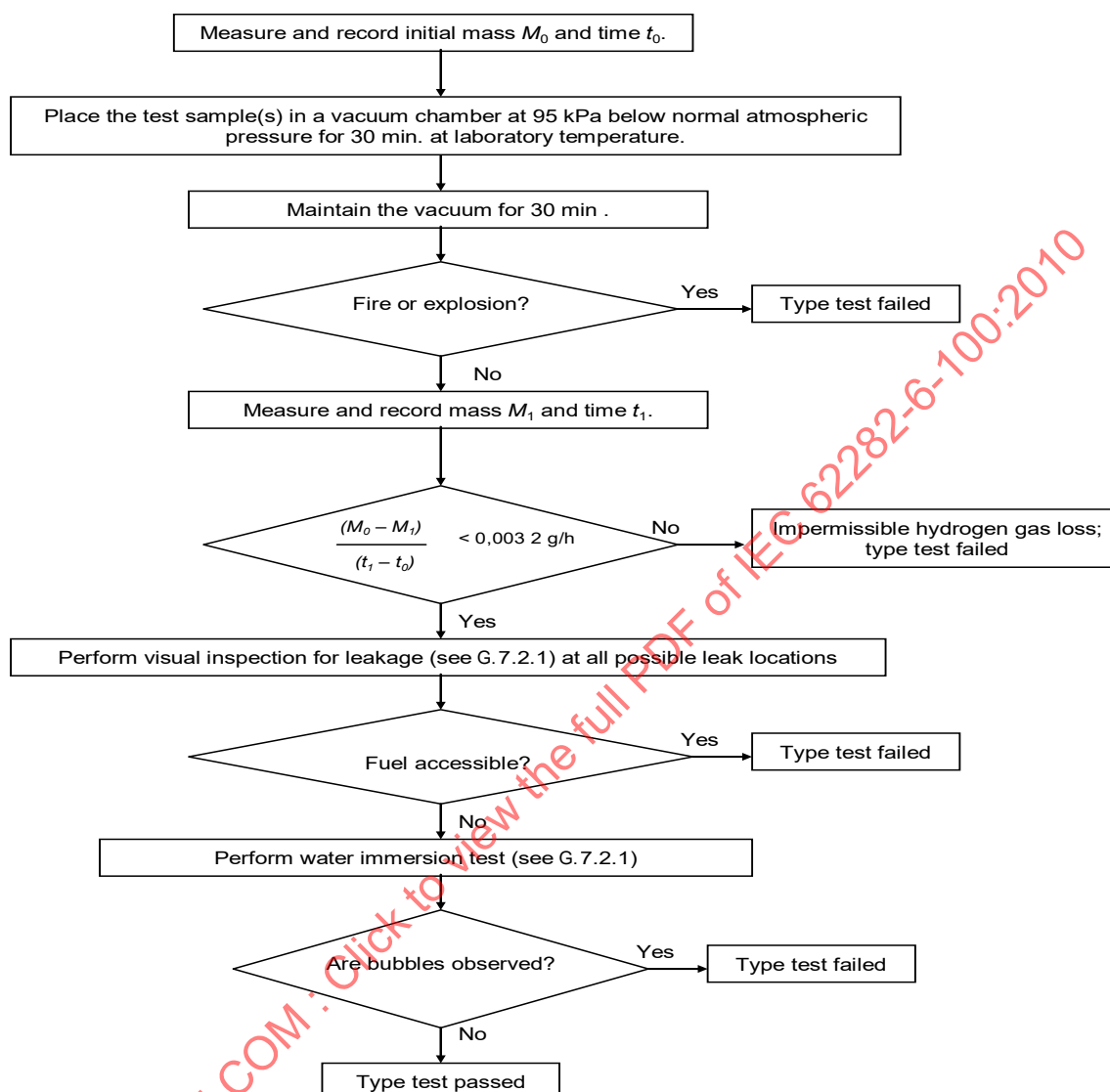


Figure G.13 – Fuel cartridge leakage test flow chart for low external pressure test

G.7.3 Type tests

G.7.3.1 Pressure differential tests

G.7.3.1.1 General

Subclause G.7.3.1 replaces Subclause 7.3.1.

Portions of this test check compliance with Subclause 4.12.1.2 to verify that there shall be no leakage from the fuel cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater. Depending upon which of the two limiting pressure conditions is greater, two options for testing are provided:

- a) If 95 kPa internal gauge pressure plus normal working pressure of the fuel cartridge at 22 °C is greater than two times the gauge pressure of the fuel cartridge at 55 °C, either Subclause G.7.3.1.2 or subclause G.7.3.1.3 may be used to verify compliance with Subclause 4.12.1.2.
- b) If two times the gauge pressure of the fuel cartridge at 55 °C is greater than 95 kPa internal gauge pressure plus normal working pressure at 22 °C, Subclause G.7.3.1.2 must be used to verify compliance with Subclause 4.12.1.2.

G.7.3.1.2 Fuel cartridge internal pressurization test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**
For the internal pressurization test, the fuel cartridge body and the fuel cartridge valve shall be tested separately.
 - 1) Using a suitable fluid medium such as mineral oil, pressurize the fuel cartridge body to an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater.
 - 2) The pressure rise shall not exceed a rate of 60 kPa/s.
 - 3) Maintain the maximum pressure for 30 min at laboratory temperature.
 - 4) Using a suitable fluid medium such as mineral oil, pressurize the closed fuel cartridge valve to 95 kPa gauge pressure plus the normal working pressure of the cartridge at 22 °C or two times the gauge pressure of the fuel cartridge at 55 °C, whichever is greater.
 - 5) The pressure rise shall not exceed a rate of 60 kPa/s.
 - 6) Maintain the maximum pressure for 30 min at laboratory temperature.
- d) **Passing criteria:** No accessible liquid test medium leakage and no sudden drop of pressure during the course of the test. Leakage shall be checked visually. Invert the fuel cartridge and the fuel cartridge valve over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage; if any accessible liquid leakage is found, the test fails.

NOTE Class 8 (corrosive) borohydride fuel will chemically react with water, therefore, water or water-containing substances should not be used as the fluid test medium. Class 8 (corrosive) borohydride fuels have the potential to react with substances other than water, therefore, the chemical reactivity and stability of the particular Class 8 (corrosive) borohydride fuel being tested should be used to guide the selection of a suitable liquid test medium.

G.7.3.1.3 Fuel cartridge low external pressure test

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure G.13.
 - 2) The sample shall be placed in a vacuum chamber and the pressure in the vacuum chamber shall be reduced to 95 kPa below normal atmospheric pressure.
 - 3) Maintain the vacuum for 30 min.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no Class 8 (corrosive) fuel or liquid fuel component leakage. See Figure G.2. Hydrogen gas loss shall meet the requirements of Subclause G.7.2.3 (less than 0,0032 g/h). Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

G.7.3.1.4 Micro fuel cell power system or micro fuel cell power unit pressure differential tests**G.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test**

This test is required for all Class 8 (corrosive) borohydride micro fuel cell power systems and all Class 8 (corrosive) borohydride micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure G.6.
 - 2) Test samples shall be stored at a low external pressure of 68 kPa absolute pressure for 6 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure G.6.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with G.7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel components liquid leakage. See Figure G.6. Remove the fuel cartridge, if present, from the micro fuel cell power system. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Hydrogen gas loss shall be determined by the mass loss measurement as shown in Figure G.7. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of G.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of G.7.3.12, the emission test result is acceptable.

G.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

This test is required for all Class 8 (corrosive) borohydride micro fuel cell power systems and all Class 8 (corrosive) borohydride micro fuel cell power units.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure G.7.
 - 2) Test samples shall be stored at a low external pressure of 11,6 kPa absolute pressure for 1 h at laboratory temperature. Leakage shall be measured on the basis of the procedure described in Figure G.7.
 - 3) For the micro fuel cell power system or unit, perform emission testing in accordance with G.7.3.12.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel components liquid leakage. See Figure G.7. Remove the fuel cartridge, if present, from the micro fuel cell power system / unit. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Hydrogen gas loss shall be determined by the mass loss measurement as shown in Figure G.7. Fire or flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emission testing shall meet the passing criteria of G.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of G.7.3.12, the emission test result is acceptable.

G.7.3.2 Vibration test

Subclause G.7.3.2 replaces Subclause 7.3.2 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

- a) **Test sample:** an unused fuel cartridge, a partially filled fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in G.7.3.1 or a micro fuel cell power system used in G.7.3.1.
- b) **Purpose:** to simulate the effects of normal transportation vibration and ensure no leakage.
- c) **Test procedure:**
- 1) Perform these tests in accordance with Figure G.2 for the fuel cartridge and Figure G.4 for the micro fuel cell power system or unit.
 - 2) The test sample shall be firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.
 - 3) The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min.
 - 4) This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions of the test samples.
 - 5) The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g_n is maintained until 18 Hz is reached. The amplitude is then maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of 8 g_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.
 - 6) For the micro fuel cell power system or unit, perform emission testing in accordance with 7.3.12.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte of liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in G.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of G.7.3.12, the emission test is acceptable.

G.7.3.3 Temperature cycling test

Subclause G.7.3.3 replaces Subclause 7.3.3 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

- a) **Test sample:** a fuel cartridge used in G.7.3.2, a used fuel cartridge used in G.7.3.2, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in G.7.3.2 or a micro fuel cell power system used in G.7.3.2.
- b) **Purpose:** to simulate the effects of low-temperature and high temperature exposure and the effects of extreme temperature change.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure G.3 for the fuel cartridge and Figure G.4 for the micro fuel cell power system or unit.
 - 2) For a fuel cartridge, two fuel cartridge orientations shall be tested – valve up and valve down. For a micro fuel cell power system or a micro fuel cell power unit, only one orientation needs to be tested.
 - 3) See Figure G.8 for the temperature profile to be used.
 - 4) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from laboratory temperature to $55\text{ °C} \pm 2\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $55\text{ °C} \pm 2\text{ °C}$ for a minimum of 4 h.
 - 5) Decrease the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$ then decrease the chamber temperature to $-40\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $-40\text{ °C} \pm 5\text{ °C}$ for a minimum of 4 h.
 - 6) Increase the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$.
 - 7) The above process is to be done twice.
 - 8) After 1 h at $22\text{ °C} \pm 5\text{ °C}$, leakage and fuel vapour loss shall be measured based upon the procedure described in Figure G.3 (for fuel cartridge) and Figure G.4 (for micro fuel cell power system or unit).
 - 9) For the micro fuel cell power system or micro fuel cell power unit, perform emission testing in accordance with G.7.3.12.
 - 10) For an internal reservoir, if applicable, perform hydrogen leakage measurement testing, in accordance with G.7.2.1.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in G.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of G.7.3.12, the emission test is acceptable.

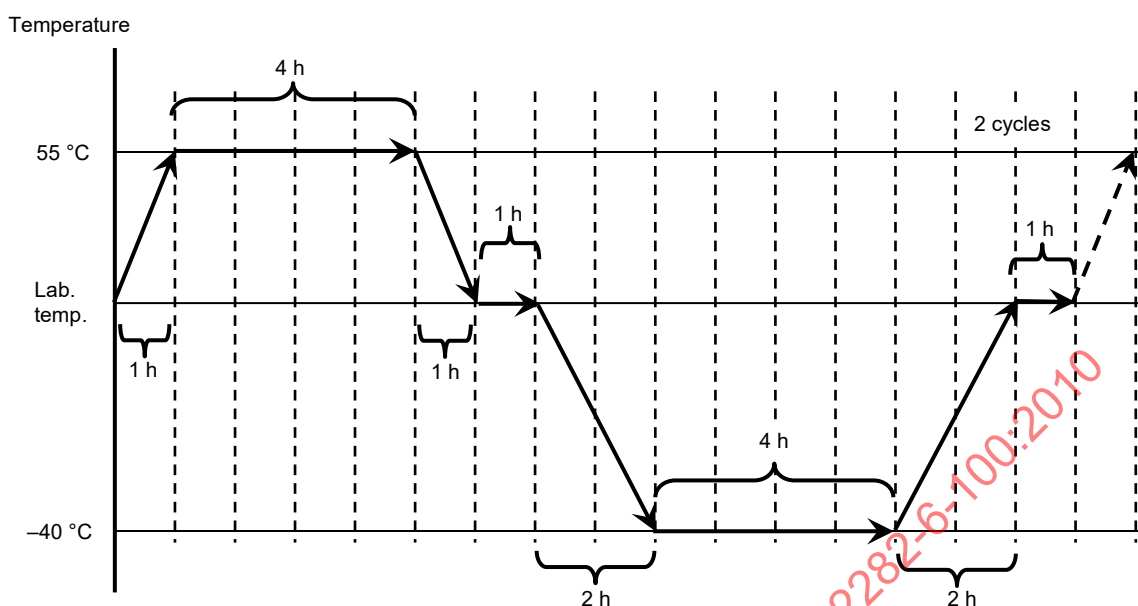


Figure G.8 – Temperature cycling – Replaces Figure 8

G.7.3.4 High temperature exposure test

Subclause G.7.3.4 replaces Subclause 7.3.4 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of a fuel cartridge left in high temperature environments.
- c) **Test procedure:**
 - 1) Two orientations shall be tested – valve up and valve down.
 - 2) Place the test sample in a temperature controlled test chamber that is at a temperature of $70\text{ °C} \pm 2\text{ °C}$ and allow chamber temperature to recover to $70\text{ °C} \pm 2\text{ °C}$ and maintain that temperature for at least 4 h with the sample in the chamber.
 - 3) Remove the test sample to laboratory temperature.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

G.7.3.5 Drop test

Subclause G.7.3.5 replaces Subclause 7.3.5 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

- a) **Test sample:** an unused fuel cartridge, a used fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an inadvertent drop and ensure no leakage.

c) Test procedure:

- 1) The test sample shall be dropped on a horizontal surface that consists of hardwood at least 13 mm thick, mounted on two layers of plywood each 18 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor from a predetermined height.
 - 2) The height of the drop shall be:
 - i) 1 200 mm $\pm$ 10 mm: in the case of a micro fuel cell power unit and/or a micro fuel cell power system;
 - ii) 1 500 mm $\pm$ 10 mm: in the case of a fuel cartridge of more than 200 g solid fuel or more than 200 ml of liquid fuel component;
 - iii) 1 800 mm $\pm$ 10 mm: in the case of a fuel cartridge of up to 200 g of solid fuel or up to 200 ml of liquid fuel component.
 - 3) For the fuel cartridge tests, the drop test shall be carried out in four drop orientations with the same sample.
 - 4) For the micro fuel cell power unit or the micro fuel cell power system, one micro fuel cell power system or unit may be used for all four drop orientations, or more than one micro fuel cell power system or unit may be used in subsequent drops, at the discretion of the manufacturer.
 - 5) For all tests, drop orientations shall be:
 - i) valve up;
 - ii) valve down;
 - iii) two other mutually perpendicular orientations.
 - 6) For micro fuel cell power system or micro fuel cell power unit tests, perform emission testing in accordance with G.7.3.12.
 - 7) For an internal reservoir, if applicable, perform hydrogen leakage measurement testing, in accordance with G.7.2.1.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in G.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of G.7.3.12, the emission test is acceptable. If the micro fuel cell power system or unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

G.7.3.6 Compressive loading test

Subclause G.7.3.6 replaces Subclause 7.3.6 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

G.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the micro fuel cell power unit, or micro fuel cell power system.

c) **Test procedure:**

- 1) The micro fuel cell power system or unit test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $245 \text{ N} \pm 9,8 \text{ N}$.
- 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
- 3) A compressive force of $245 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
- 4) The test shall be carried out in three mutually perpendicular orientations as a rule. If the sample would not stand on its own, it does not need to be tested in that orientation.
- 5) Perform emission testing in accordance with G.7.3.12 following the compressive loading test.
- 6) For an internal reservoir, if applicable, perform hydrogen leakage measurement testing, in accordance with G.7.2.1.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte of liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit. Emissions shall meet the passing criteria in G.7.3.12. If the micro fuel cell power system/unit does not operate but emissions do not exceed the limits of G.7.3.12, the emission test is acceptable.

G.7.3.6.2 Fuel cartridge

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge.

- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the fuel cartridge.

c) **Test procedure:**

- 1) The fuel cartridge test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $981 \text{ N} \pm 9,8 \text{ N}$.
- 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
- 3) A compressive force of $981 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
- 4) Fuel cartridge orientations shall be selected on the basis of likely stable resting positions when accidentally dropped (e.g. those orientations having the lowest centres of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic fuel cartridge that is sufficiently cubic and the curved surface of a cylindrical fuel cartridge with a longitudinal axis length longer than twice the diameter.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte of liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually.

G.7.3.7 External short-circuit test

Subclause G.7.3.7 replaces Subclause 7.3.7 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an external short-circuit.
- c) **Test procedure:**
 - 1) External short-circuit testing shall be done separately on both operating [DEVICE ON] and non-operating [DEVICE OFF] micro fuel cell power systems or micro fuel cell power units respectively.
 - 2) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power system or unit with wire having a maximum resistance load of 0,1 Ω for at least 5 min.
 - 3) Perform emission testing in accordance with G.7.3.12 after each short-circuit test.
 - 4) For an internal reservoir, if applicable, perform hydrogen leakage measurement testing, in accordance with G.7.2.2.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

Exterior surfaces shall not exceed temperatures in Table 2 during or after short circuit testing.

Emissions shall meet the passing criteria in G.7.3.12. If the micro fuel cell power system or unit does not operate but emissions do not exceed the limits of G.7.3.12, the emission test is acceptable.

NOTE The external short-circuit test can be done sequentially with the surface, component and exhaust gas temperature test using the same sample.

G.7.3.9 Long-term storage test

Subclause G.7.3.9 replaces Subclause 7.3.9 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

- a) **Test sample:** an unused or a used fuel cartridge.
- b) **Purpose:** to simulate the effects of long term storage at elevated temperature and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure G.9 for fuel cartridges.
 - 2) Record initial mass M_0 and time t_0 and place sample in temperature chamber at 50 °C $\pm$ 2 °C with a chamber relative humidity of at least 60 %.
 - 3) The temperature chamber shall be equipped with ventilation and measurement instruments capable of accurately measuring the concentration of hydrogen in the chamber similar to the configuration in Figure G.10.
 - 4) The ventilation flow rate and the hydrogen concentration of interest in the chamber shall be monitored continuously and recorded. See Table G.7. At no time during the test shall the hydrogen concentration in the chamber shall exceed 25 % LFL.
 - 5) The sample shall remain in the chamber at 50 °C $\pm$ 2 °C with a chamber relative humidity of at least 60 % for at least 28 days.

- 6) At the end of the 28 days, remove the fuel cartridge from the test chamber and record the time the fuel cartridge was removed from the test chamber, t_1 . Allow the fuel cartridge to stabilize at laboratory temperature and record the final mass, M_1 . Hydrogen gas loss is calculated as follows and shall not exceed 0,0032 g/h:

$$\frac{M_0 - M_1}{t_1 - t_0} < 0,0032 \text{ g/h}$$

- 7) Perform fuel, fuel byproduct, electrolyte and liquid fuel component leakage testing using visual inspection with pH indicator and water immersion test in accordance with Subclause G.7.2.1 for the fuel cartridge.
- 8) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power system. Check for fuel, fuel byproduct, electrolyte, or liquid fuel component leakage using visual inspection with pH indicator and water immersion test as described in G.7.2.1. See Figure G.9.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No impermissible hydrogen gas loss and no leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, or liquid fuel components. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge. The hydrogen concentration in the chamber shall not exceed 25 % LFL at any time during the test. The hydrogen gas loss rate from the cartridge shall not exceed 0,0032 g/h at any time during the test. Fire, flame and explosion shall be checked using cheesecloth, infrared camera, or other suitable methods.

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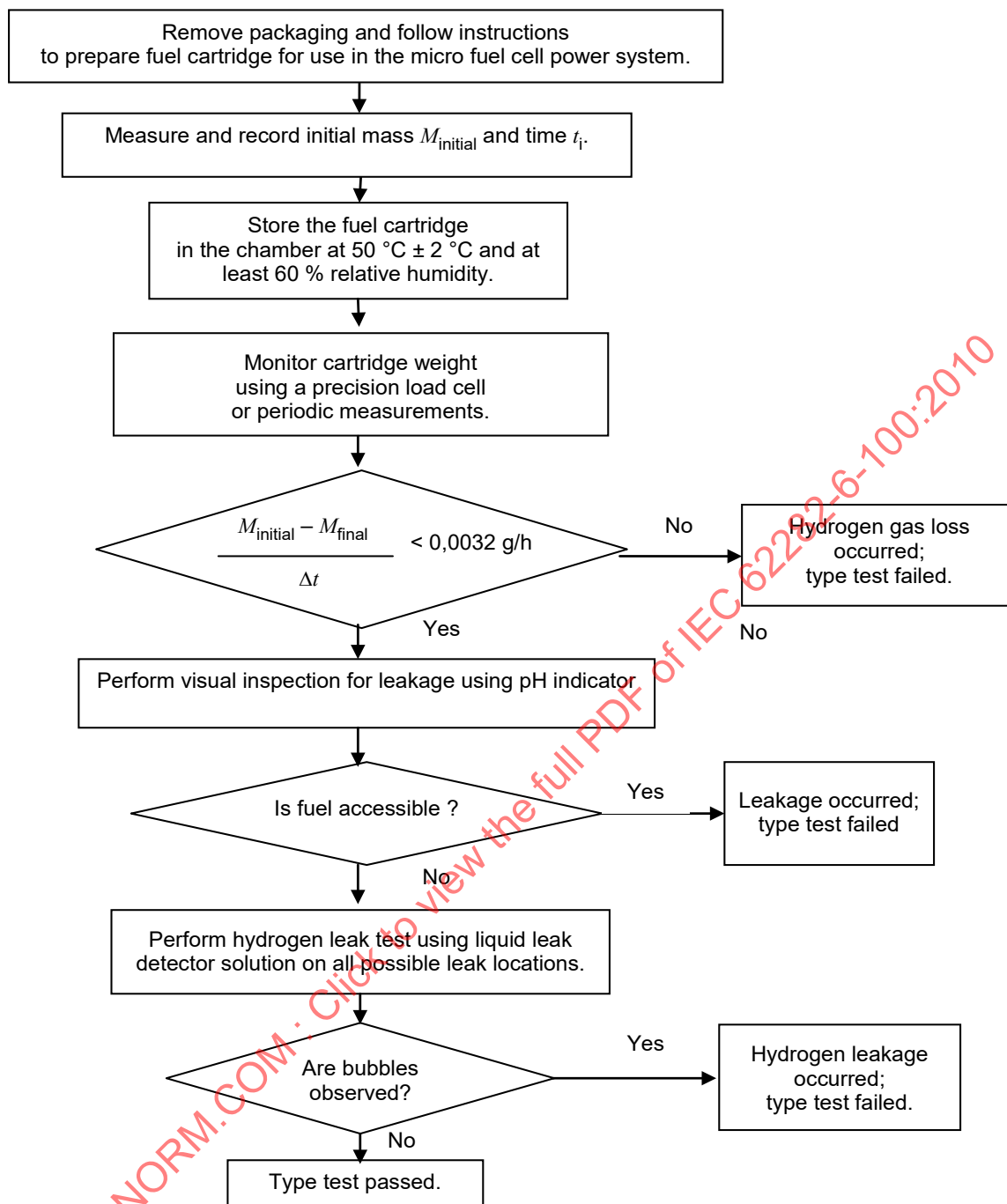


Figure G.9 – Fuel cartridge hydrogen leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

G.7.3.10 High-temperature connection test

Subclause G.7.3.10 replaces Subclause 7.3.10 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

- a) **Test sample:** an unused fuel cartridge or a used fuel cartridge and a micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry.

- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage, no fire, no explosion.
- c) **Test procedure:**
 - 1) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of $50\text{ °C} \pm 2\text{ °C}$ for at least 4 h.
 - 2) The micro fuel cell power unit or test fixture with micro fuel cell power unit valve is kept at laboratory temperature.
 - 3) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or test fixture with micro fuel cell power unit valve within 5 min of removal from the chamber.
 - 4) Check for leakage upon connection.
 - 5) Disconnect the fuel cartridge and check for leakage.
 - 6) For micro fuel cell power system or micro fuel cell power unit tests, perform emission testing in accordance with G.7.3.12.
 - 7) For an internal reservoir, if applicable, perform hydrogen leakage measurement testing, in accordance with G.7.2.2.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel by-products, electrolyte or liquid fuel components. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, this is acceptable. Leakage of Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte, and liquid fuel components shall be determined visually using pH indicator and with the water immersion test as specified in the leakage measurement and test procedure in Subclause G.7.2.1. Hydrogen leakage shall meet the no hydrogen leakage requirements (no bubbles formed) of the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system/unit.

G.7.3.11 Connection cycling tests

Subclause G.7.3.11 replaces Subclause 7.3.11 for micro fuel cell power systems, units and fuel cartridges covered by this Annex G.

G.7.3.11.1 Fuel cartridge

G.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

- a) **Test sample:** an unused or a used insert cartridge, exterior cartridge or attached cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve and fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve. Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as in the leakage test and measurement procedure specified in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts,

electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in G.7.2.1.

- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage as specified in the leakage test and measurement procedure in Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as in specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage specified in the leakage test and measurement procedure specified in Subclause G.7.2.1.
- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in G.7.2.1.
- 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure specified in Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen specified in the leakage test and measurement procedure in Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as described in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage as specified in the leakage test and measurement procedure in Subclause G.7.2.1.
- 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure in Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the leakage test and measurement procedure in Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 13) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the leakage test and measurement procedure in Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage as specified in the leakage test and

measurement procedure in Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.

- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of the hydrogen leakage measurement procedure (no bubbles) of Subclause G.7.2.2 for the fuel cartridge. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause G.7.2.3. Emissions must meet passing criteria of Subclause G.7.3.12 for operational and non-operating systems.

G.7.3.11.1.2 Satellite cartridge

- a) **Test sample:** an unused satellite fuel cartridge and an unused micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
- 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve. Check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproduct, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1. Initiate or simulate fuel flow.
 - 2) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 3) Repeat this twice more for a total of three connections and disconnections.
 - 4) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria

for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.

- 5) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
 - 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 7) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 9) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and initiate or simulate fuel flow.
 - 10) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 11) Repeat steps 1 through 10 four more times for a total of 55 cycles, waiting 1 h between each set of 11 cycles.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of the hydrogen leakage measurement procedure (no bubbles) of Subclause G.7.2.2 for the fuel cartridge. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause G.7.2.3. Emissions must meet passing criteria of G.7.3.12 for operational and non-operating systems.

G.7.3.11.1.3 Micro fuel cell power unit

- a) **Test sample:** a minimum of two unused fuel cartridges and an additional 98 fuel cartridges or suitable test fixtures with fuel cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the fuel cartridge valve geometry and material and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage both at initial use and after suitable ageing of the micro fuel cell power unit connection.

First fuel cartridge (#1) and final fuel cartridge (#100) are inspected; the other 980 cycles are only to age the micro fuel cell power unit.

In the case of a micro fuel cell power unit using satellite cartridge, it shall be tested according to the following procedure by simulating fuel flow between the satellite cartridge and the micro fuel cell power unit.

c) Test procedure:

- 1) Connect the first fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 4) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 5) Repeat this twice more for a total of three connections and disconnections.
- 6) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.

- 7) Connect and disconnect the first fuel cartridge four more times for a total of seven connections and disconnections.
- 8) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 9) Connect and disconnect the first fuel cartridge three more times for a total of ten connections and disconnections.
- 10) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 11) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 12) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
- 13) Turn off the micro fuel cell power unit or stop simulated fuel flow.
- 14) Disconnect the first fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 15) In order to age the micro fuel cell power unit fuel cartridge connection, perform the following steps.

- i) Using either fuel cartridges or a suitable test fixture with fuel cartridge valves, cycle the micro fuel cell power unit fuel cartridge connection for a total of 980 connections and disconnections.
 - ii) Simulate fuel flow after each set of 50 connection-disconnection cycles.
 - iii) Inversion of the micro fuel cell power unit or the fuel cartridges is not necessary, but, if leakage is found, the test fails.
 - iv) Following this ageing, a final unused fuel cartridge will be tested.
- 16) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 17) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 18) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 19) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 20) Repeat this twice more for a total of three connections and disconnections.
 - 21) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 22) Connect and disconnect the final fuel cartridge four more times for a total of seven connections and disconnections.
 - 23) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for

- no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- 24) Connect and disconnect the final fuel cartridge three more times for a total of ten connections and disconnections.
 - 25) Check for hydrogen leakage using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 26) Connect the fuel cartridge to the micro fuel cell power unit and check for hydrogen leakage upon connection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon connection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
 - 27) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 28) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 29) Disconnect the fuel cartridge and check for hydrogen leakage upon disconnection using a liquid leak detector (bubble forming) solution in accordance with the hydrogen leakage measurement procedure of Subclause G.7.2.2 for the fuel cartridge, the fuel management system and internal reservoir, if applicable. Hydrogen leakage shall meet the criteria for no hydrogen leakage found in the hydrogen leakage measurement procedure of Subclause G.7.2.2. Check for Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage upon disconnection using visual inspection with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall meet the criteria for no leakage found in the leakage test and measurement procedure in Subclause G.7.2.1.
- d) **Passing criteria:** No fire or flame at any time. No explosion at any time. No hydrogen leakage, no Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte or liquid fuel component leakage, no impermissible hydrogen gas loss or emissions. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually. Hydrogen leakage shall meet the no hydrogen leakage requirements of the hydrogen leakage measurement procedure (no bubbles) of Subclause G.7.2.2 for the fuel cartridge and internal reservoir, if applicable. Class 8 (corrosive) borohydride fuel, fuel byproducts, electrolyte and liquid fuel component leakage shall be tested visually with pH indicator as specified in the leakage test and measurement procedure in Subclause G.7.2.1. Hydrogen gas loss shall meet the requirements of Subclause G.7.2.3. Emissions must meet passing criteria of G.7.3.12 for operational and non-operating systems.

G.7.3.12 Emission test

This Subclause G.7.3.12 shall replace Subclause 7.3.12 for Class 8 (corrosive) borohydride micro fuel cell power systems or units tested in accordance with Annex G. The included Table G.7, Emission limits, replaces Table 7 in Subclause 7.3.12. Figure G.10 replaces Figure 10 and is identical to Figure 10. Hydrogen emissions are evaluated separately. The procedure for hydrogen emission testing is detailed in Figure G.12, which is to be used as an additional figure when testing is done in accordance with Annex G.

- a) **Test sample:** A micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under normal operating conditions, indirect borohydride powered micro fuel cell power systems may have emissions. The emissions may be comprised of water or hydrogen, both of which are known not to be toxic. Indirect borohydride micro fuel cell power systems do not normally emit CO, CO₂, formaldehyde or other volatile organic compounds. However, there is a remote possibility that indirect borohydride micro fuel cell power systems utilizing fuels or liquid fuel components containing organic additives may emit CO, CO₂, formaldehyde, or other volatile organic compounds under abnormal circumstances. Because this possibility exists, emission limits for CO, CO₂, formaldehyde, and volatile organic compounds for micro fuel cell power systems utilizing fuels or liquid fuel components containing organic compounds are imposed by this annex and are listed in Table G.7.

Micro fuel cell power systems emit water vapour and under certain conditions this water vapour can condense. This condensation is not considered an emission or a leak if the pH of the condensate is between 3,5 pH and 10,5 pH.

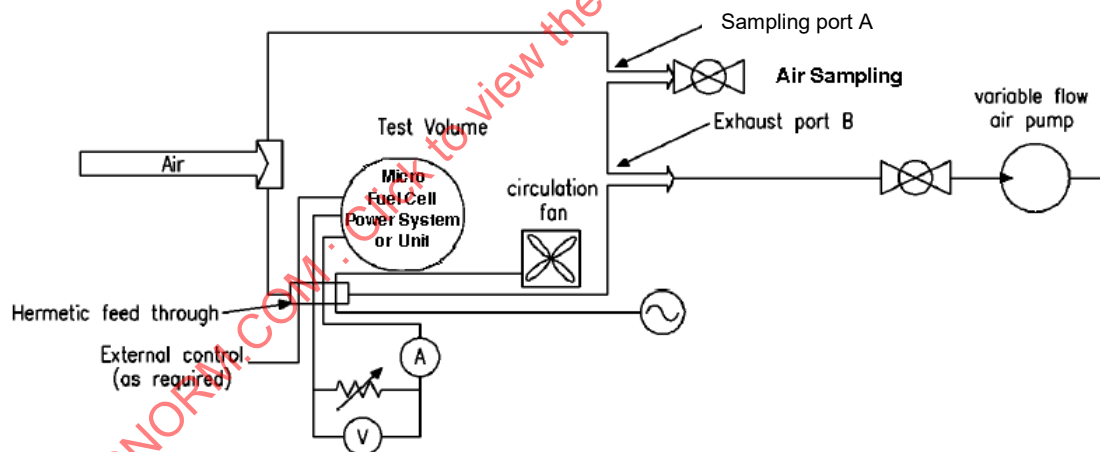


Figure G.10 – Operational emission rate testing apparatus – Replaces Figure 10

- c) **Test apparatus:** An example of the operational emission test apparatus is shown in Figure G.10. The configuration shown in Figure G.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex G. Emission rate testing in accordance with G.7.3.12 d) 1) is required for all types of micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex G.

To analyse the hydrogen emissions, a mass spectrometer, gas chromatograph, or other suitable instrument calibrated to measure hydrogen concentration shall be used and connected to sampling port A in Figure A.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

For micro fuel cell power systems or units that are intended to be used in close proximity to a consumer's mouth or nose (such as micro fuel cell power systems or units used to power cell phones, handheld games, etc.), additional testing in accordance with G.7.3.12 d) 3) and G.7.3.12 d) 4) is required to verify that emission concentrations in the vicinity of a user's mouth or nose are kept within appropriate limits. This emission concentration testing shall be done in a large open room using a different emission concentration testing apparatus. An example of the operational emission concentration testing apparatus is shown in Figure G.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell power system or unit to a consumer's mouth or nose when in use) for emissions concentration limit testing.

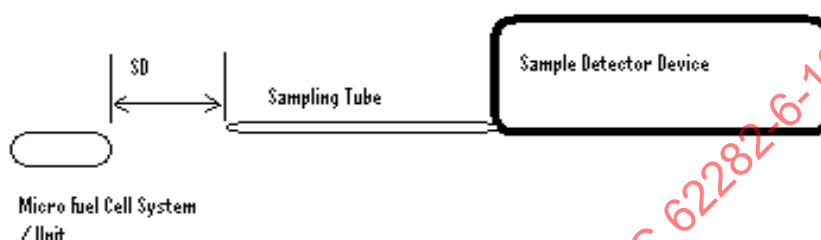


**Figure G.11 – Operational emission concentration testing apparatus –
Replaces Figure 11**

Emission gases might be composed of toxic organic materials such as carbon dioxide, carbon monoxide and formaldehyde, which are potentially exhausted from a micro fuel cell power system or a micro fuel cell power unit.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) shall be used by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyzer through sampling port A in Figure G.10. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

A hydrogen detector calibrated for the zero-to-one-percent mass concentration hydrogen range can be used to measure the hydrogen concentration.

The concentration of CO and CO₂ gas can be measured by a non-dispersive infrared absorption analyzer. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) Test procedure:

Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure G.12, which is to be used as an additional figure when testing is done in accordance with Annex G.*

Emission rate sampling tests shall be performed both with the micro fuel cell power system or unit on ("DEVICE – ON") and with the micro fuel cell power system or unit off ("DEVICE – OFF") as follows.

- 1) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed with the micro fuel cell power system or unit on ("DEVICE – ON") as follows.
 - i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure G.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test

shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").

- ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- iii) Gaseous emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure G.10.
- iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure G.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vi) Record the concentrations of chemical compounds of interest. See Table G.7.
- vii) Calculate the emission rate of chemical compounds being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:

$$ER = (F_P + F_S) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in litres per hour;

F_S is the sample flow rate in litres per hour;

C is the concentration in grams per litre.

- viii) Compare the maximum measured "DEVICE – ON" emission rate to Table G.7. If the emission rate is not less than the emission rate limit in Table G.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria G.7.3.12 e) 1) i) and G.7.3.12 e) 2) i).
 - ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 2) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emissions concentration sampling test shall be performed with the micro fuel cell power system or unit on "DEVICE – ON" as follows.
- i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling system do not contribute emissions (that is, contaminants) to the test. Prior to testing, a system check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results. Air changes in the room shall be kept to a minimum corresponding to

- normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
- ii) Operate the micro fuel cell power system or micro fuel cell power unit at rated power in the large open room while sampling the emission concentrations using the operational emission concentration testing apparatus shown in Figure G.11. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission concentration test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "ON" position ("DEVICE – ON").
 - iii) Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - iv) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the operational emission concentration testing apparatus shown in Figure G.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - v) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - vi) Allow the sample flow rate to stabilise.
 - vii) Sample and record the fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - viii) Record the concentrations of the chemical compounds of interest. See Table G.7.
 - ix) Compare the maximum measured concentrations to Table G.7. If the emission concentrations are not less than the emission concentration limits in Table G.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria G.7.3.12 e) 2) ii).
 - x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 3) Upon completion of the emissions measurements with both "DEVICE – ON" and "DEVICE – OFF" in accordance with Table G.7, "DEVICE – ON" hydrogen emissions are evaluated as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure G.10. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "on" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure G.10.
 - iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.

- v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure G.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
- vi) Record the hydrogen concentration.
- vii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:

$$ER = (F_P + F_S) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in litres per hour;

F_S is the sample flow rate in litres per hour;

C is the concentration in grams per litre.

- viii) Compare the maximum measured "DEVICE – ON" hydrogen emission rate to Table G.7.

NOTE This is a stabilised concentration measurement.

- ix) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.
- 4) Upon completion of the hydrogen emissions measurements with "DEVICE – ON", hydrogen emissions with ("DEVICE – OFF") are evaluated as follows.
- i) Operate the micro fuel cell power system or micro fuel cell power unit at rated power inside the small test chamber shown in Figure G.10 for 10 min or until 10 % of the fuel capacity of a full fuel cartridge is used up, whichever is less.
 - ii) Turn the micro fuel cell power system or unit off ("DEVICE – OFF") and measure the emission rates with the micro fuel cell power system or unit off ("DEVICE – OFF") inside the small test chamber shown in Figure G.10.
 - iii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iv) Gaseous hydrogen emissions from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown on Figure G.10.
 - v) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - vi) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure G.10, while simultaneously measuring and recording the variable flow air pump flow rate and measuring and recording the sample flow rate through air sampling port A.
 - vii) Record the hydrogen concentration.
 - viii) Calculate the emission rate of hydrogen being emitted by multiplying the maximum stabilized concentration of hydrogen by the simultaneous total air flow through the system. The total air flow through the system is determined by adding

the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate. See below:

$$ER = (F_P + F_S) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in litres per hour;

F_S is the sample flow rate in litres per hour;

C is the concentration in grams per litre.

- ix) Compare the maximum measured "DEVICE – OFF" hydrogen emission rate to Table G.7.

NOTE This is a stabilised concentration measurement.

- x) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

5) Evaluate the hydrogen emission rate as follows.

- i) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and below the allowable 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or unit passes the test and no further testing is necessary.
- ii) If the hydrogen emission rate measurement is not below the allowable 0,0032 g/h with the "DEVICE – OFF" and not below the total allowable 0,8 g/h with the "DEVICE – ON", the system or unit fails the test and no further testing is necessary.
- iii) If the hydrogen emission rate measurement is below the allowable 0,0032 g/h with the "DEVICE – OFF" and is below the total allowable 0,08 g/h with the "DEVICE – ON" but is not below 0,016 g/h with the "DEVICE – ON", then proceed with B.7.3.13, hydrogen point source gas loss detection test to verify that no single source of hydrogen exceeds 0,016 g/h.

e) **Passing criteria:**

- 1) For micro fuel cell power systems and micro fuel cell power units not intended to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table G.7 shall be less than the emission rate limit value in Table G.7 when tested in accordance with G.7.3.12 d) 1) for "DEVICE – ON". If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 2) For micro fuel cell power systems and micro fuel cell power units to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table G.7 shall be less than the emission rate limit value in Table G.7 when tested in accordance with G.7.3.12 d) 1) for "DEVICE – ON" and G.7.3.12 d) 2) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.

- ii) For micro fuel cell power systems and micro fuel cell power units intended to be used in close proximity to a consumer's mouth or nose; in addition to meeting the emission rate limit above, the maximum emission concentration for each of the constituents of interest shall not exceed the emission concentration limit in Table G.7 when tested in accordance with G.7.3.12 d) 3) "DEVICE – ON" and G.7.3.12 d) 4) for "DEVICE – OFF" testing respectively. If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 3) Hydrogen emissions are evaluated separately. *The procedure for hydrogen emission testing is detailed in Figure G.12, which is to be used as an additional figure when testing is done in accordance with Annex G.* Upon completion of the hydrogen emissions measurements with both "DEVICE – ON" and "DEVICE – OFF" in accordance with Table G.7, hydrogen emissions are evaluated as follows.
 - i) **Passing criteria for non-operating systems:** The hydrogen emission rate shall be less than 0,0032 g/h with the "DEVICE – OFF".
 - ii) **Passing criteria for operational systems:** If the total hydrogen emission rate is less than 0,016 g/h with the "DEVICE – ON", the micro fuel cell power system or micro fuel cell power unit passes the emission test and no further testing is required. If the total hydrogen emission rate is not less than 0,8 g/h with the "DEVICE – ON", the micro fuel cell power system or unit fails the emission test and no further testing is required. If the hydrogen emission rate is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON", G.7.3.13, hydrogen point source gas loss detection test must be performed with acceptable results to show no more than 0,016 g/h hydrogen leakage from any single point leak.

NOTE 1 The allowable flammable hydrogen emission level that will not support a standing flame is 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain and M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). The non-flammable hydrogen emissions limit is based on the criteria that hydrogen emission does not build up to more than 25 % of LFL in the reference volume.

NOTE 2 Hydrogen is defined as a simple asphyxiant but for this risk to exist, oxygen levels have to fall less than 18 % at normal atmospheric pressure. Hydrogen related flammability risk arises at hydrogen-in-air concentrations greater than 4 %, while the asphyxiant risk arises at hydrogen-in-air concentrations greater than 12 %. Therefore, the flammability limits are used in defining the limits for hydrogen emissions.

NOTE 3 Carbon dioxide and carbon monoxide vapour emission level limits are based on toxicity effects on humans while the hydrogen emissions level limit is based on the risk of creating a flammable atmosphere in confined spaces and the risk of a potential standing hydrogen flame.

Table G.7 – Emission limits – Replaces Table 7

Emissions	"DEVICE – ON" Concentration limit ^a based on TWA values for "DEVICE – ON" test condition	"DEVICE – ON" Permissible emissions rate in 10 m³ ACH volume ^b
Water	Unlimited for pH between 3,5 and 10,5	Unlimited for pH between 3,5 and 10,5
Hydrogen	0,8 g/m ³	0,8 g/h total 0,016 g/h from single point leak
Formaldehyde^d	0,000 1 g/m ³	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Volatile organic carbon compounds	0,000 1 g/m ³	0,000 6 g/h

Table G.7 replaces Table 7.

^a The concentration limits for CO and CO₂ in this table are the mg/m³ equivalent of the TWA and STEL exposure limits.

^b The "DEVICE – ON" emission rate limit was based on 10 m³ ACH, selected as the product of the reference volume times the air changes per hour (ACH) because it covers the reasonably foreseeable environments where micro fuel cell power systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is over 20 m³, so a product of 10 is conservative.

^c A seated human adult has a CO₂ emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO₂ concentration does not reach the WHO eight-hour concentration limit of 9 g/m³. In an environment with 10 m³ ACH, this limits the contribution from the fuel cell to 60 g/h.

^d WHO guideline limit is 0,000 1 g/m³. Background levels are 0,000 03 g/m³. The emission limit cannot push the background level above the guideline limit.

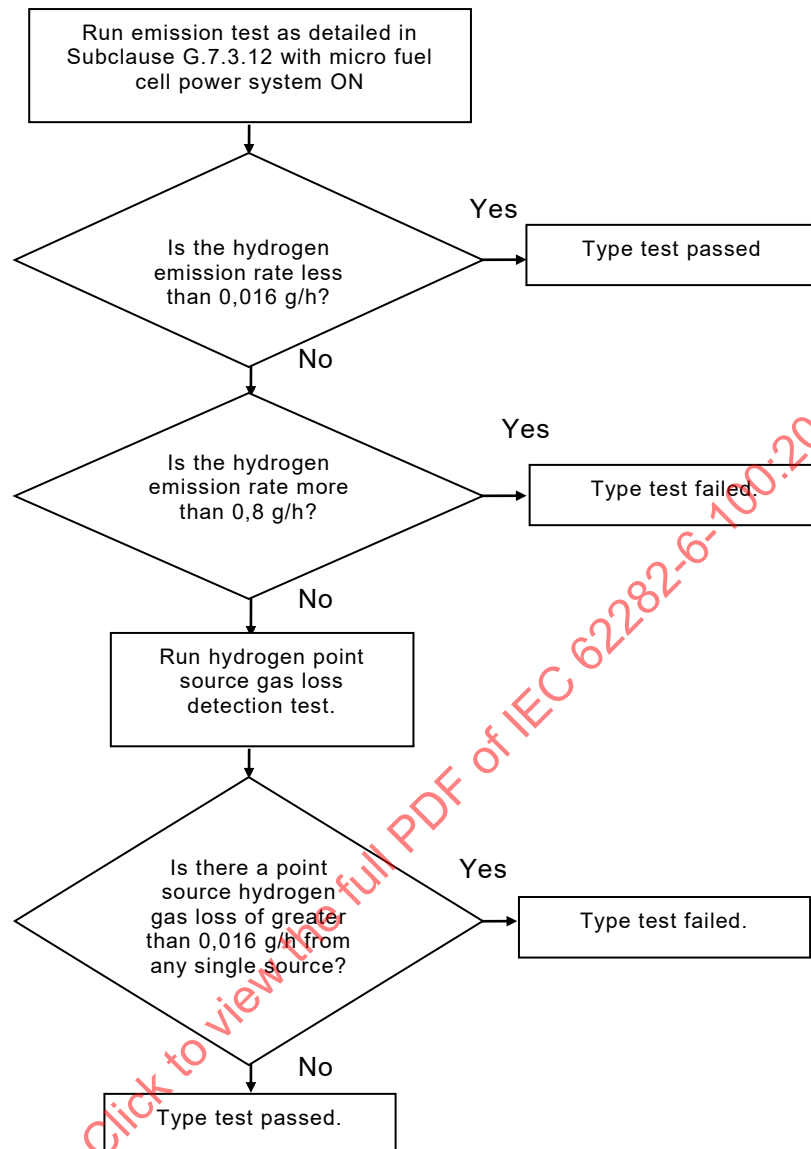


Figure G.12 – Hydrogen emission test procedure for operating micro fuel cell power system

G.7.3.13 Hydrogen point source gas loss detection test

The procedure for hydrogen emission testing is detailed in Figure G.12, which is to be used as an additional figure when testing is done in accordance with Annex G.

This subclause shall be used if required by subclause G.7.3.12 e) 3) ii) to show compliance with Table G.7, for Class 8 (corrosive) borohydride micro fuel cell power systems and Class 8 (corrosive) borohydride micro fuel cell power units. This subclause is required to be performed to meet the passing criteria of Subclause G.7.3.12 e) 3) ii) if the total hydrogen emission rate from an operational Class 8 (corrosive) borohydride micro fuel cell power system or unit is less than 0,8 g/h but more than 0,016 g/h with the "DEVICE – ON". This subclause is additional to the requirements in Clause 7.

- a) **Test sample:** A micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.

- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or a micro fuel cell power unit – that is fuelled with Class 8 (corrosive) borohydride – emission of hydrogen shall be maintained at less than the specified values in Table G.7. The hydrogen point source gas loss detection test shall be performed to determine that no single source on the micro fuel cell power system or unit can support a flame in all cases where such compliance cannot be definitively determined by the hydrogen emission test. Maintaining these limits ensures that, in addition to not permitting a flammable concentration to build up in the reference volume, there is no gas loss of hydrogen from the specimen that could support a flame and along with the other emissions testing ensures an adequate supply of oxygen is maintained in the operating environment.
- c) **Test apparatus:** The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, a hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL. The response of the aforementioned hydrogen detectors is commonly slow, with a response time of many seconds, thus high sweep speeds may cause underestimation of the hydrogen concentration. It is important that the sweep speed shall be slow enough to accurately measure the hydrogen concentration.
- d) **Test procedure:**
- 1) The micro fuel cell power system or micro fuel cell power unit shall remain turned on ("DEVICE – ON") throughout the duration of the hydrogen point source gas loss detection test.
 - 2) The testing shall be conducted in a space with no substantial air movement. The measured wind speed 10 cm above the micro fuel cell power system or unit shall not exceed 0,02 m/s. The local concentration of hydrogen diffusion measured in this test is very susceptible to the effect of wind. It is desirable that wind speed anywhere in the test space is as close to zero as possible. Testing in a closed space, such as a glove box or equivalent chamber, is one available method to achieve this requirement.
 - 3) The surface of the micro fuel cell power system or unit shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen detector, or other instrument suitable for measuring small quantities of hydrogen from a point source that is at least as accurate, if not more so, than the aforementioned instruments. The hydrogen detector shall be tuned to detect a level of hydrogen that is at 25 % of LFL.
 - 4) The sensor of the hydrogen detector shall sweep the micro fuel cell power system or unit at a distance no more than 3 mm normal to the surface of the micro fuel cell power system or unit. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the micro fuel cell power system or unit. The entire surface of the micro fuel cell power system or unit shall be swept in this manner.
 - 5) An effective method for completing these sweeps would be to attach a stand off to the sensor that ensures that a spacing of 3 mm from the micro fuel cell power system or unit is maintained at all times. A pen or other marking utensil attached to the stand off could be used to identify swept areas and ensure that the distance between sweeps does not exceed 8 mm.
 - 6) The sensor should always face directly downward, and the micro fuel cell power system or unit should be moved beneath it such that the surface directly below the sensor is always horizontal.
 - 7) If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the micro fuel cell power system or unit shall be considered to have passed.

- 8) When some point source sweeps show a large region of 25 % LFL or greater in the initial linear sweeps, recording the measured concentration values will assist in determining the starting point of secondary spiral sweeps. Point sources are supposed to be where local maximum values exist in the distribution of measured concentration values.
 - 9) If any points are detected to have a hydrogen concentration of 25 % LFL or greater, a second test shall be conducted to ensure that the emission does not exceed 0,016 g/h of pure hydrogen from any single source.
 - 10) The second test shall be performed with the sensor height adjusted to 6,5 mm above the micro fuel cell power system or unit.
 - 11) A spiral sweep shall then be made, originating from the point where the detection of 25 % LFL or greater of hydrogen occurred during the initial linear sweep. The spiral sweep shall have a spacing of 1 mm or less between sweeps, and shall spiral out to a radial distance of at least 4 mm and far enough to detect the maximum hydrogen level from the particular hydrogen source.
 - 12) If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the micro fuel cell power system or unit passes the test.
- e) **Passing criteria:** No gas loss of hydrogen from any single source at greater than 0,016 g/h as indicated by sweep testing. No indications of hydrogen that is 25 % of LFL during the primary sweep testing or no indications of hydrogen that is 25 % of LFL during the secondary sweep testing at 6,5 mm above the micro fuel cell power system or unit. If the spiral sweep at 6,5 mm above the micro fuel cell power system or unit detects a maximum concentration of hydrogen that is 25 % of LFL or greater, the micro fuel cell power system or unit fails the test. See Table G.7.

Annex H (normative)

Butane solid oxide micro fuel cell power systems

H.1 Scope

H.1.2 Fuels and technologies covered

Annex H covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use butane and butane/propane mixtures – consisting of at least 75 % butane by mass – as fuel. These systems and units use solid oxide fuel cell technologies.

Figure H.1 replaces Figure 1 showing a butane solid oxide micro fuel cell power system block diagram for use with this annex.

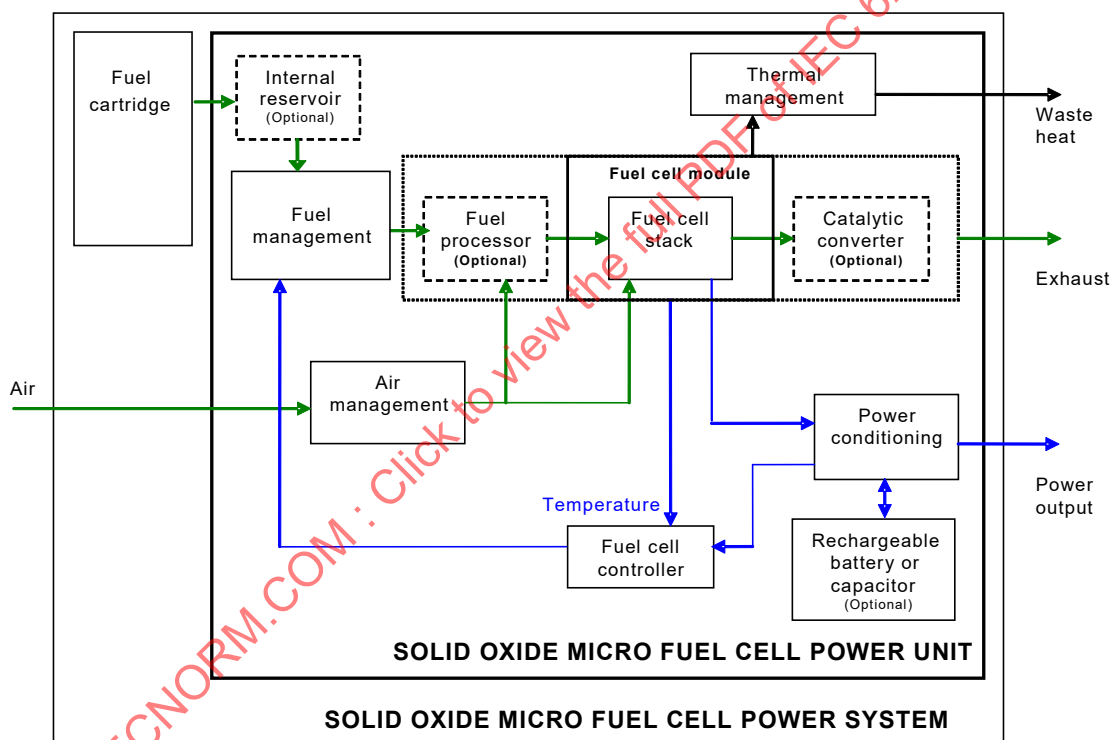


Figure H.1 – Butane solid oxide micro fuel cell power system block diagram –
Replaces Figure 1

H.3 Terms and definitions

The terms and definitions below replace those corresponding terms and definitions in Clause 3 for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex H. All terms and definitions in Clause 3 not specifically mentioned here also apply.

H.3.5

fuel

butane and butane/propane mixtures comprising at least 75 % butane by mass

H.3.7

hazardous liquid fuel

not applicable for this Annex H

H.3.11

leakage

impermissible leakage as defined in H.3.37

H.3.18

no accessible liquid

not applicable for this Annex H

H.3.19

no fuel vapour loss

no impermissible leakage as defined in H.3.37

H.3.26

waste cartridge

not applicable for this Annex H

H.3.27

water cartridge

not applicable for this Annex H

The additional term and definition below is needed for micro fuel cell power systems, micro fuel cell power units and fuel cartridges covered by this Annex H in addition to those given in Clause H.3 and in Clause 3.

H.3.37

impermissible leakage

a release of fuel in excess of 0,045 g/h from a non-operating micro fuel cell power system or fuel cartridge

In addition, no impermissible leakage shall mean fuel cartridges are bubble-tight as confirmed by the water bath test described in this annex. For micro fuel cell power systems, no impermissible leakage shall also mean compliance with the emission test limits specified in this annex.

H.4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges

H.4.1 General

These requirements apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex H. These requirements replace the corresponding requirements of Subclause 4.1.

- a) Compliance with the requirements of Clause H.4 shall be verified during the review of the safety FMEA and/or during type tests specified in Clause H.7.
- b) The micro fuel cell power unit, when coupled to the fuel cartridge, shall be designed and constructed to avoid any credible risk of leakage, fire or explosion posed by the micro fuel cell power system itself or gases, vapours, liquids or other substances produced or used by the micro fuel cell power system.
- c) To prevent a fire or explosion hazard within the micro fuel cell power system, the manufacturer shall eliminate potential ignition source(s) within areas where fuel is present (or can be potentially released).
- d) Flammable, toxic or corrosive materials shall be kept within a closed containment system such as within fuel piping, in a reservoir, a fuel cartridge or similar enclosure.

H.4.2 FMEA / hazard analysis

These requirements apply to micro fuel cell power systems, units and fuel cartridges covered by this Annex H. These requirements replace the corresponding requirements of Subclause 4.2.

H.4.2.1 A failure modes and effects analysis (FMEA) or equivalent reliability analysis shall be conducted by the manufacturer to identify faults which can have safety related consequences and the design features that serve to mitigate those faults. The analysis shall include failures that may result in leakage. Failures related to refilling of non-user refillable fuel cartridges, if anticipated by the manufacturer or trained technicians, shall be considered.

H.4.2.2 Guidance can be found in the following informative references: IEC 61025, and IEC 60812.

H.4.2.3 It shall be the responsibility of the manufacturer to ensure that any emission from the micro fuel cell power system does not result in harmful or dangerous effects on the user or others during normal use, reasonably foreseeable misuse, and consumer transportation.

H.4.2.4 The FMEA shall include consideration of the effects of the micro fuel cell power system and cartridges being exposed to fire.

H.4.12 Fuel supply construction

H.4.12.1 Fuel cartridge construction

These requirements apply to micro fuel cell power systems and units covered by this Annex H. These requirements replace the corresponding requirements of Subclause 4.12.1.

Fuel cartridges shall conform to the following requirements:

H.4.12.1.1 There shall be no leakage from the fuel cartridge in the temperature range of –40 °C to +70 °C. Compliance shall be determined by type testing in accordance with H.7.3.3 and H.7.3.4.

H.4.12.1.2 There shall be no leakage from the fuel cartridge at an internal pressure of two times the gauge pressure of the fuel cartridge at 55 °C. Compliance shall be determined by type testing in accordance with H.7.3.1.

H.4.12.1.3 Maximum fuel volume in the fuel cartridge shall not exceed 1 l.

H.4.12.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a micro fuel cell power unit by a consumer, means to prevent fuel leakage prior to, during, and after connection or transfer of fuel to the micro fuel cell power unit shall be provided. Compliance is checked by H.7.3.11.

H.4.12.1.5 A fuel cartridge shall be resistant to corrosion in its usage environment.

H.4.12.1.6 A fuel cartridge shall be provided with a means to prevent misconnection that would result in leakage of fuel when it is installed in a micro fuel cell power system. Compliance is checked by the connection cycling test, H.7.3.11.

H.4.12.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel when not attached to a micro fuel cell power unit during normal usage, reasonably foreseeable misuse, and consumer transportation. Compliance is checked by the drop test, H.7.3.5, and the connection cycling test, H.7.3.11.

H.4.12.1.8 In the case where a pressure release valve or similar means is provided, such pressure release valve shall satisfy the performance requirement for each type test. This valve shall pass all type tests with no leakage.

H.4.12.1.9 The structure at the connection to the fuel cartridge shall not allow fuel to leak.

H.4.12.1.10 A fuel cartridge, including the fuel cartridge interface to the micro fuel cell power unit, including the valve, shall have a construction sufficient to withstand normal use and reasonably foreseeable misuse generated by vibration, heat, pressure, being dropped or otherwise subject to a mechanical shock etc. Compliance is checked by:

- pressure differential tests, H.7.3.1;
- vibration test, H.7.3.2;
- temperature cycling test, H.7.3.3;
- high temperature exposure test, H.7.3.4;
- drop test, H.7.3.5;
- compressive loading test, H.7.3.6;
- long-term storage test, H.7.3.9;
- high-temperature connection test, H.7.3.10;
- connection cycling tests, H.7.3.11.

H.4.12.1.11 The fuel cartridge valves shall operate as intended without the use of tools and without excessive force needed to connect or disconnect.

H.4.12.1.12 Fuel cartridges containing in excess of 120 ml of fuel will be designed to provide a controlled release of fuel in the case of exposure to fire. This may be accomplished through either a thermally sensitive or pressure sensitive feature. This may be integrally incorporated into the fuel cartridges, such as through a portion of the fuel cartridge having a designed weakness that will vent at an appropriate pressure or temperature.

H.4.12.1.13 Fuel cartridges in excess of 200 ml shall be fire tested in accordance with H.7.3.15.

H.4.12.2 Fuel cartridge fill requirement

These requirements apply to micro fuel cell power systems and units covered by this Annex H. These requirements replace the corresponding requirements of Subclause 4.12.2.

Fuel cartridges shall conform to the following requirements.

The fuel cartridge design and fuel fill amount shall allow fuel expansion without leakage to a fuel cartridge temperature of 70 °C in the case of the fuel cartridge alone and when the fuel cartridge is constrained by the micro fuel cell power system or a comparable test fixture.

H.6 Instructions and warnings for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

H.6.2 Minimum markings required on the fuel cartridge

These markings replace the markings required by Subclause 6.2.

As a minimum, the following shall be marked on the fuel cartridge.

- a) CONTENTS ARE FLAMMABLE, DO NOT DISASSEMBLE.

- b) KEEP AWAY FROM CHILDREN.
- c) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES OR IGNITION SOURCES.
- d) FOLLOW USAGE INSTRUCTIONS.
- e) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- f) COMPOSITION AND AMOUNT OF FUEL.
- g) TEXT OR MARKING THAT INDICATES THAT THE FUEL CARTRIDGE COMPLIES WITH IEC 62282-6-100.

H.6.3 Minimum markings required on the micro fuel cell power system

These markings replace the markings required by Subclause 6.3.

In addition, as a minimum, the following shall also be marked on the micro fuel cell power system to show:

- a) CONTENTS ARE FLAMMABLE, DO NOT DISASSEMBLE.
- b) DO NOT EXPOSE TO TEMPERATURES ABOVE 50 °C OR OPEN FLAMES OR IGNITION SOURCES.
- d) FOLLOW USAGE INSTRUCTIONS.
- e) TRADE MARK AND/OR MANUFACTURER NAME, MODEL DESIGNATION AND TRACEABILITY REQUIRED BY THE MANUFACTURER.
- g) COMPOSITION OF FUEL.
- h) MAXIMUM CAPACITY OF FUEL IN THE INTERNAL RESERVOIR, IF APPLICABLE.
- i) TEXT OR MARKING THAT INDICATES THAT THE MICRO FUEL CELL POWER SYSTEM COMPLIES WITH IEC 62282-6-100.
- j) ELECTRICAL OUTPUT (VOLTAGE, CURRENT, RATED POWER).

H.7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges

H.7.1 General

This Clause H.7 replaces Clause 7 for this annex H when testing micro fuel cell power systems, micro fuel cell power units and fuel cartridges that use butane and butane/propane mixtures as fuel.

- a) The type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall provide that these micro fuel cell power systems, units and fuel cartridges are safe for normal use.
- b) Table H.5 lists the type tests that shall be performed. *Table H.5 replaces Table 5.*
- c) Unless otherwise explicitly prescribed elsewhere in this clause, laboratory conditions are specified by Table H.6. *Table H.6 replaces Table 6.*
- d) The micro fuel cell power system, power unit and/or fuel cartridge shall be conditioned at a standard laboratory temperature of 22 °C ± 5 °C for a minimum of 3 h prior to each test being performed.
- e) Warning: These type tests use procedures that may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

Table H.5 – List of type tests – Replaces Table 5

Test reference	Test item	Test sample
H.7.3.1	Pressure differential tests	Fuel cartridge Fuel cartridge valve Micro fuel cell power system or power unit
H.7.3.2	Vibration test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
H.7.3.3	Temperature cycling test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
H.7.3.4	High temperature exposure test	Fuel cartridge Partially filled fuel cartridge
H.7.3.5	Drop test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
H.7.3.6	Compressive loading test	Fuel cartridge Partially filled fuel cartridge Micro fuel cell power system or power unit
H.7.3.7	External short-circuit test	Micro fuel cell power system or power unit
7.3.8	Surface, component and exhaust gas temperature test	Micro fuel cell power system or power unit
H.7.3.9	Long-term storage test	Fuel cartridge Partially filled fuel cartridge
H.7.3.10	High-temperature connection test	Fuel cartridge and micro fuel cell power unit Partially filled fuel cartridge and micro fuel cell power unit
H.7.3.11	Connection cycling test	Fuel cartridge and micro fuel cell power unit
H.7.3.12	Emission test	Micro fuel cell power system or power unit
H.7.3.13	High temperature shutdown test	Micro fuel cell power system or power unit
H.7.3.14	High temperature operation test	Micro fuel cell power system or power unit

Table H.5 replaces Table 5.

Test sample: The quantity of the sample shall be a minimum of six (6) fuel cartridges, either unused or partially filled, as specified by the individual tests above, or a minimum of three (3) micro fuel cell power systems or units for each type test.

Test sequence: Tests H.7.3.2 and H.7.3.3 shall be conducted sequentially for testing the same fuel cartridges. Tests H.7.3.1, H.7.3.2, and H.7.3.3 shall be done sequentially for testing the same micro fuel cell power systems or power units.

Reuse of samples: Fuel cartridges and micro fuel cell power systems or units may be re-used at the manufacturer's discretion if it does not compromise the individual test.

Table H.6 – Laboratory standard conditions – Replaces Table 6

Item	Condition
Laboratory temperature	Laboratory temperature is "room temperature" (standard temperature condition, 22 °C ± 5 °C)
Laboratory room atmosphere; for micro fuel cell power system and micro fuel cell power unit testing only.	The laboratory atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The laboratory atmosphere contains at least 18 % oxygen but not more than 21 % oxygen.

H.7.2 Leakage measurement of fuel and the measuring procedure

The leakage measurement of butane or butane/propane mixture fuel shall be executed in principle in accordance with the procedure shown in Figures H.2 through H.7 and H.9 respectively. Any exceptions will be noted in the various subclauses.

If fuel cartridges are made of a material that can absorb and release moisture which could affect the accuracy of mass loss measurements, an empty fuel cartridge may optionally be subject to the type tests along with the test fuel cartridges and any weight change in the empty fuel cartridge used to correct the measurement of the test fuel cartridge.

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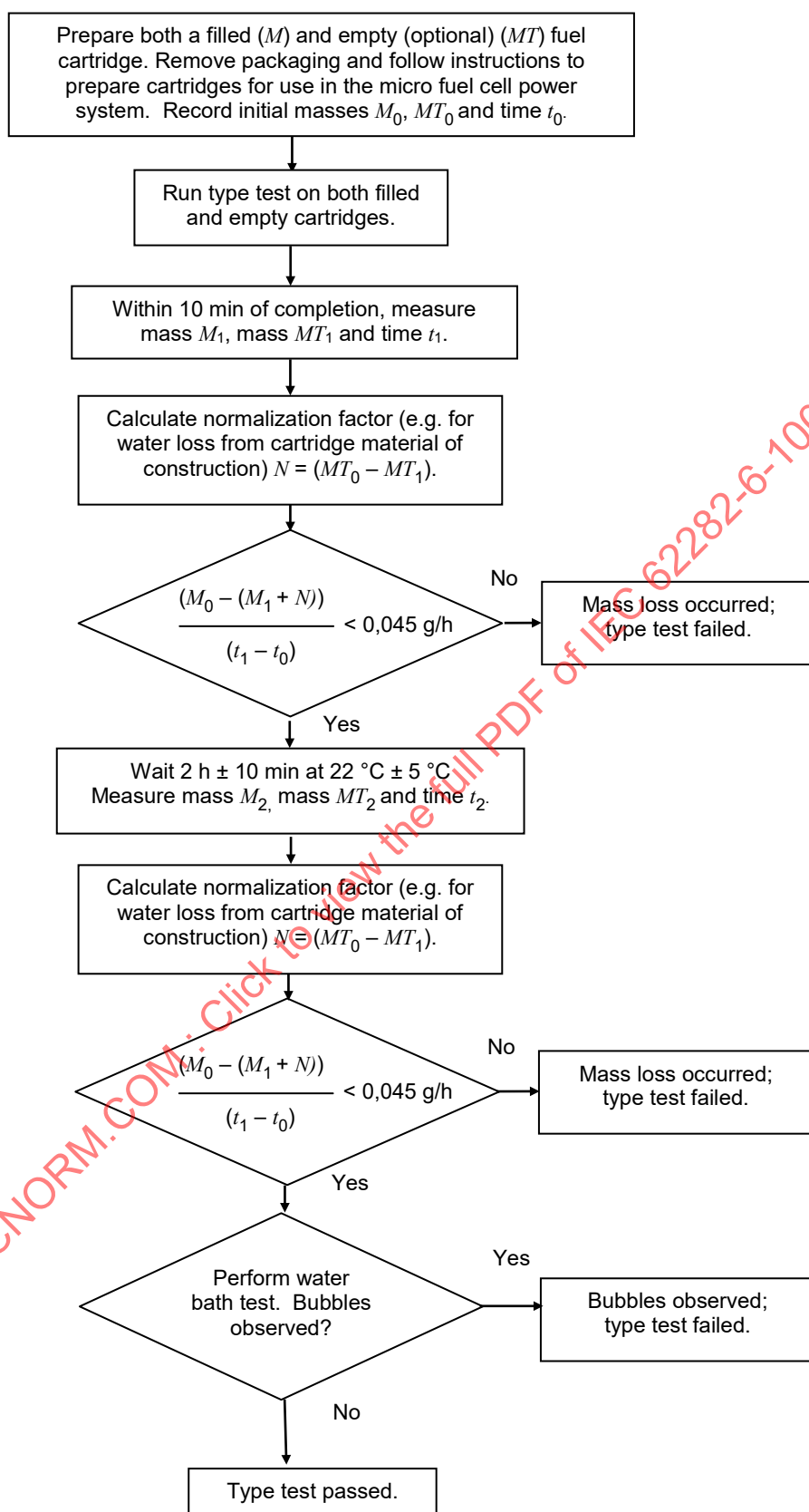


Figure H.2 – Fuel cartridge leakage and mass loss test flow chart for vibration, drop and compressive loading tests – Replaces Figure 2

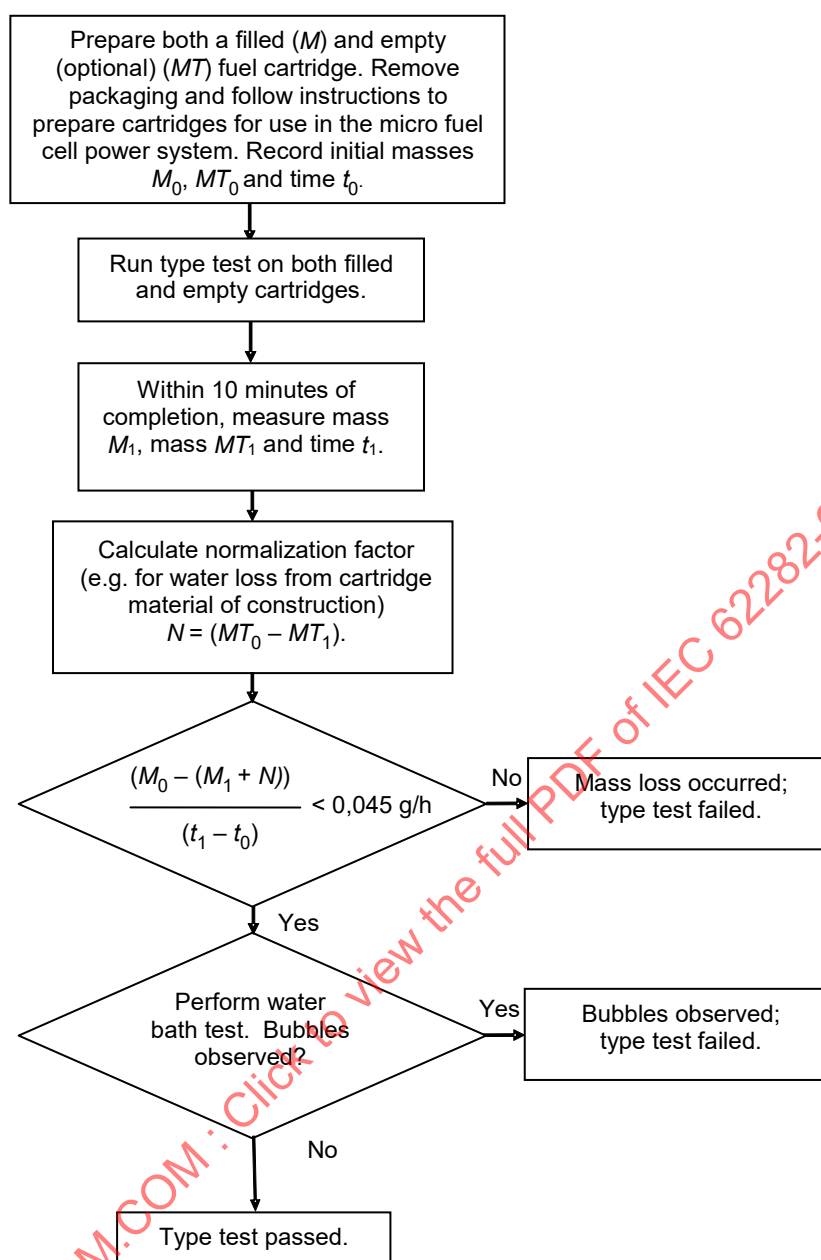


Figure H.3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test – Replaces Figure 3

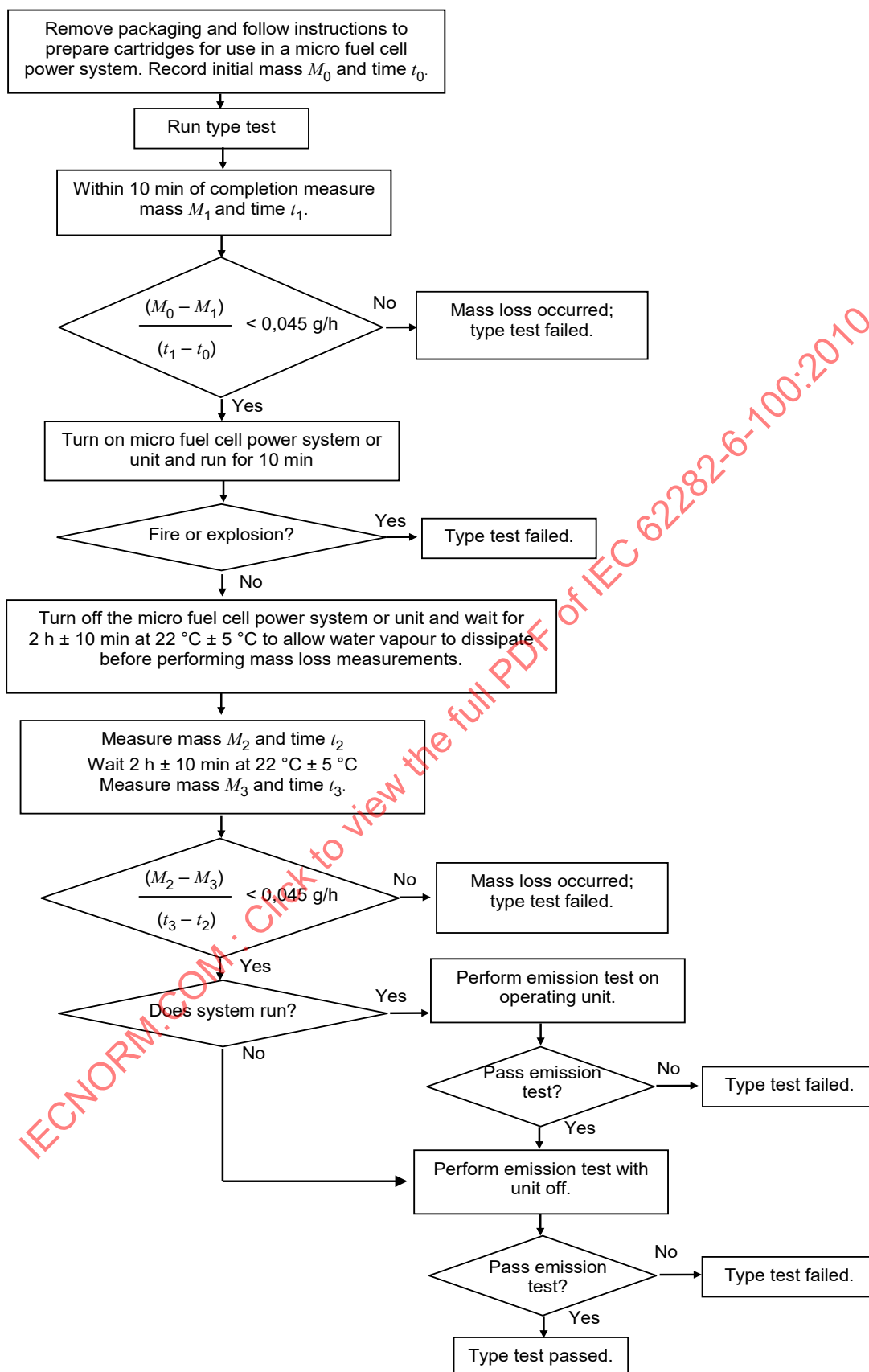


Figure H.4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests – Replaces Figure 4

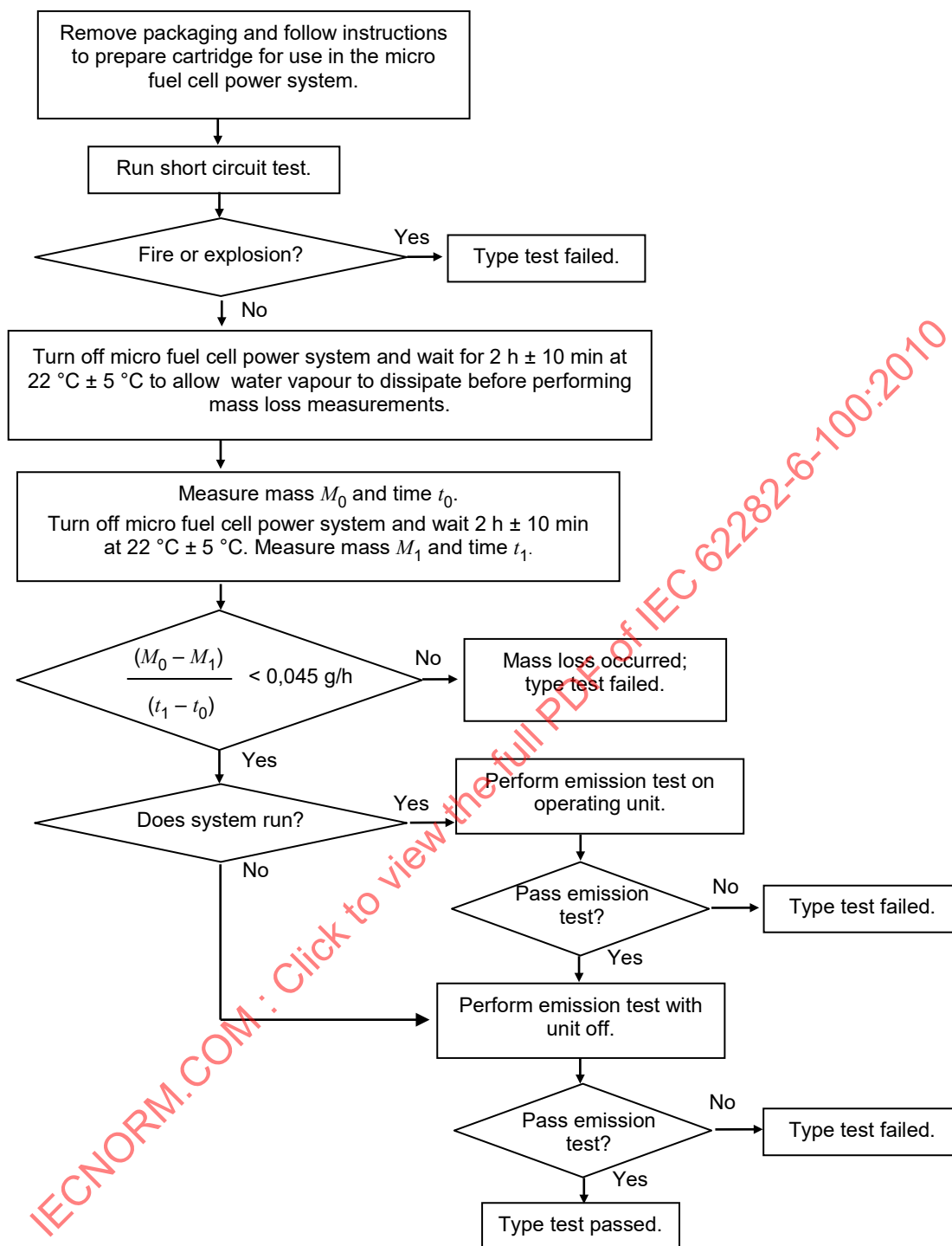


Figure H.5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test – Replaces Figure 5

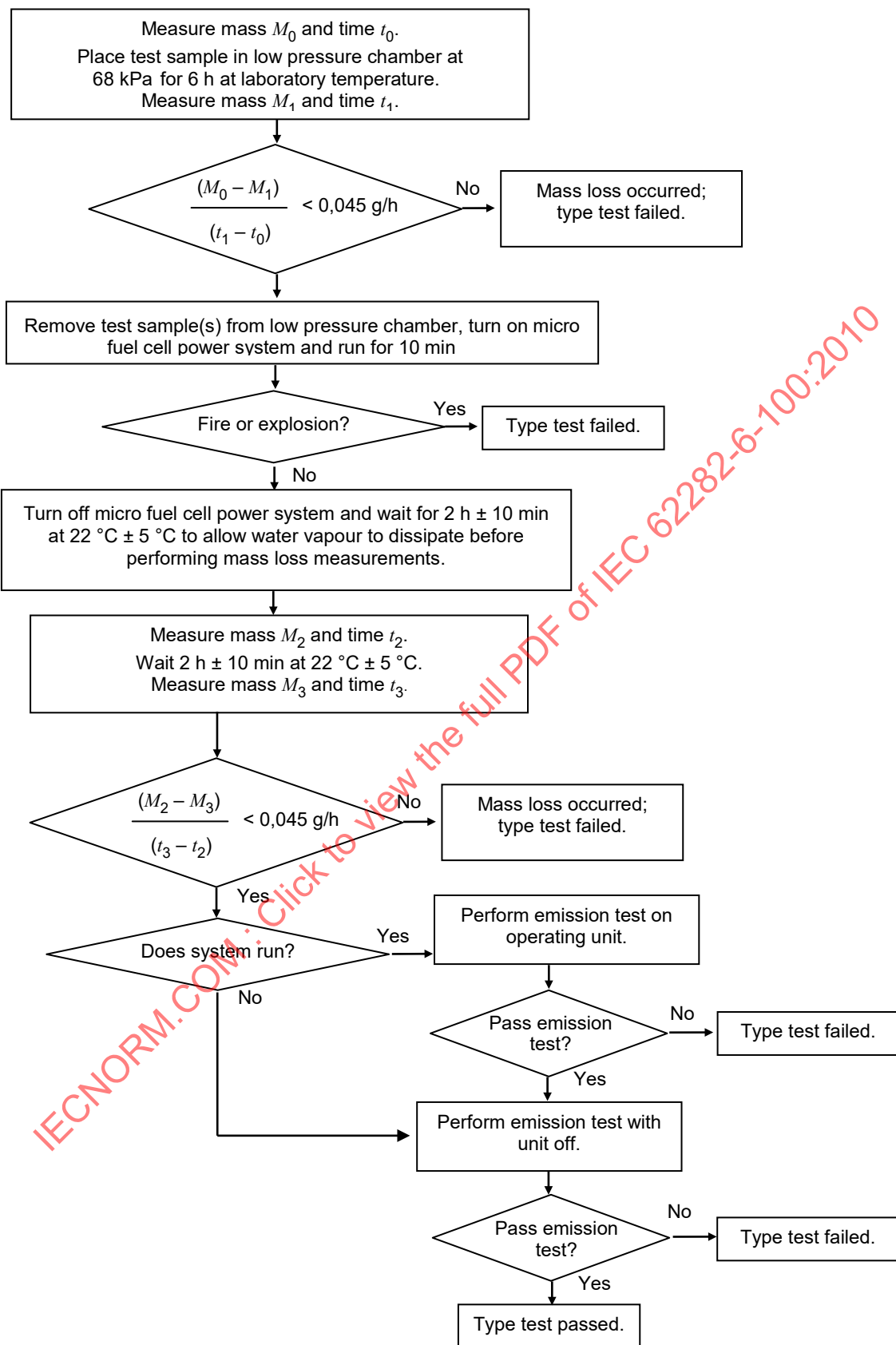


Figure H.6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test – Replaces Figure 6

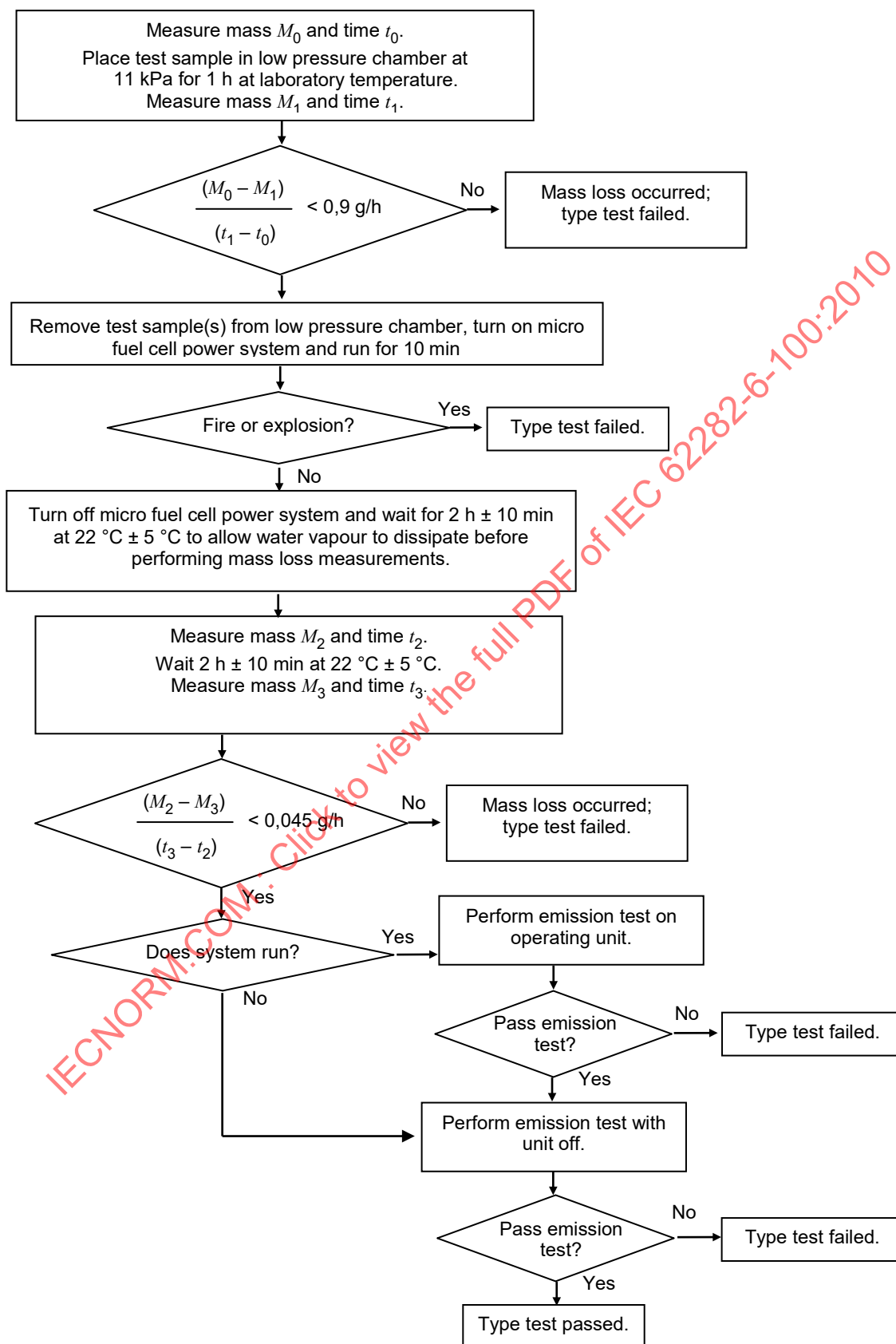


Figure H.7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test – Replaces Figure 7

H.7.3 Type tests

H.7.3.1 Pressure differential tests

H.7.3.1.1 General

Portions of this test check compliance with Subclause H.4.12.1.2 to verify that there shall be no leakage from the fuel cartridge at an internal pressure of two times the gauge pressure of the fuel cartridge at 55 °C.

H.7.3.1.2 Fuel cartridge internal pressurization test

Either H.7.3.1.2.1 (Option 1), H.7.3.1.2.2 (Option 2) or H.7.3.1.2.3 (Option 3) may be used.

H.7.3.1.2.1 Option 1 – Mass flow measurement

- a) **Test sample:** a fuel cartridge body and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**

For the internal pressurization test mass flow measurement, the fuel cartridge body and the fuel cartridge valve shall be tested separately.

- 1) Using a suitable fluid medium such as butane, air, nitrogen, or similar gas, pressurize the fuel cartridge body to an internal pressure of twice the vapour pressure of the fuel at 55 °C. A flow sensor suitable for measuring the impermissible leakage rate shall be placed in line with the pressurizing medium. The pressure rise shall not exceed a rate of 60 kPa/s.
- 2) Maintain the maximum pressure for 30 min at laboratory temperature.
- 3) Using a suitable fluid medium such as butane, air, nitrogen, or similar gas, pressurize the closed fuel cartridge valve to a pressure of twice the vapour pressure of the fuel at 55 °C. A flow sensor suitable for measuring the impermissible leakage rate shall be placed in line with the pressurizing medium. The pressure rise shall not exceed a rate of 60 kPa/s.
- 4) Maintain the maximum pressure for 30 min at laboratory temperature.
- 5) If an alternative reference gas is used for the pressurizing fluid media, the measured leak rate shall be normalized to an equivalent butane leakage rate.

See below:

$$LR_{\text{Beq}} = D_B \times FR_{\text{RG}} \times \frac{V_{\text{RG}}}{V_B}$$

where

LR_{Beq} is the butane equivalent leakage rate in grams per hour;

D_B is the density of butane gas at standard laboratory conditions in grams per cubic meter;

FR_{RG} is the reference gas flow rate in cubic meters per hour;

V_{RG} is the viscosity of the reference gas;

V_B is the viscosity of butane gas.

- d) **Passing criteria:** No impermissible leakage or sudden loss of pressure. Mass loss shall be less than 0,045 g/h of butane or equivalent.

H.7.3.1.2.2 Option 2 – Mass emission rate measurement

- a) **Test sample:** a fuel cartridge body and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test apparatus:** An example of the mass emission rate testing apparatus is shown in Figure H.10.
- d) **Test procedure:**

For the internal pressurization test mass flow measurement, both the fuel cartridge body and the fuel cartridge valve must be pressurized, but may be tested either separately or concurrently.

- 1) Place the fuel cartridge body and a fuel cartridge valve inside the small test chamber shown in Figure H.10.
- 2) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
- 3) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- 4) Using a suitable reference gas medium such as helium, hydrogen, carbon dioxide, or other detectable gas, pressurize the fuel cartridge body and the fuel cartridge valve to an internal pressure of twice the vapour pressure of the fuel at 55 °C. The pressure rise shall not exceed a rate of 60 kPa/s.
- 5) Maintain the pressure for 30 min at laboratory temperature.
- 6) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure H.10, while simultaneously measuring and recording the flow through the test chamber. The flow through the test chamber can be computed from the sum of the variable flow air pump flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber.
- 7) Record the concentrations of the reference gas media and calculate the emission rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- 8) Compute the mass equivalent leakage rate of butane using the density and viscosity of the reference gas and of butane.

See below:

$$ER_{\text{Beq}} = ER_{\text{RG}} \times \frac{D_{\text{B}}}{D_{\text{RG}}} \times \frac{V_{\text{RG}}}{V_{\text{B}}}$$

where

ER_{Beq} is the butane equivalent emission rate in grams per hour;

ER_{RG} is the reference gas emission rate as calculated above;

D_{B} is the density of butane gas at standard laboratory conditions;

D_{RG} is the density of the reference gas at standard laboratory conditions;

V_{RG} is the viscosity of the reference gas;

V_{B} is the viscosity of butane gas.

- e) **Passing criteria:** No impermissible leakage or sudden loss of pressure. Mass loss shall be less than 0,045 g/h of butane or equivalent.

H.7.3.1.2.3 Option 3 – Immersion test

- a) **Test sample:** a fuel cartridge body and a fuel cartridge valve.
- b) **Purpose:** to simulate the effects of high internal fuel cartridge pressure and ensure no leakage.
- c) **Test procedure:**
For the internal pressurization test, the fuel cartridge body and the fuel cartridge valve shall be tested separately.
- 1) Using a suitable fluid medium such as butane, air, nitrogen, or similar gas, pressurize the fuel cartridge body to an internal pressure of twice the vapour pressure of the fuel at 55 °C. The pressure rise shall not exceed a rate of 60 kPa/s.
 - 2) Maintain the maximum pressure for 30 min at laboratory temperature.
 - 3) While maintaining pressure, place the fuel cartridge body in a room temperature water bath and verify that the cartridge body is bubble tight.
 - 4) Using a suitable fluid medium such as butane, air, nitrogen, or similar gas, pressurize the closed fuel cartridge valve to a pressure of twice the vapour pressure of the fuel at 55 °C. The pressure rise shall not exceed a rate of 60 kPa/s.
 - 5) Maintain the maximum pressure for 30 min at laboratory temperature.
 - 6) While maintaining pressure, place the fuel cartridge valve in a room temperature water bath and verify that the fuel cartridge valve is bubble tight.
- d) **Passing criteria:** No bubbles, impermissible leakage or sudden loss of pressure. Fuel cartridge body and fuel cartridge valve shall be bubble tight.

H.7.3.1.3 Fuel cartridge low external pressure test

This subclause of the main body is not applicable to this Annex H, as twice the vapour pressure of the Annex H fuel will always exceed a gauge pressure of 95 kPa plus the normal cartridge working pressure at 22 °C, making this test unsuitable as an alternative to the fuel cartridge internal pressurization test.

H.7.3.1.4 Micro fuel cell power system or micro fuel cell power unit pressure differential tests

H.7.3.1.4.1 Micro fuel cell power system or micro fuel cell power unit 68 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex H.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform this test in accordance with Figure H.6.
 - 2) Place test sample in low pressure chamber and reduce pressure to 68 kPa.
 - 3) Allow the test sample to remain at 68 kPa for 6 h at laboratory temperature.
 - 4) Return the chamber to atmospheric pressure and remove test sample from chamber.
 - 5) Leakage shall be measured on the basis of the procedure described in Figure H.6.
 - 6) Perform emission testing in accordance with H.7.3.12.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.6 and shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Perform emission testing on the micro fuel cell power system or micro fuel cell power unit with the micro fuel cell power unit both on and off. The emission shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but the emission does not exceed the limits of H.7.3.12, the emission test is acceptable.

H.7.3.1.4.2 Micro fuel cell power system or micro fuel cell power unit 11,6 kPa low external pressure test

This test is required for all micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex H.

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system.
- b) **Purpose:** to simulate the effects of high internal pressure or low external pressure and ensure no leakage.
- c) **Test procedure:**

Perform this test in accordance with Figure H.7.

 - 1) Place test sample in low pressure chamber and reduce pressure to 11 kPa.
 - 2) Allow the test sample to remain at 11 kPa for 1 h at laboratory temperature.
 - 3) Return the chamber to atmospheric pressure and remove test sample from chamber.
 - 4) Leakage shall be measured on the basis of the procedure described in Figure H.7.
 - 5) Perform emission testing in accordance with H.7.3.12.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.7 and shall be less than 0,9 g/h while at 11 kPa and less than 0,045 g/h the remainder of the test. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Perform emission testing on the micro fuel cell power system or micro fuel cell power

unit with the micro fuel cell power unit both on and off. The emission shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but the emission does not exceed the limits of H.7.3.12, the emission test is acceptable.

H.7.3.2 Vibration test

- a) **Test sample:** an unused fuel cartridge, a partially filled fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in H.7.3.1 or a micro fuel cell power system used in H.7.3.1.
- b) **Purpose:** to simulate the effects of normal transportation vibration and ensure no leakage.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure H.2 for the fuel cartridge and Figure H.4 for the micro fuel cell power system or micro fuel cell power unit.
 - 2) The test sample shall be firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.
 - 3) The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 min.
 - 4) This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions of the test samples.
 - 5) The logarithmic frequency sweep is as follows: from 7 Hz a peak acceleration of 1 g_n is maintained until 18 Hz is reached. The amplitude is then maintained at 0,8 mm (1,6 mm total excursion) and the frequency increased until a peak acceleration of 8 g_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.
 - 6) For the micro fuel cell power system or micro fuel cell power unit, perform emission testing in accordance with H.7.3.12.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no impermissible leakage. Leakage and fuel vapour loss shall be measured based upon Figure H.2 for the fuel cartridge and Figure H.4 for the micro fuel cell power system or micro fuel cell power unit. Leakage shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak. Perform emission testing on the micro fuel cell power system or micro fuel cell power unit with the micro fuel cell power unit both on and off. The emission shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but the emission does not exceed the limits of H.7.3.12, the emission test is acceptable.

H.7.3.3 Temperature cycling test

- a) **Test sample:** a fuel cartridge used in H.7.3.2, a partially filled fuel cartridge used in H.7.3.2, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications used in H.7.3.2 or a micro fuel cell power system used in H.7.3.2.
- b) **Purpose:** to simulate the effects of low-temperature and high temperature exposure and the effects of extreme temperature change.
- c) **Test procedure:**
 - 1) Perform these tests in accordance with Figure H.3 for the fuel cartridge and Figure H.4 for the micro fuel cell power system or micro fuel cell power unit.
 - 2) For a fuel cartridge, two fuel cartridge orientations shall be tested – valve up and valve down. For a micro fuel cell power system or a micro fuel cell power unit, only one orientation needs to be tested.
 - 3) See Figure H.8 for the temperature profile to be used.

- 4) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from laboratory temperature to $55\text{ °C} \pm 2\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $55\text{ °C} \pm 2\text{ °C}$ for a minimum of 4 h.
 - 5) Decrease the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $1\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$, then decrease the chamber temperature to $-40\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $-40\text{ °C} \pm 5\text{ °C}$ for a minimum of 4 h.
 - 6) Increase the chamber temperature to $22\text{ °C} \pm 5\text{ °C}$ in $2\text{ h} \pm 5\text{ min}$ and keep it at $22\text{ °C} \pm 5\text{ °C}$ for $1\text{ h} \pm 5\text{ min}$.
 - 7) The above process is to be done twice.
 - 8) Upon completion of the second cycle, leakage and fuel vapour loss shall be measured based upon the procedure described in Figure H.3 (for fuel cartridge) and Figure H.4 (for micro fuel cell power system or micro fuel cell power unit).
 - 9) For the micro fuel cell power system or micro fuel cell power unit, perform emission testing in accordance with H.7.3.12.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no impermissible leakage. Leakage and fuel vapour loss shall be measured based upon Figure H.3 for the fuel cartridge and Figure H.4 for the micro fuel cell power system or micro fuel cell power unit. Leakage shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C . No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak. Perform emission testing on the micro fuel cell power system or micro fuel cell power unit with the micro fuel cell power unit both on and off. The emission shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but the emission does not exceed the limits of H.7.3.12, the emission test is acceptable.

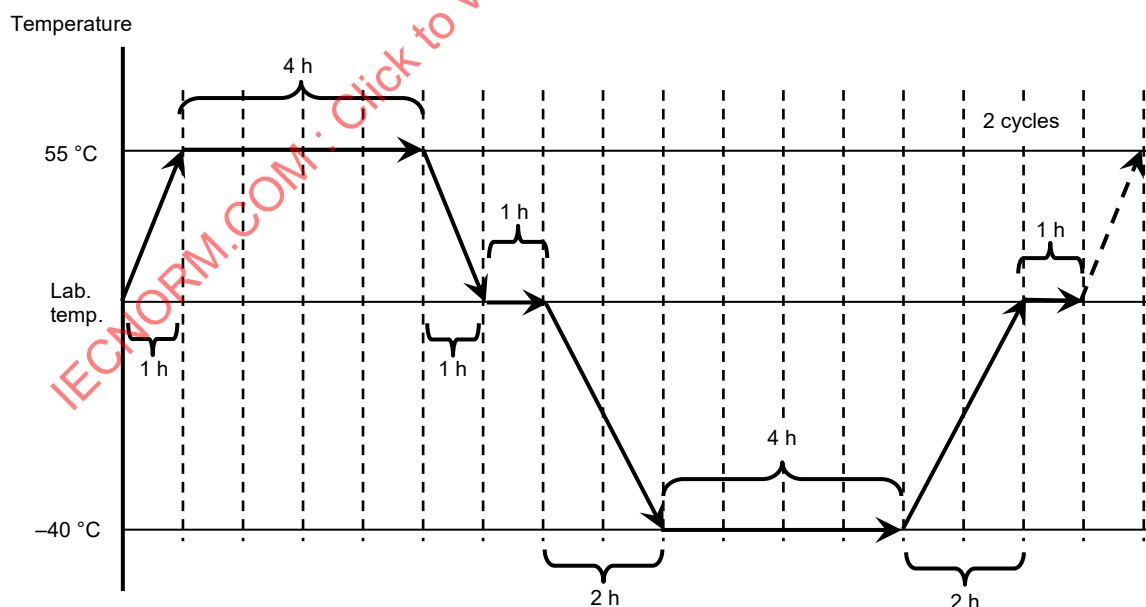


Figure H.8 – Temperature cycling – Replaces Figure 8

H.7.3.4 High temperature exposure test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of a fuel cartridge left in high temperature environments.
- c) **Test procedure:**
 - 1) Two orientations shall be tested – valve up and valve down.
 - 2) Place the test sample in a temperature controlled test chamber that is at a temperature of $70\text{ °C} \pm 2\text{ °C}$ and allow chamber temperature to recover to $70\text{ °C} \pm 2\text{ °C}$ and maintain that temperature for at least 4 h with the sample in the chamber.
 - 3) Remove the test sample to laboratory temperature.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.3 and shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the fuel cartridge. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C . No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.5 Drop test

- a) **Test sample:** an unused fuel cartridge, a partially filled fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an inadvertent drop and ensure no leakage.
- c) **Test procedure:**
 - 1) The test sample shall be dropped on a horizontal surface that consists of hardwood at least 13 mm thick, mounted on two layers of plywood each 18 mm to 20 mm thick, all supported on a concrete or equivalent non-resilient floor from a predetermined height.
 - 2) The height of the drop shall be:
 - i) $1\,200\text{ mm} \pm 10\text{ mm}$: in the case of a micro fuel cell power unit and/or a micro fuel cell power system.
 - ii) $1\,500\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge of more than 200 ml.
 - iii) $1\,800\text{ mm} \pm 10\text{ mm}$: in the case of a fuel cartridge of up to 200 ml.
 - 3) For the fuel cartridge tests, the drop test shall be carried out in four drop orientations with the same sample.
 - 4) For the micro fuel cell power unit or the micro fuel cell power system, one micro fuel cell power system or micro fuel cell power unit may be used for all four drop orientations, or more than one micro fuel cell power system or micro fuel cell power unit may be used in subsequent drops, at the discretion of the manufacturer.
 - 5) For all tests, drop orientations shall be:
 - i) valve up;
 - ii) valve down;
 - iii) two other mutually perpendicular orientations.
 - 6) For micro fuel cell power system or micro fuel cell power unit tests, perform emission testing in accordance with H.7.3.12.

- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no impermissible leakage. Leakage and fuel vapour loss shall be measured based upon Figure H.2 for the fuel cartridge and Figure H.4 for the micro fuel cell power system or micro fuel cell power unit. Leakage shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak. Perform emission testing on the micro fuel cell power system or micro fuel cell power unit with the micro fuel cell power unit both on and off. The emission shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but the emission does not exceed the limits of H.7.3.12, the emission test is acceptable. If the micro fuel cell power system or micro fuel cell power unit is still operational, protective circuitry specified by the FMEA as part of the safety systems shall still be fully functional. There shall be no exposure of hazardous parts.

H.7.3.6 Compressive loading test

H.7.3.6.1 Micro fuel cell power system or micro fuel cell power unit

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the micro fuel cell power unit, or micro fuel cell power system.
- c) **Test procedure:**
- 1) The micro fuel cell power system or micro fuel cell power unit test sample shall be placed between two flat hardwood blocks approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $245 \text{ N} \pm 9,8 \text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $245 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) The test shall be carried out in three mutually perpendicular orientations as a rule. If the sample would not stand on its own, it does not need to be tested in that orientation.
 - 5) Perform emission testing in accordance with H.7.3.12 following the compressive loading test.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no impermissible leakage. Leakage and fuel vapour loss shall be measured based upon Figure H.2 for the fuel cartridge and Figure H.4 for the micro fuel cell power system or micro fuel cell power unit. Leakage shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Perform emission testing on the micro fuel cell power system or micro fuel cell power unit with the micro fuel cell power unit both on and off. Emission shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but emission does not exceed the limits of H.7.3.12, the emission test is acceptable.

H.7.3.6.2 Fuel cartridge

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of the forces reasonably encountered due to something heavy being placed on the fuel cartridge.
- c) **Test procedure:**
 - 1) The fuel cartridge test sample shall be placed between two flat hardwood blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick equipped with suitable force applicator(s) capable of exerting a compressive force on the sample of $981 \text{ N} \pm 9,8 \text{ N}$.
 - 2) A compressive force shall be applied to the sample gradually at a rate of less than or equal to 12,7 mm/min (1/2 inch/min).
 - 3) A compressive force of $981 \text{ N} \pm 9,8 \text{ N}$ shall be applied to the stationary sample for 5 s.
 - 4) Fuel cartridge orientations shall be selected on the basis of likely stable resting positions when accidentally dropped (e.g. those orientations having the lowest centres of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic fuel cartridge that is sufficiently cubic and the curved surface of a cylindrical fuel cartridge with a longitudinal axis length longer than twice the diameter.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.2 and shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the fuel cartridge. Cartridge shall be subjected to a water bath test and shall be bubble tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.7 External short-circuit test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** to simulate the effects of an external short-circuit.
- c) **Test procedure:**
 - 1) External short-circuit testing shall be done separately on both operating [DEVICE ON] and non-operating [DEVICE OFF] micro fuel cell power systems or micro fuel cell power units respectively.
 - 2) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power system or micro fuel cell power unit with wire having a maximum resistance load of 0,1 Ω for at least 5 min.
 - 3) Perform emission testing in accordance with 7.3.12 after each short-circuit test.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time, and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.5 and shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Perform emission testing on the micro fuel cell power system or micro fuel cell power unit with the micro fuel cell power unit both on and off. Emission shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but emission does not exceed the limits of H.7.3.12, the emission test is acceptable. Exterior surfaces shall not exceed temperatures in Table 2 during or after short circuit testing.

NOTE The external short-circuit test can be done sequentially with the surface, component and exhaust gas temperature test using the same sample.

H.7.3.9 Long-term storage test

H.7.3.9.1 General

Either H.7.3.9.2 (Option 1), H.7.3.9.3 (Option 2) or H.7.3.9.4 (Option 3) may be used.

H.7.3.9.2 Option 1 – continuous weight measurement

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure H.9):
 - 1) Use a load cell (continuous electronic weight sensing device) designed and calibrated for use at 50 °C inside the temperature chamber.
 - 2) Place the load cell in a temperature chamber at 50 °C ± 2 °C. Place the fuel cartridge on top of the load cell so that all the weight is being applied to the load cell. A fixture may be used to control the position of the fuel cartridge, to ensure all the weight is applied to the load cell.
 - 3) Connect a digital readout to the load cell and collect the data either manually or automatically. The data should be collected with a high degree of confidence to assure that the fuel vapour loss is less than 0,045 g/h.
 - 4) Measure and record initial mass M_{initial} and time t_i .
 - 5) The sample shall remain in the temperature test chamber at 50 °C ± 2 °C for at least 28 days.
 - 6) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,045 g/h, then the test sample passes the test for fuel vapour loss.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ days} \times 24 \text{ h/day} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{final}} = \text{the final mass of the fuel cartridge.}$$

- 7) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,045 g/h.

$$\text{i) Fuel vapour loss} = \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$$

$$\text{ii) } \Delta t_{\text{last}} = \text{the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

$$\text{iii) } M_{\text{initial}} = \text{the initial mass of the fuel cartridge.}$$

$$\text{iv) } M_{\text{last}} = \text{the last weight measurement taken when liquid fuel still remained in the fuel cartridge.}$$

- d) **Passing criteria:** No fire at any time, no explosion at any time and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.9 and shall be less than 0,045 g/h. Flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the fuel cartridge. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.9.3 Option 2 – periodic weight measurements

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure H.9):
- 1) Measure and record initial mass M_{initial} and time t_i .
 - 2) Place the fuel cartridge in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. Weight measurements should be collected with a high degree of confidence to determine if the fuel vapour loss is less than 0,045 g/h with a minimum of once every three days.
 - 3) The time in which the test samples are removed from the chamber for measurement shall not be included in the time the test sample is to be tested (28 days). Additional time should be added to get the test sample to the test temperature ($50\text{ °C} \pm 2\text{ °C}$) each time the test sample is removed from the chamber. The test samples should only be stabilised at laboratory temperature if the mass loss will be affected.
 - 4) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,045 g/h, then the test sample passes the test for fuel vapour loss.

i) Fuel vapour loss $= \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$

ii) $\Delta t = t_f - t_i = 28\text{ days} \times 24\text{ h/day} = 672\text{ h}$.

iii) M_{initial} = the initial mass of the fuel cartridge.

iv) M_{final} = the final mass of the fuel cartridge.

- 5) If the fuel cartridge is empty prior to the end of the test, the mass loss rate shall be calculated based on the elapsed time at the last measured data point (Δt_{last}) and the final mass (M_{last}) at the last measured data point before the fuel cartridge became empty. The test is passed if the fuel vapour loss is less than 0,045 g/h.

i) Fuel vapour loss $= \frac{M_{\text{initial}} - M_{\text{last}}}{\Delta t_{\text{last}}}$

ii) Δt_{last} = the elapsed time period between the initial weight measurement taken at the start of the test and the last weight measurement taken when liquid fuel still remained in the fuel cartridge.

iii) M_{initial} = the initial mass of the fuel cartridge.

iv) M_{last} = the last weight measurement taken when liquid fuel still remained in the fuel cartridge.

- d) **Passing criteria:** No fire or flame at any time, no explosion at any time and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.9 and shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the fuel cartridge. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.9.4 Option 3 – One weight measurement

This option is intended for fuel cartridges with very small leak rates.

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge.
- b) **Purpose:** to simulate the effects of long-term storage at elevated temperature and ensure no leakage.
- c) **Test procedure** (See Figure 9):
- 1) Measure and record initial mass M_{initial} and time t_i .
 - 2) Place the fuel cartridges in a temperature chamber at $50\text{ °C} \pm 2\text{ °C}$. After 28 days, the fuel cartridges are removed from the chamber for measurement. The test samples should be stabilised at laboratory temperature if the mass loss will be affected. Then weight measurement is executed.
 - 3) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, calculate the fuel vapour loss by dividing the mass loss by the number of hours that the test sample was in the chamber. Within five minutes of completing the test, measure and record mass M_{final} and record time t_f . If the average mass loss rate is less than 0,045 g/h, then the test sample passes the test for fuel vapour loss.
 - i) Fuel vapour loss $= \frac{M_{\text{initial}} - M_{\text{final}}}{\Delta t}$
 - ii) $\Delta t = t_f - t_i = 28\text{ days} \times 24\text{ h/day} = 672\text{ h}$.
 - iii) M_{initial} = the initial mass of the fuel cartridge.
 - iv) M_{final} = the final mass of the fuel cartridge.
 - 4) If the fuel cartridge is empty after 28 days, then the type test according to H.7.3.9.2 Option 1 or H.7.3.9.3 Option 2 shall be done.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time and no impermissible leakage. Leakage shall be measured on the basis of the procedure described in Figure H.9 and shall be less than 0,045 g/h. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the fuel cartridge. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

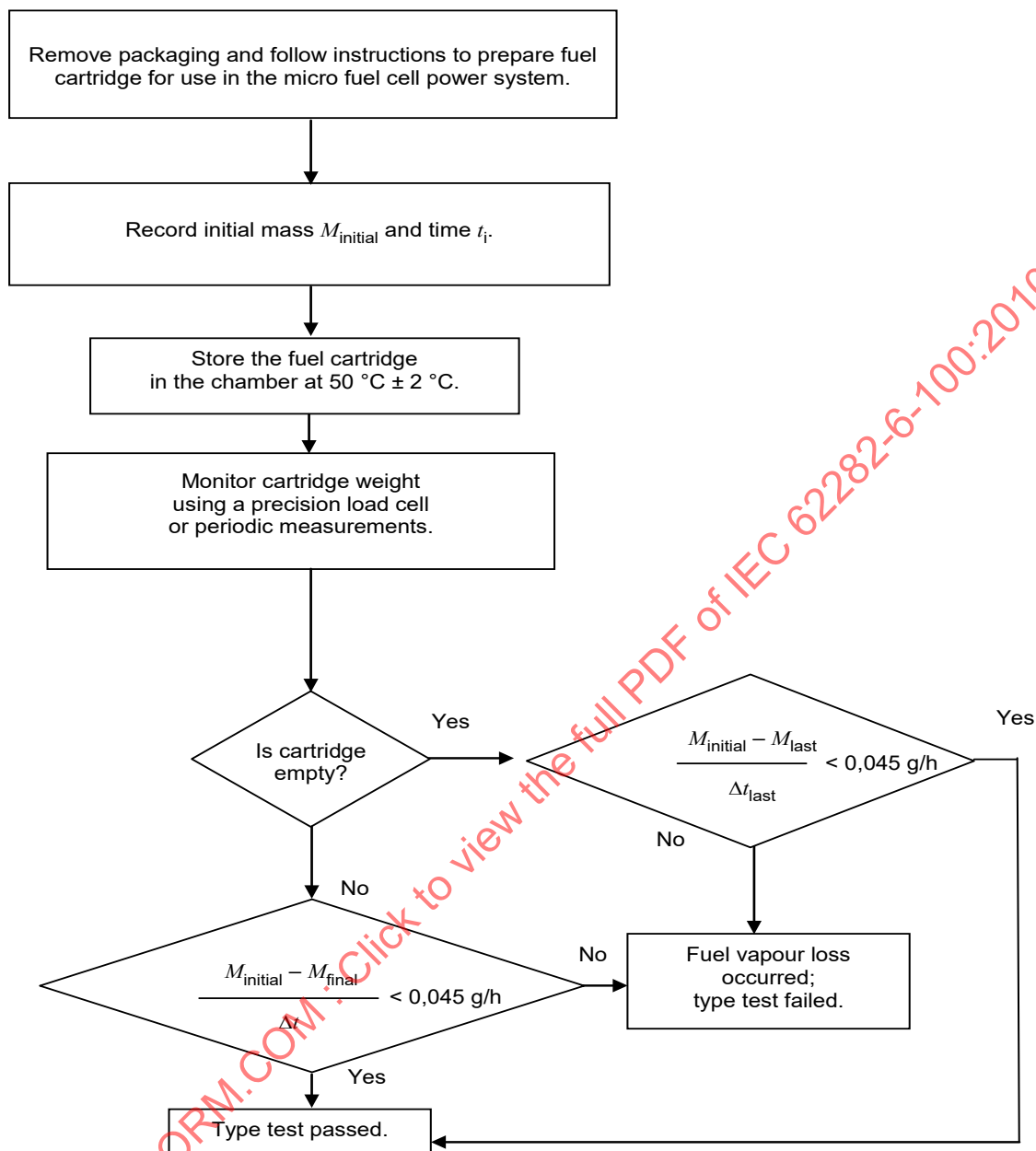


Figure H.9 – Fuel cartridge leakage and mass loss test flow chart for long-term storage test – Replaces Figure 9

H.7.3.10 High-temperature connection test

- a) **Test sample:** an unused fuel cartridge or a partially filled fuel cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage, no fire, no explosion.
- c) **Test procedure:**
 - 1) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of $50\text{ °C} \pm 2\text{ °C}$ for at least 4 h.
 - 2) The micro fuel cell power unit or test fixture with a micro fuel cell power unit valve is kept at laboratory temperature. If the micro fuel cell power unit or test fixture has an internal reservoir, it should be filled prior to connection with the test sample in order to prevent fill volume from being a source of error in the leakage measurement.
 - 3) Remove the test sample from the chamber and, within 5 min of removal from the chamber, weigh test sample and connect the fuel cartridge to the micro fuel cell power unit or test fixture with a micro fuel cell power unit valve.
 - 4) Disconnect the fuel cartridge and weigh. The maximum acceptable mass loss is 0,045 g.
- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. If, using normal force, the fuel cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, this is acceptable. Leakage shall be determined by the difference in mass before and after the connection cycle. Mass loss shall be less than 0,045 g. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit or cartridge. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C . No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.11 Connection cycling test

H.7.3.11.1 Fuel cartridge

H.7.3.11.1.1 Insert cartridge, exterior cartridge or attached cartridge

- a) **Test sample:** an unused insert cartridge, exterior cartridge or attached cartridge and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions or a suitable test fixture with a micro fuel cell power unit valve and fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection.
 - 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 4) Disconnect the fuel cartridge and measure the mass of the cartridge.
 - 5) Connect and disconnect the cartridge for a total of three connections and disconnections.

- 6) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is greater than 0,9 g, the fuel cartridge fails the type test.
 - 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
 - 8) Weigh the fuel cartridge and record the mass.
 - 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 10) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is greater than 0,9 g, the fuel cartridge fails the type test.
 - 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 13) Disconnect the fuel cartridge and check for leakage by subjecting the cartridge to a water bath test.
- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. Leakage shall be determined by the difference in mass before and after the connection cycle. Mass loss shall be less than 0,9 g over three connection cycles. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the cartridge, micro fuel cell power unit or test fixture. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.11.1.2 Satellite cartridge

- a) **Test sample:** an unused satellite fuel cartridge and an unused micro fuel cell power unit or a suitable test fixture with a micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the micro fuel cell power unit geometry and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the micro fuel cell power unit and ensure no leakage.
- c) **Test procedure:**
 - 1) Connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve.
 - 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 4) Disconnect the fuel cartridge and measure the mass of the cartridge.
 - 5) Connect and disconnect the cartridge for a total of three more connections and disconnections.
 - 6) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is equal to or greater than 0,9 g, the fuel cartridge fails the type test.
 - 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
 - 8) Weigh the fuel cartridge and record the mass.
 - 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.

- 10) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is equal to or greater than 0,9 g, the fuel cartridge fails the type test.
 - 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 13) Disconnect the fuel cartridge and check for leakage by subjecting the cartridge to a water bath test.
 - 14) Repeat steps 5 through 13 four more times for a total of 55 cycles, waiting 1 h between each set of 11 cycles.
- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. Leakage shall be determined by the difference in mass before and after the connection cycle. Mass loss shall be less than 0,9 g over three connection cycles. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the cartridge, micro fuel cell power unit or test fixture. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.11.3 Micro fuel cell power unit

- a) **Test sample:** a minimum of two unused fuel cartridges and an additional 98 fuel cartridges or suitable test fixtures with fuel cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions. The test fixture shall have a configuration representative of the fuel cartridge valve geometry and material and shall have the ability to simulate fuel flow.
- b) **Purpose:** to simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage both at initial use and after suitable ageing of the micro fuel cell power unit connection.
- First fuel cartridge (#1) and final fuel cartridge (#100) are inspected; the other 980 cycles are only to age the micro fuel cell power unit.

In the case of a micro fuel cell power unit using satellite cartridge, it shall be tested according to the following procedure by simulating fuel flow between the satellite cartridge and the micro fuel cell power unit.

- c) **Test procedure:**
- 1) Connect the first fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve.
 - 2) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 3) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 4) Disconnect the fuel cartridge and measure the mass of the cartridge.
 - 5) Connect and disconnect the cartridge for a total of three more connections and disconnections.
 - 6) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is equal to or greater than 0,9 g, the fuel cartridge fails the type test.
 - 7) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
 - 8) Weigh the fuel cartridge and record the mass.
 - 9) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.

- 10) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is equal to or greater than 0,9 g, the fuel cartridge fails the type test.
 - 11) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 12) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 13) In order to age the micro fuel cell power unit fuel cartridge connection, perform the following steps.
 - i) Using either fuel cartridges or a suitable test fixture with fuel cartridge valves, cycle the micro fuel cell power unit fuel cartridge connection for a total of 980 connections and disconnections. Cartridges or valves may be changed every 10 or more cycles.
 - ii) Simulate fuel flow after each set of 50 connection-disconnection cycles.
 - iii) Mass loss does not need to be checked during the aging process, but if obvious leakage is noted, the test fails.
 - iv) Following this ageing, a final unused fuel cartridge will be tested.
 - 14) Connect the final fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve.
 - 15) Operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 16) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 17) Disconnect the fuel cartridge and measure the mass of the cartridge.
 - 18) Connect and disconnect the cartridge for a total of three more connections and disconnections.
 - 19) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is equal to or greater than 0,9 g, the fuel cartridge fails the type test.
 - 20) Connect and disconnect the fuel cartridge four more times for a total of seven connections and disconnections.
 - 21) Weigh the fuel cartridge and record the mass.
 - 22) Connect and disconnect the fuel cartridge three more times for a total of ten connections and disconnections.
 - 23) Weigh the fuel cartridge and calculate the mass loss during the three connect-disconnect cycles. If the accumulated mass loss is equal to or greater than 0,9 g, the fuel cartridge fails the type test.
 - 24) Connect fuel cartridge and operate the micro fuel cell power unit or otherwise simulate fuel flow for at least 1 min.
 - 25) Turn off the micro fuel cell power unit or stop simulated fuel flow.
 - 26) Disconnect the fuel cartridge and check for leakage by subjecting the cartridge to a water bath test.
- d) **Passing criteria:** No leakage, no fire or flame, and no explosion. Leakage shall be determined by the difference in mass before and after the connection cycle. Mass loss shall be less than 0,9 g over three connection cycles. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power unit. Cartridge shall be subjected to a water bath test and shall be bubble-tight. The temperature of the water bath and the duration of the test shall be such that the internal pressure in the cartridge reaches that which would be reached at 55 °C. No leakage or permanent deformation may occur, except that a plastic cartridge may be deformed through softening provided that it does not leak.

H.7.3.12 Emission test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** Under operating conditions (or attempted operating conditions) of a micro fuel cell power system or micro fuel cell power unit, emission of carbon monoxide (CO), carbon dioxide (CO₂) and organic compounds such as butane, formaldehyde, and other materials listed in Table H.7 shall be maintained at less than the specified values. Maintaining these limits not only prevents inadvisable exposure but also ensures that an adequate supply of oxygen is maintained in the operating environment.

The "DEVICE-OFF" emission test is performed solely to assure there is no impermissible leakage of fuel. Butane solid oxide micro fuel cell power units must be operating at temperature in order to generate reaction-based emissions, which are evaluated in the "DEVICE ON" emission test.

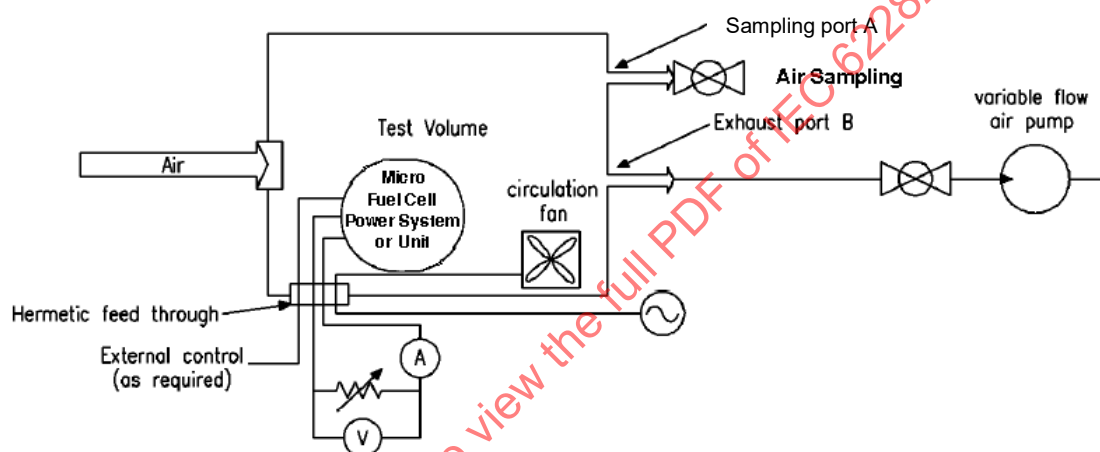


Figure H.10 – Operational emission rate testing apparatus – Replaces Figure 10

- c) **Test apparatus:** An example of the emission rate testing apparatus is shown in Figure H.10. The configuration shown in Figure H.10 is for emission rate testing of all micro fuel cell power systems or units tested in accordance with this Annex H. Emission rate testing in accordance with H.7.3.12 d) 1) is required for all types of micro fuel cell power systems and micro fuel cell power units tested in accordance with this Annex H.

For micro fuel cell power systems or units that are intended to be used in close proximity to a consumer's mouth or nose (such as micro fuel cell power systems or units used to power cell phones, handheld games, etc.), additional testing in accordance with H.7.3.12 d) 2) is required to verify that emission concentrations in the vicinity of a user's mouth or nose are kept within appropriate limits. This emission concentration testing shall be done in a large open room using a different emission concentration testing apparatus. An example of the operational emission concentration testing apparatus is shown in Figure H.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell power system or unit to a consumer's mouth or nose when in use) for emission concentration limit testing.

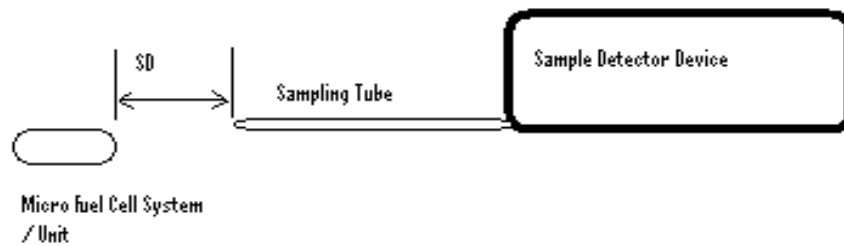


Figure H.11 – Operational emission concentration testing apparatus

Emission gases might be composed of toxic organic materials such as methanol, formaldehyde, formic acid and methyl formate, which are potentially exhausted from a micro fuel cell power system or a micro fuel cell power unit.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS), a high-performance liquid chromatography (HPLC) system, a visible absorption spectrophotometer (VAS), or an ultraviolet visible absorption spectrophotometer (UV-VAS) shall be used either by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyzer through sampling port A in Figure H.10. However, the use of other instruments is allowed, provided that the performance for this measurement is sufficient to accurately determine compliance with the emission limits.

The concentration of CO and CO₂ gas can be measured by a non-dispersive infrared absorption analyzer. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance for this measurement is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) Test procedure:

- 1) For all micro fuel cell power systems and units – both those intended to be used in close proximity to a consumer's mouth or nose and those not intended to be used in close proximity to a consumer's mouth or nose – the following emission rate sampling test shall be performed.
 - i) Place the micro fuel cell power system or micro fuel cell power unit inside the small test chamber shown in Figure H.10, with the unit on and operating at rated power. If the micro fuel cell power system or unit is no longer operational due to a type test, the emission test shall be performed with the micro fuel cell power system or unit fully fuelled and the power switch in the "ON" position ("DEVICE – ON").
 - ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.
 - iii) Gaseous emission from the micro fuel cell power system or unit shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure H.10.
 - iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
 - v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure H.10, while simultaneously measuring and recording the flow through the test chamber. The flow through the test chamber can be computed from the sum of the variable flow air pump flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber.

- vi) Record the concentrations of the chemical compounds of interest for the “unit on” emission criteria. See Table H.7.
- vii) Turn the unit off, opening and closing the chamber as necessary. Allow the micro fuel cell power unit to complete any shut down cycle and transition to its full OFF state.
- viii) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilise.
- ix) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure H.10, while simultaneously measuring and recording the flow through the test chamber. The flow through the test chamber can be computed from the sum of the variable flow air pump flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber.
- x) Record the concentrations of the chemical compounds of interest for the “unit off” emission criteria. See Table H.7.
- xi) Calculate the emission rate of chemical compounds of interest by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the chamber. The total air flow through the chamber is determined by adding the steady-state variable flow air pump flow rate through the chamber to the simultaneous sample flow rate or by measuring the inlet air flow rate.

NOTE The total air flow into the chamber is equal to the sum of the air flow rates out of the chamber. Therefore, the air flow rate at the inlet of the chamber is equal to the air flow rate at the outlet of the chamber plus the sampling flow rate. The two values both represent the total air flow rate through the chamber, and either may be used to calculate the emission rate.

See below:

$$ER = (F_P + F_S) \times C$$

or

$$ER = (F_i) \times C$$

where

ER is the emission rate in grams per hour;

F_P is the variable flow air pump flow rate in standard litres per hour;

F_S is the sample flow rate in standard litres per hour;

F_i is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

- xii) Compare the maximum measured emission rate to Table H.7. If the emission rate is not less than the emission rate limit in Table H.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria H.7.3.12 e) 1) i) and H.7.3.12 e) 2) i).
- xiii) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

- 2) For micro fuel cell power systems and units that are intended to be used in close proximity to a consumer's mouth or nose, the following additional emission concentration sampling test shall be performed. This test only need be performed with the unit on, as leakage rate with the unit off is assessed under Subclause H.7.3.12 1) and the associated emission limit does not present a hazard to humans.
 - i) Emission rate testing of micro fuel cell power systems or units shall be done in a large open room. It is the intent of this test to approximate and to measure the expected emission concentrations near a person's mouth or nose in still air. A mannequin or other mock-up may be used to improve the accuracy of the test. The air in the room shall be sampled prior to testing to ensure accuracy and to avoid false non-compliant results. Be careful to ensure that materials in the room or in the sampling apparatus do not contribute emissions (that is, contaminants) to the test. Prior to testing, a check for contamination without the micro fuel cell power system or unit in place is recommended to avoid false non-compliant results. Air changes in the room shall be kept to a minimum corresponding to normal residential or commercial designs (e.g. less than one air change per hour). Take care not to disturb the sampling area with extraneous air flows.
 - ii) Gaseous emission concentrations from the micro fuel cell power system or unit shall be sampled using the operational emission concentration testing apparatus shown in Figure H.11. For emission concentration testing, the air sampling tube shall extend to a separation distance (SD) from the micro fuel cell power system or micro fuel cell power unit that is representative of the breathing zone of a consumer (the distance from the micro fuel cell system or unit to a consumer's mouth or nose when in use).
 - iii) The sampling rate for the close proximity emission concentration measurements shall be 5 l per minute, which represents the breathing rate of an adult human being.
 - iv) Allow the sample flow rate to stabilize.
 - v) Sample and record the fuel cell power system or unit gaseous emissions that occur at a distance that is representative of the breathing zone of a consumer.
 - vi) Record the concentrations of the chemical compounds of interest. See Table H.7.
 - vii) Compare the maximum measured concentrations to Table H.7. If the emission concentrations are not less than the emission concentration limits in Table H.7, the micro fuel cell power system or unit fails the test and no further testing is required. See passing criteria H.7.3.12 e) 2) ii).
 - viii) Emission measurements shall be averaged over a certain time duration which is representative of the normal operation of the micro fuel cell power system or unit and the equipment that it powers (i.e. one fuel cartridge worth of operation). The test does not need to be measured continuously, providing that the initial start-up, at least 3 h of operation, and the end of the fuel cartridge are measured. If the fuel cartridge does not last for 3 h, the entire fuel cartridge duration shall be measured continuously.

e) Passing criteria:

- 1) For micro fuel cell power systems and micro fuel cell power units not intended to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table H.7 shall be less than the emission rate limit value in Table H.7 when tested in accordance with H.7.3.12 d) 1). If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.
- 2) For micro fuel cell power systems and micro fuel cell power units to be used in close proximity to a consumer's mouth or nose:
 - i) The maximum emission rate for each of the constituents of interest in Table H.7 shall be less than the emission rate limit value in Table H.7 when tested in accordance with H.7.3.12 d) 1). If the micro fuel cell power system or unit does not

operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.

- ii) For micro fuel cell power systems and micro fuel cell power units intended to be used in close proximity to a consumer's mouth or nose; in addition to meeting the emission rate limit above, the maximum emission concentration for each of the constituents of interest shall be less than the emission concentration limit in Table H.7 when tested in accordance with H.7.3.12 d) 2). If the micro fuel cell power system or unit does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.

Table H.7 – Emission Limits – Replaces Table 7

	"DEVICE – ON" Concentration limit ^a	"DEVICE – OFF" Emission rate limit ^c	"DEVICE – ON" Emission rate limit ^b
Butane^g	1,9 g/m ³	0,045 g/h	0,9 g/h
CO	0,029 g/m ³	N/A	0,290 g/h
CO₂	9 g/m ³	N/A	60 g/h ^d
Formic acid	0,009 g/m ³	N/A	0,09 g/h
Formaldehyde ^e	0,000 1 g/m ³	N/A	0,000 6 g/h
Hydrogen ^f	N/A	N/A	0,016 g/h
Methyl formate	0,245 g/m ³	N/A	2,45 g/h
NO	0,031 g/m ³	N/A	0,31 g/h
NO₂	0,005 7 g/m ³	N/A	0,57 g/h

^a The concentration limits in this table are in units of g/m³ and are the equivalent of the TWA exposure limits expressed in ppmv, as shown in Table H.8. Concentration limits are not tested with the device off, as the leakage rate with the unit off is assessed under Subclause H.7.3.12 1) and the associated emission limit does not present an inhalation hazard to humans.

^b The "DEVICE – ON" emission rate limit is based on 10 m³ ACH, selected as the product of the reference volume times the air changes per hour (ACH), as this represents the reasonably foreseeable environments where micro fuel cell power systems or units will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m³. The minimum ACH used on passenger aircraft is 10 and the lowest ventilation setting in cars is 10 ACH. Homes and offices may have ACH levels as low as 0,5 but the per person volume is over 20 m³, so a product of 10 is conservative.

^c The "DEVICE – OFF" emission test is performed solely to assure there is no impermissible leakage of fuel. Butane solid oxide micro fuel cell power units must be operating at temperature in order to generate reaction-based emissions, which are evaluated in the "device – on" emission test.

^d A seated human adult has a CO₂ emission rate of 30 g/h. The fuel cell plus human adult emission rates are limited such that the CO₂ concentration does not reach the WHO eight-hour concentration limit of 9 g/m³. In an environment with 10 m³ ACH, this limits the contribution from the fuel cell to 60 g/h.

^e WHO guideline limit for formaldehyde is 0,000 1 g/m³. Background levels are 0,000 03 g/m³. The fuel cell emission cannot push the background level above the guideline limit.

^f The operating hydrogen emission rate of 0,016 g/h equates to the highest leak rate that will not support a flame and is less than the 0,8 g/h leak rate necessary to achieve a 25 % LFL in a 1 cubic meter chamber with 1 air change per hour.

^g The operating butane emission rate of 0,9 g/h equates to the highest leak rate that will not support a flame and is less than the 1,9 g/h leak rate necessary to achieve the TLV limit of 800 ppm in a 1 cubic meter chamber with 1 air change per hour. The non-operating butane leakage criteria have been chosen based on a scenario of micro fuel cell power systems or units in an enclosed space with no ventilation. The space chosen has a volume of 0,28 m³, or approximately 10 cubic feet. The criterion has been prescribed so that a butane concentration of greater than 25 % LFL is not permitted to develop over a twenty-four hour (24 h) period, if three micro fuel cell power systems are in the enclosed space.

Table H.8 – Occupational exposure limits

	TWA exposure limit (TWA – time weighted average over 8 h of operation)
Butane	< 800 ppmv
CO	< 25 ppmv
CO ₂	< 5 000 ppmv
Formic acid	< 5 ppmv
Formaldehyde	< 0,08 ppmv
Hydrogen	N/A
Methyl formate	< 100 ppmv
NO	< 25 ppmv
NO ₂	< 3 ppmv

H.7.3.13 High temperature shutdown test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with the manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** To verify that the micro fuel cell power unit initiates a shutdown sequence within a reasonable time period if the SOFC stack reaches an abnormal high temperature. If the micro fuel cell power unit fails to operate normally after testing one of these components, a different unit may be used for testing the remaining components. If any combination of components is integrated into an isothermal module, those components may be tested concurrently.
- c) **Test procedure:**
 - 1) While the micro fuel cell power unit is operating at its rated output, use the manufacturer's specified method to set the SOFC stack to a temperature 20 °C above the maximum operating temperature.
 - 2) Verify that the micro fuel cell power system shutdown sequence is initiated either prior to the test component reaching or within 5 s of reaching the elevated temperature set point.
 - 3) If the micro fuel cell power unit does not contain a high temperature reformer, or if the reformer is in the same thermal module as the SOFC stack, proceed to step 5. Otherwise, while the micro fuel cell power unit is operating at its rated output, use the manufacturer's specified method to set the reformer to a temperature 20 °C above the maximum operating temperature.
 - 4) Verify that the micro fuel cell power system shutdown sequence is initiated either prior to the test component reaching or within 5 s of reaching the elevated temperature set point.
 - 5) If the micro fuel cell power unit does not contain a high temperature catalytic converter, or if the catalytic converter is in the same thermal module as the SOFC stack, the test is complete. Otherwise, while the micro fuel cell power unit is operating at its rated output, use the manufacturer's specified method to set the catalytic converter to a temperature 20 °C above the maximum operating temperature.
 - 6) Verify that the micro fuel cell power system shutdown sequence is initiated either prior to the test component reaching or within 5 s of reaching the elevated temperature set point.
- d) **Passing criteria:** The micro fuel cell power unit shutdown sequence shall initiate before reaching, or no later than 5 s after reaching, the elevated temperature set point.

H.7.3.14 High temperature operation test

- a) **Test sample:** a micro fuel cell power unit fuelled in accordance with the manufacturer's specifications or a micro fuel cell power system with unused fuel cartridge.
- b) **Purpose:** To verify that the micro fuel cell power unit operates safely if the SOFC stack is at a temperature of 30 °C above the maximum operating temperature. If the micro fuel cell power unit contains a reformer, or catalytic converter, these components shall also be tested. If the micro fuel cell power unit fails to operate normally after testing one of these components, a different unit may be used for testing the remaining components. If any combination of components is integrated into an isothermal module, those components may be tested concurrently.
- c) **Test procedure:**
- 1) Use manufacturer's specified method to disable the automatic shutdown mechanism described in H.7.3.13. Set the SOFC stack temperature at 30 °C above the maximum specified operating temperature.
 - 2) Run the micro fuel cell power unit at full load as specified by the manufacturer for 1 h at this elevated temperature. The micro fuel cell power unit is not required to deliver the rated load or function normally, as a result of the elevated temperature.
 - 3) Perform emission testing in accordance with H.7.3.12 with the unit on and off.
 - 4) If the micro fuel cell power unit does not contain a high temperature reformer or if the reformer is in the same thermal module as the SOFC stack, proceed to step 7. Otherwise, use the manufacturer's specified method to disable the automatic shutdown mechanism described in H.7.3.13. Set the reformer temperature at 30 °C above the maximum specified operating temperature.
 - 5) Run the micro fuel cell power unit at full load as specified by the manufacturer for 1 h at this elevated temperature. The micro fuel cell power unit is not required to deliver the rated load or function normally, as a result of the elevated temperature.
 - 6) Perform emission testing in accordance with H.7.3.12 with the unit on and off.
 - 7) If the micro fuel cell power unit does not contain a high temperature catalytic converter, or if the catalytic converter is in the same thermal module as the SOFC stack, the test is complete. Otherwise, use the manufacturer's specified method to disable the automatic shutdown mechanism described in H.7.3.13. Set the catalytic converter temperature at 30 °C above the maximum specified operating temperature.
 - 8) Run the micro fuel cell power unit at full load as specified by the manufacturer for 1 h at this elevated temperature. The micro fuel cell power unit is not required to deliver the rated load or function normally, as a result of the elevated temperature.
 - 9) Perform emission testing in accordance with H.7.3.12 with the unit on and off.
- d) **Passing criteria:** No fire or flame at any time, no explosion at any time. Fire and flame shall be checked using cheesecloth, infrared camera, or other suitable methods. Explosion shall be checked visually to verify that there is no disturbance to the micro fuel cell power system or micro fuel cell power unit. Micro fuel cell power system or micro fuel cell power unit shall be emission tested with the micro fuel cell power unit both on and off and shall meet the acceptance criteria in H.7.3.12. If the micro fuel cell power unit does not operate but the emission does not exceed the limits of H.7.3.12, the emission test is acceptable.

H.7.3.15 Fire test

a) **Test sample:** an unused fuel cartridge.

b) **Purpose:** Fire testing shall be performed on all new fuel cartridge designs with a butane capacity of over 200 ml. The test is to demonstrate that the fire protection system, such as pressure relief devices (PRD) and/or integral thermal insulation will prevent the uncontrolled venting of the fuel cartridge under the specified fire conditions.

Any significant change to the design, for example changes in: diameter, length, or PRD shall necessitate repeating the fire testing. Exception: A manufacturer can use data and engineering calculations, based on previous fire testing results on existing designs, to show that a new design does not require fire testing.

Precautions shall be taken to insure safety of personnel and property during fire testing in the event that fuel cartridge rupture occurs.

c) **Test procedure:**

- 1) Fuel cartridges shall be filled to rated capacity with butane. The fuel cartridges tested shall be representative of production cartridges.
- 2) Temperature and pressure of the fuel cartridge shall be monitored remotely and recorded at intervals of every 15 s or less. Where practical, a manual valve shall be installed to allow venting of the fuel cartridge in the event of a test equipment or micro fuel cell power system malfunction.

In addition to the pressure and temperature readings, the following information shall also be recorded for each test, as applicable:

- i) fuel cartridge manufacturer;
- ii) fuel cartridge part or model number;
- iii) unique fuel cartridge identifier;
- iv) PRD location and orientation;
- v) date of test;
- vi) fuel cartridge pressure in MPa;
- vii) fuel cartridge orientation (vertical, horizontal or inverted);
- viii) laboratory temperature;
- ix) estimated wind condition/direction;
- x) names of witnesses;
- xi) time of activation of pressure relief device; and
- xii) elapsed time to completion of the test.

Exception: For fuel cartridge designs that preclude monitoring pressure during the fire test, a statement of justification for not monitoring pressure during the fire test shall be given, a means for determining activation of the PRD shall be provided and additional safety precautions shall be taken to safely carry out the fire test.

- 3) Fire tests shall be conducted on at least three fuel cartridges in each orientation of intended use and/or transportation. For fuel cartridge designs for which the orientation of use and transportation are not specified, at least three fuel cartridges shall be fire tested in at least the vertical and horizontal orientation.

Fuel cartridges shall be subjected to a heat source over their entire width. For fuel cartridges less than or equal to 0,30 m in length, a temperature-indicating device shall be installed within 0,05 m of, but not in contact with, the fuel cartridge surface near each end. For fuel cartridges longer than 0,30 m, install a temperature indicating device at each end and one at the midpoint. Temperature-indicating devices are permitted to be inserted into small metallic blocks (less than 0,025 m per side).

- 4) The fuel cartridges shall be tested either by direct (bonfire) or indirect (chimney) flame impingement methods. The fire source shall totally engulf the test apparatus described above. Any fuel may be used for the fire source provided it supplies uniform heat sufficient to maintain the specified test temperatures for a minimum of 20 min or until the fuel cartridge is vented. The selection of a fuel should take into consideration air pollution concerns. The arrangement of the fire shall be recorded in sufficient detail to ensure that the rate of heat input to the fuel cartridge is reproducible.

i) Direct flame impingement

Sufficient fuel shall be supplied to ensure a burn time of at least 20 min. The fuel cartridge shall be placed in the test orientation with the fuel cartridge at least 0,100 m above the fuel or at a sufficiently greater height to ensure total flame engulfment. Metallic shielding shall be used to prevent direct flame impingement on tank valves, fittings, and/or pressure relief devices. The metallic shielding shall not be in direct contact with the specified fire protection system (pressure relief devices or tank valve).

ii) Indirect flame impingement

The fuel cartridge shall be placed in a test apparatus that is designed to contain the test subject and provide a controlled and reproducible rate of heat input without localized overheating. The apparatus can be constructed of any suitable material capable of withstanding the test environment. The fire source shall be installed to provide heat to the chimney and test specimen in a uniform manner.

Immediately following ignition, the fire shall produce a flame entirely engulfing the test apparatus. The temperature of at least one temperature-indicating device shall indicate a temperature of at least 590 °C within 5 min of ignition. One temperature-indicating device shall maintain an average temperature of at least 590 °C for the duration of the test.

d) **Passing criteria:**

- 1) The fuel cartridge design is deemed to have passed the test if, for all valid tests, either of the following criteria is met in the same manner.
 - i) The internal pressure vents to zero gauge pressure in a controlled manner as intended by the fuel cartridge design.
 - ii) The fuel cartridge withstands the fire for a minimum of 20 min without venting.
- 2) Any failure or inconsistency of the fire or heat source during a test shall invalidate the result, and a re-test shall be required. Any venting through or failure of the shell, a valve, fitting or tubing during the test that is not part of the intended protection system shall invalidate the result and a re-test shall be required.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

TECHNOLOGIES DES PILES A COMBUSTIBLE –

Partie 6-100: Systèmes à micropiles à combustible – Sécurité

AVANT-PROPOS

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- 8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
- 9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets et de ne pas avoir signalé leur existence.

La Norme internationale IEC 62282-6-100 a été établie par le comité d'études 105 de l'IEC: Technologies des piles à combustible.

Cette norme annule et remplace le document IEC/PAS 62282-6-1 paru en 2006. Cette première édition constitue une révision technique.

La présente version bilingue (2019-01) correspond à la version anglaise monolingue publiée en 2010-03.

Le texte anglais de cette norme est issu des documents 105/255/FDIS et 105/261/RVD.

Le rapport de vote 105/261/RVD donne toute information sur le vote ayant abouti à l'approbation de cette norme.

La version française de cette norme n'a pas été soumise au vote.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Mode d'emploi de la présente norme:

Les articles et paragraphes du corps du texte sont modifiés, remplacés ou appliqués tel qu'ils apparaissent dans chacune des annexes, qui s'applique à une technologie différente. Les instructions figurent en italique.

- a) Pour les combustibles au méthanol ou au méthanol et eau qui font l'objet des Articles 1 à 7, toutes les exigences sont données dans ces mêmes articles, et il convient de ne pas se référer aux annexes pour ces combustibles.
- b) Pour les combustibles et technologies spécifiques qui font l'objet des Annexes A à H, chaque annexe met en évidence les exigences additionnelles ou les modifications par rapport aux exigences des Articles 1 à 7 pour la certification de tels systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et leurs cartouches de combustible respectives qui font l'objet de l'annexe spécifique.
- c) Dans la mesure du possible, la hiérarchisation des annexes correspond à la numérotation des Articles 1 à 7 et de leurs paragraphes. Les exigences des Articles 1 à 7 et de leurs paragraphes auxquelles il n'est pas spécifiquement fait référence dans une annexe, s'appliquent aux combustibles et technologies qui font l'objet de cette annexe particulière tel que spécifié dans les Articles 1 à 7.
- d) Lorsqu'une annexe se réfère à un paragraphe spécifique – précédé de la lettre qui désigne l'annexe (ces paragraphes spécifiques de l'annexe rendent compte des exigences additionnelles ou des modifications pour les combustibles et technologies qui font l'objet de cette annexe particulière) et doivent être appliqués pour cette annexe. Tous les paragraphes additionnels se sont vu attribuer de nouveaux numéros et doivent être appliqués.
- e) Les figures ou tableaux modifiés ou de remplacement se sont vu attribuer des désignations modifiées (basées sur les numéros de figure ou de tableau des Articles 1 à 7 précédés par la lettre qui désigne l'annexe). Les nouvelles figures ou nouveaux tableaux des annexes se sont vu attribuer des désignations nouvelles et doivent également être utilisés.

Une liste de toutes les parties de la série IEC 62282, publiées sous le titre général *Technologies des piles à combustible*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "<http://webstore.iec.ch>" dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

NOTE L'attention des Comités Nationaux est attirée sur le fait que les fabricants d'appareils et les organismes d'essai peuvent avoir besoin d'une période transitoire après la publication d'une nouvelle publication IEC, ou d'une publication amendée ou révisée, voire d'une publication qui remplace une Spécification accessible au public (PAS) existante, pour fabriquer des produits conformes aux nouvelles exigences et se doter des moyens nécessaires pour procéder à des essais selon des méthodes nouvelles ou révisées.

Le comité recommande que le contenu de cette publication soit entériné au niveau national au plus tôt 12 mois après la date de publication.

Avant cette date, le document IEC/PAS 62282-6-1 peut toujours être commandé auprès du Comité National membre de l'IEC ou du Bureau Central de l'IEC.

Le contenu du corrigendum de décembre 2011 a été pris en considération dans cet exemplaire.

IMPORTANT – Le logo "colour inside" qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

TECHNOLOGIES DES PILES A COMBUSTIBLE –

Partie 6-100: Systèmes à micropiles à combustible – Sécurité

1 Domaine d'application

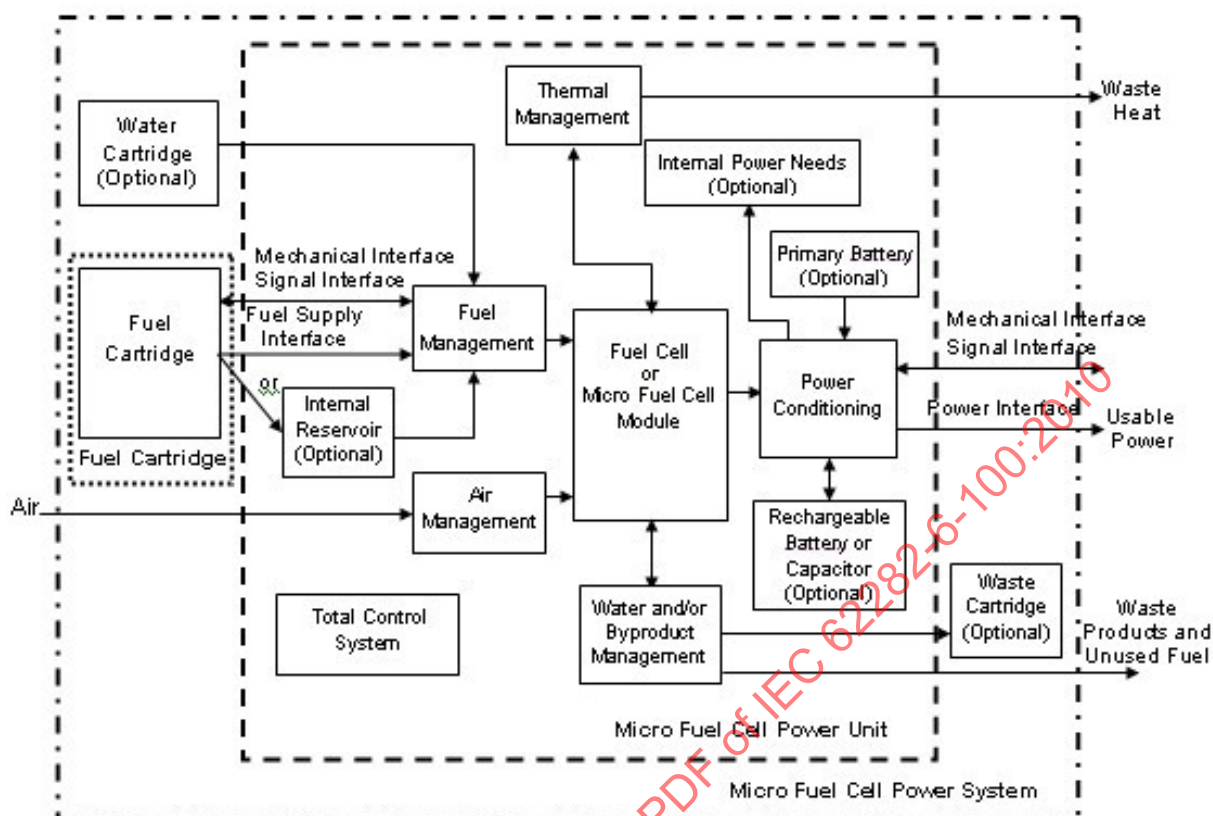
1.1 Généralités

- a) Cette norme de sécurité pour les consommateurs traite des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible, qui sont portatifs ou qui peuvent être facilement portés à la main, fournissant une tension de sortie en courant continu ne dépassant pas 60 V et une puissance de sortie ne dépassant pas 240 VA. Les systèmes à piles à combustible portatifs qui fournissent des tensions de sortie supérieures à ces limites électriques relèvent de l'IEC 62282-5-1.
- b) Les circuits accessibles de l'extérieur sont alors considérés comme des circuits à très basse tension de sécurité (TBTS), tels que définis dans l'IEC 60950-1:2005, et comme des circuits à puissance limitée, si la conformité à 2.5 de l'IEC 60950-1:2005 est démontrée par la suite. Il convient que les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible ayant des circuits internes dépassant 60 V en courant continu ou 240 VA soient évalués de façon appropriée, conformément aux critères distincts de l'IEC 60950-1:2005.
- c) Cette norme de sécurité pour les consommateurs traite de tous les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible. La présente norme établit des exigences pour tous les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible, afin d'assurer un degré de sécurité raisonnable pour l'utilisation normale, le mauvais usage raisonnablement prévisible, et le transport pour la vente de tels éléments. Les cartouches de combustible couvertes par la présente norme ne sont pas destinées à être rechargées par le consommateur. Les cartouches de combustible rechargées par le fabricant ou par des techniciens formés doivent satisfaire à toutes les exigences de la présente norme.
- d) Ces produits ne sont pas destinés à une utilisation dans des emplacements dangereux au sens de l'IEV 426-03-01.

1.2 Combustibles et technologies

- a) Un schéma de principe de système à micropile à combustible est représenté à la Figure 1.
- b) Toutes les parties de cette norme, y compris les annexes, s'appliquent aux systèmes à micropiles à combustible, aux blocs d'alimentation électriques des micropiles à combustible et aux cartouches de combustible tels que définis au 1.1 ci-dessus.
- c) Les Articles 1 à 7 de la présente norme traitent des piles à combustible au méthanol qui utilisent des solutions composées de méthanol ou de méthanol et d'eau. Les Articles 1 à 7 traitent des exigences spécifiques pour les piles à combustible au méthanol qui utilisent des technologies de membrane à échange de protons. Les Articles 1 à 7 traitent également des exigences générales applicables à toutes les technologies de piles à combustible et à toutes les piles à combustible relevant des Annexes A à H.
- d) Les Annexes A à H traitent des combustibles et technologies de piles à combustible comme suit.
 - 1) L'Annexe A traite des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible de l'acide formique en solutions aqueuses (à une concentration en acide formique inférieure à 85 % en poids). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à l'acide formique direct.

- 2) L'Annexe B traite des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible de l'hydrogène (contenu dans un récipient en alliage métallique absorbant l'hydrogène). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de protons.
- 3) L'Annexe C traite des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible qui convertissent en utilisant un reformeur et utilisent comme combustible des solutions de méthanol ou de méthanol et d'eau en hydrogène reformé riche en méthanol, lequel est immédiatement injecté dans la pile à combustible ou le bloc de piles à combustible. Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de proton.
- 4) L'Annexe D traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible des solutions de méthanol ou de méthanol et d'eau (dérivées de composés de clathrate de méthanol). Ces systèmes et blocs d'alimentations utilisent des technologies de piles à combustible au méthanol direct.
- 5) L'Annexe E traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible l'hydrogène produit à partir de composés de borohydrure de classe 8 (corrosifs). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de proton. Les conceptions peuvent inclure des sous-systèmes de traitement de combustibles pour obtenir un gaz hydrogène à partir du combustible à base de composés à borohydrure.
- 6) L'Annexe F traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible l'hydrogène produit à partir de composés de borohydrure de classe 4.3 (hydroréactifs). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de proton. Les conceptions peuvent inclure des sous-systèmes de traitement de combustibles pour obtenir un gaz hydrogène à partir du combustible à base de composés à borohydrure.
- 7) L'Annexe G traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible des composés de borohydrure de classe 8 (corrosifs). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à borohydrure direct.
- 8) L'Annexe H traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible le butane et des mélanges butane/propane (contenant au moins 75 % de butane). Ces systèmes et blocs d'alimentations utilisent des technologies de piles à combustible à oxyde solide.



Anglais	Français
Water cartridge (optional)	Cartouche d'eau (facultatif)
Thermal management	Gestion thermique
Waste heat	Chaleur résiduelle
Internal power needs (optional)	Besoins internes en énergie (facultatif)
Fuel cartridge	Cartouche de combustible
Mechanical interface	Interface mécanique
Signal interface	Interface de signal
Fuel supply interface	Interface de l'alimentation en combustible
Fuel management	Gestion du combustible
Primary battery (optional)	Pile électrique (facultatif)
Fuel cell or micro fuel cell module	Micropile à combustible ou module à micropiles à combustible
Power conditioning	Conditionnement de l'énergie
Power interface	Interface de puissance
Or	ou
Usable power	Puissance utile
Internal reservoir (optional)	Réservoir interne (facultative)
Air	Air
Air management	Gestion de l'air
Rechargeable battery or capacitor (optional)	Batterie rechargeable ou condensateur (facultatif)
Total control system	Système global de commande
Water and/or by-product management	Gestion de l'eau et/ou des sous-produits
Waste cartridge (optional)	Cartouche usagée (facultatif)

Anglais	Français
Waste products and unused fuel	Déchets et combustible inutilisé
Micro fuel cell power unit	Bloc d'alimentation électrique de micropiles à combustible
Micro fuel cell power system	Système à micropile à combustible

Figure 1 – Schéma de principe d'un système à micropile à combustible

1.3 Niveau de sécurité équivalent

- a) Les exigences de la présente norme ne sont pas destinées à limiter l'innovation. Le fabricant peut prendre en considération des combustibles, des matériaux, des conceptions ou des constructions qui ne sont pas spécifiquement traités dans la présente norme. Il convient d'évaluer ces alternatives selon leur aptitude à fournir des niveaux de sécurité équivalents à ceux définis dans la présente norme.
- b) Il est évident que tous les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible doivent être conformes aux exigences locales et nationales, y compris, entre autres, à celles relatives au transport, la protection des enfants et le stockage, le cas échéant.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-426:2008, *Vocabulaire Électrotechnique International – Partie 426: Matériel pour atmosphères explosives*

IEC 60079-15:2005, *Matériel électrique pour atmosphères explosives gazeuses – Partie 15: Construction, essais et marquage des matériels électriques du mode de protection*

IEC 60086-4, *Piles électriques – Partie 4: Sécurité des piles au lithium*

IEC 60086-5, *Piles électriques – Partie 5: Sécurité des piles à électrolyte aqueux*

IEC 60695-1-1, *Essais relatifs aux risques du feu – Partie 1-1: Guide pour l'évaluation des risques du feu des produits électrotechniques – Directives générales*

IEC 60695-2-11, *Essais relatifs aux risques du feu – Partie 2-11: Essais au fil incandescent/chauffant – Méthode d'essai d'inflammabilité pour produits finis*

IEC 60695-11-10, *Essais relatifs aux risques du feu – Partie 11-10: Flamme d'essai – Méthodes d'essai horizontale et verticale à la flamme de 50 W*

IEC 60730-1:1999, *Dispositifs de commande électrique automatiques à usage domestique et analogue – Partie 1: Règles générales*

Amendement 1 (2003)

Amendement 2 (2007)¹

IEC 60950-1:2005, *Matériels de traitement de l'information – Sécurité – Partie 1: Règles générales*

¹ Il existe une édition consolidée 3.2 (2007) qui comprend l'IEC 60730-1 (1999), son Amendement 1 (2003) et son Amendement 2 (2007).

IEC 61032:1997, *Protection des personnes et des matériels par les enveloppes – Calibres d'essai pour la vérification*

IEC 62133:2002, *Accumulateurs alcalins et autres accumulateurs à électrolyte non acide – Exigences de sécurité pour les accumulateurs portables étanches, et pour les batteries qui en sont constituées, destinés à l'utilisation dans des applications portables*

IEC 62281:2004, *Sécurité des piles et des accumulateurs au lithium pendant le transport*

ISO 175, *Plastiques – Méthodes d'essai pour la détermination des effets de l'immersion dans des produits chimiques liquides*

ISO 188, *Caoutchouc vulcanisé ou thermoplastique – Essais de résistance au vieillissement accéléré et à la chaleur*

ISO 1817, *Caoutchouc vulcanisé – Détermination de l'action des liquides*

ISO 9772, *Plastiques alvéolaires – Détermination des caractéristiques de combustion de petites éprouvettes en position horizontale, soumises à une petite flamme*

ISO 15649, *Industries du pétrole et du gaz naturel – Tuyauterie*

ISO 16000-3, *Air intérieur – Partie 3: Dosage du formaldéhyde et d'autres composés carbonylés – Méthode par échantillonnage actif*

ISO 16000-6, *Air intérieur – Partie 6: Dosage des composés organiques volatils dans l'air intérieur des locaux et enceintes d'essai par échantillonnage actif sur le sorbant Tenax TA, désorption thermique et chromatographie en phase gazeuse utilisant MS/FID*

ISO 16017-1, *Air intérieur, air ambiant et air des lieux de travail – Partie 1: Échantillonnage et analyse des composés organiques volatils par tube à adsorption/désorption thermique/chromatographie en phase gazeuse sur capillaire – Partie 1: Échantillonnage par pompage*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

3.1

cartouche fixée

cartouche de combustible, ayant sa propre enveloppe qui est connectée au dispositif alimenté par le système à micropile à combustible

3.2

enveloppe électrique

parties du système à micropile à combustible destinées à limiter l'accès aux éléments qui peuvent être à des niveaux de tension ou d'énergie dangereux

3.3

cartouche externe

cartouche de combustible, ayant sa propre enveloppe qui forme une partie de l'enveloppe du dispositif alimenté par le système à micropile à combustible

3.4

enveloppe contre le feu

parties du système à micropile à combustible destinées à réduire le plus possible l'extension du feu ou des flammes provenant de l'intérieur

3.5

combustible

toute substance parmi les substances suivantes:

- a) solution de méthanol pur ou de méthanol et d'eau;
- b) solution d'acide formique et d'eau;
- c) hydrogène stocké dans un alliage métallique absorbant l'hydrogène;
- d) composés à borohydrure;
- e) butane

NOTE Le combustible a), solutions de méthanol pur ou de méthanol et d'eau, fait l'objet des Articles 1 à 7 et des Annexes C et D de la norme. Les Annexes A, B, E, F, G et H traitent des combustibles b) à e).

3.6

cartouche de combustible

pièce amovible qui contient et fournit le combustible au bloc d'alimentation électrique de la micropile à combustible ou au réservoir interne, qui n'est pas à recharger par l'utilisateur

3.7

système à pile à combustible

système qui utilise un (des) module(s) à pile à combustible électriquement et thermiquement connecté(s) pour générer de l'énergie électrique utile et/ou de l'énergie thermique

3.8

combustible liquide dangereux

tout combustible liquide ayant une concentration de méthanol supérieure ou égale à 4 % ou, pour des concentrations de méthanol inférieures à 4 %, une quantité supérieure à 5 ml. D'autres définitions relatives aux combustibles dangereux sont données dans les Annexes A à H

3.9

cartouche insérable

cartouche de combustible, ayant sa propre enveloppe et qui est installée à l'intérieur de l'enveloppe du dispositif alimenté par le système à micropile à combustible

3.10

réservoir interne

structure dans un bloc d'alimentation électrique de la micropile à combustible, qui emmagasine les combustibles et qui ne peut être retirée

3.11

fuite

combustible liquide dangereux accessible à l'extérieur du système à micropile à combustible ou de la cartouche de combustible

3.12

sources à puissance limitée

alimentation électrique isolée d'un réseau d'alimentation ou fournie par une batterie ou autre dispositif (par exemple, bloc d'alimentation électrique d'une pile à combustible), pour laquelle les niveaux de tension, de courant et de puissance sont limités par construction ou non, aux niveaux qui n'entraînent pas de risque de choc électrique ni de danger de feu

NOTE Une source à puissance limitée par construction ne repose pas sur un dispositif de limitation de courant pour satisfaire aux exigences de puissance limitée, bien qu'elle puisse reposer sur une impédance pour limiter sa

sortie. Néanmoins, une source à puissance non limitée par construction repose sur un dispositif de limitation de courant tel qu'un fusible, etc., pour satisfaire aux exigences de puissance limitée.

3.13

matière toxique

toute matière ayant une évaluation de danger toxique de 2 (moyenne) ou supérieure, dans l'ouvrage *Sax's dangerous properties of industrial materials*, 11e Édition, ou dans un guide de référence correspondant

3.14

enveloppe mécanique

parties du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible destinées à constituer une barrière pour protéger, couvrir et contrôler l'accès aux composants ou au matériau interne(s)

3.15

micropile à combustible

pile à combustible portative ou qui peut être facilement portée à la main, fournissant une tension de sortie en courant continu ne dépassant pas 60 V et une puissance de sortie ne dépassant pas 240 VA

3.16

système à micropile à combustible

bloc d'alimentation électrique d'une micropile à combustible et cartouches de combustible associées, qui sont portatifs ou qui peuvent être facilement portés à la main

3.17

bloc d'alimentation électrique de la micropile à combustible

générateur électrique, tel que défini sur la Figure 1, fournissant une tension de sortie en courant continu ne dépassant pas 60 V et une puissance de sortie continue ne dépassant pas 240 VA

Le bloc d'alimentation électrique de la micropile à combustible ne comprend pas de cartouche de combustible.

3.18

liquide non accessible

combustible liquide non soumis à un contact avec les consommateurs

3.19

absence de perte de vapeur de combustible

émission de combustible sous forme de vapeur provenant de la cartouche de combustible, du système à micropile à combustible en non-fonctionnement ou du bloc d'alimentation électrique de la micropile à combustible, et limitée à 0,08 g/h

L'émission de combustible sous forme de vapeur pour les systèmes en fonctionnement se limite à une quantité définie en 7.3.12.

3.20

conditions d'utilisation normale

plage de conditions telles que pression, température, conditions d'utilisation physiques, chimiques et thermiques, définies par le fabricant

3.21

cartouche de combustible remplie partiellement

cartouche de combustible remplie environ à moitié de combustible (remplissage de 45 % à 55 %)

3.22**puissance assignée**

capacité de puissance continue maximale spécifiée par le fabricant du système à micropile à combustible

3.23**cartouche satellite**

cartouche de combustible destinée à être connectée au bloc d'alimentation électrique de la micropile à combustible et à être retirée de ce dernier, afin de transférer le combustible dans le réservoir interne situé à l'intérieur du bloc d'alimentation électrique de la micropile à combustible

3.24**vanne de recharge**

composant de la cartouche de combustible non rechargeable par l'utilisateur, permettant le rechargement de la cartouche de combustible uniquement par des techniciens formés

3.25**vanne d'arrêt**

composant d'une cartouche de combustible qui contrôle le rejet de combustible

3.26**cartouche usagée**

cartouche qui emmagasine les déchets et les sous-produits provenant du bloc d'alimentation électrique de la micropile à combustible

3.27**cartouche d'eau**

cartouche remplie d'eau (sans additifs) pour ajuster la concentration en combustible

3.28**gestion du combustible**

composants qui peuvent être utilisés pour contrôler les propriétés du combustible, si nécessaire, afin de soutenir le fonctionnement du système à micropile à combustible, par exemple le débit, la concentration, la propreté, la température, l'humidité ou la pression

Tous les systèmes à micropiles à combustible n'intègrent pas toutes les fonctions. Certains systèmes à micropiles à combustible intègrent des fonctions supplémentaires.

3.29**gestion de l'air**

composants qui peuvent être utilisés pour contrôler les propriétés de l'air, si nécessaire, afin de soutenir le fonctionnement du système à micropile à combustible, par exemple le débit, la concentration, la propreté, la température, l'humidité ou la pression

Tous les systèmes n'intègrent pas toutes les fonctions. Certains systèmes intègrent des fonctions supplémentaires

3.30**système global de commande**

composants du système à micropile à combustible qui coordonnent les propriétés du système à micropile à combustible et des produits réactifs à l'aide d'entrées et de sorties électriques, mécaniques, et/ou numériques, de logiciels et/ou de fonctions pour initier le démarrage, le fonctionnement et l'arrêt corrects du système à micropile à combustible, si nécessaire

3.31**pile électrique (facultatif)**

batterie non rechargeable

3.32**pile à combustible**

dispositif électrochimique qui convertit l'énergie provenant de la réaction chimique entre un combustible, tel que l'hydrogène ou les gaz riches en hydrogène, les alcools, les hydrocarbures et un oxydant, tel que l'air ou l'oxygène, en puissance en courant continu, chaleur et autres produits de réaction

3.33**module à micropile à combustible**

assemblage incluant une ou des piles à combustible, qui convertit électrochimiquement l'énergie chimique en énergie électrique

3.34**bloc de piles à combustible**

assemblage de deux piles à combustible ou plus qui sont électriquement connectées

3.35**en non-fonctionnement**

système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible en position «off» («désactivée») ou qui n'est plus en fonctionnement

3.36**niveau d'énergie dangereux**

niveau de puissance disponible supérieur ou égal à 240 VA pour une durée supérieure ou égale à 60 s, ou niveau de l'énergie emmagasinée supérieur ou égal à 20 J (par exemple à partir d'un ou plusieurs condensateurs), à un potentiel supérieur ou égal à 2 V

[1.2.8.10 de l'IEC 60950-1: 2005]

4 Matériaux et construction des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible

4.1 Généralités

- a) La conformité aux exigences de l'Article 4 doit être vérifiée pendant la revue de l'AMDE de sécurité et/ou au cours des essais de type spécifiés à l'Article 7.
- b) Le bloc d'alimentation électrique de la micropile à combustible lorsqu'il est couplé à la cartouche de combustible, doit être conçu et construit pour éviter tout risque crédible de fuite, feu ou d'explosion posé par le système à micropile à combustible lui-même ou par les gaz, les vapeurs, les liquides ou d'autres substances produites ou utilisées par le système à micropile à combustible.
- c) Pour éviter un danger de feu ou d'explosion à l'intérieur du système à micropile à combustible, le fabricant doit éliminer la ou les sources d'inflammation potentielles dans les zones où le combustible est présent (ou peut être potentiellement dégagé).
- d) Les matériaux inflammables, toxiques ou corrosifs doivent être maintenus à l'intérieur d'un système de confinement fermé, par exemple dans une tuyauterie pour combustible, un réservoir, une cartouche de combustible ou une enveloppe similaire.

4.2 AMDE / analyse des dangers

4.2.1 Une analyse des modes de défaillance et de leurs effets (AMDE) ou une analyse de fiabilité équivalente doit être réalisée par le fabricant afin d'identifier les défauts qui peuvent avoir des conséquences liées à la sécurité et les caractéristiques de conception qui permettent d'atténuer ces défauts. L'analyse doit inclure les défaillances qui peuvent entraîner des fuites. Les défaillances liées au rechargement des cartouches de combustible non rechargeables par l'utilisateur, si elles sont anticipées par le fabricant ou par des techniciens formés, doivent être prises en considération.

4.2.2 Des recommandations figurent dans les références informatives suivantes: IEC 61025 *Analyse par arbre de panne* et IEC 60812, *Techniques d'analyse de la fiabilité du système – Procédures d'analyse des modes de défaillance et de leurs effets (AMDE)*.

4.2.3 Le fabricant doit assurer que les émissions provenant du système à micropile à combustible n'entraînent pas d'effets nocifs ou dangereux sur l'utilisateur ou d'autres personnes au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible, et du transport pour la vente.

4.3 Matériaux généraux

Les matériaux et le revêtement doivent résister à la dégradation au cours des conditions normales de transport et d'utilisation, pendant la durée de vie du produit définie par le fabricant.

4.4 Sélection des matériaux

4.4.1 Les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible sont susceptibles d'être exposés à un certain nombre de conditions environnementales pendant la durée de vie du produit définie par le fabricant, telles que les vibrations, les chocs, les niveaux d'humidité variables et les environnements corrosifs. Les matériaux utilisés dans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doivent résister à ces conditions environnementales. Si un système à micropile à combustible ou un bloc d'alimentation électrique d'une micropile à combustible doit être utilisé en service, où les conditions environnementales spécifiques sont au-delà de celles prises en compte dans les essais exigés de la présente norme, des essais supplémentaires doivent alors être effectués pour vérifier la sécurité dans ces conditions environnementales.

4.4.2 Les matériaux métalliques et non métalliques utilisés pour construire des pièces extérieures ou intérieures du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, en particulier ceux étant exposés directement ou indirectement à l'humidité, au combustible et/ou aux sous-produits sous forme gazeuse ou liquide, ainsi que toutes les pièces et tous les matériaux utilisés pour les souder ou les raccorder, par exemple les consommables pour le soudage, doivent être adaptés à toutes les conditions physiques, chimiques et thermiques raisonnablement prévisibles dans les conditions habituelles de transport et d'utilisation au cours de la durée de vie du produit définie par le fabricant, et à toutes les conditions d'essai, en particulier, ils doivent être conçus pour conserver leur stabilité mécanique dans les conditions d'utilisation normale;

- ils doivent être suffisamment résistants à l'action chimique et physique des fluides qu'ils contiennent et à la dégradation environnementale;
- les propriétés physiques et chimiques nécessaires à un fonctionnement sans risque ne doivent pas être considérablement affectées au cours de la durée de vie du produit définie par le fabricant; en particulier, lors du choix des matériaux et des méthodes de fabrication, la résistance à l'usure et à la corrosion, la conductivité électrique, la force d'impact, la résistance au vieillissement, les effets des variations de température, les effets de l'assemblage de certains matériaux (par exemple la corrosion galvanique), et les effets du rayonnement ultraviolet, doivent être pris en considération;
- lorsque des conditions d'érosion, d'abrasion, de corrosion ou d'autres attaques chimiques sont possibles, des mesures appropriées doivent être prises pour:
 - réduire le plus possible cet effet à l'aide d'une conception appropriée, par exemple une épaisseur supplémentaire, ou par une protection adaptée, par exemple l'utilisation de coussinets, de matériaux de parement ou de revêtements de surface, en prenant en compte l'utilisation normale;
 - permettre le remplacement des pièces les plus affectées;
 - et attirer l'attention, dans le manuel dont il est fait référence à l'Article 6, sur le type et la fréquence des mesures d'inspection et de maintenance nécessaires pour une

utilisation sûre et continue; les pièces sujettes à l'usure et les critères pour un remplacement doivent être spécifiés si nécessaire.

4.4.3 Les matériaux élastomères tels que les joints et les tuyaux flexibles en contact avec les combustibles doivent résister à la détérioration lorsqu'ils sont en contact avec ces combustibles et doivent être adaptés aux températures auxquelles ils sont exposés au cours d'une utilisation normale. La conformité doit être déterminée par les normes suivantes: ISO 188 et ISO 1817.

4.4.4 Les matériaux polymères en contact avec les combustibles doivent résister à la détérioration lorsqu'ils sont en contact avec ces combustibles et doivent être adaptés aux températures auxquelles ils sont exposés au cours d'une utilisation normale. La conformité doit être déterminée par l'ISO 175.

4.5 Construction générale

4.5.1 Les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible doivent avoir une construction sûre, qui soit résistante à l'affaissement, aux vibrations, à l'écrasement, aux variations environnementales telles que la température, et aux fluctuations de pression atmosphérique au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible, et du transport pour la vente de tels éléments.

4.5.2 Les mécanismes de connexion, y compris la connexion entre une cartouche de combustible amovible et le bloc d'alimentation électrique de la micropile à combustible, et la connexion électrique entre le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible et le dispositif qu'il alimente, doivent être conçus de telle manière qu'ils ne puissent pas être fixés à un emplacement incorrect ou de façon incomplète, ce qui pourrait entraîner une fuite ou un danger de choc électrique.

4.5.3 Les bords ou coins en saillie d'un bloc d'alimentation électrique de la micropile à combustible et d'une cartouche de combustible ne doivent pas être suffisamment saillants pour entraîner un risque d'accident corporel au cours de l'utilisation prévue ou de la maintenance effectuée par l'utilisateur.

4.5.4 Les effets de l'humidité et de l'humidité relative doivent être pris en compte au cours du processus d'AMDE.

4.6 Vannes de combustibles

4.6.1 Le présent paragraphe s'applique à toutes les vannes d'arrêt, les vannes de remplissage, les vannes de détente, les vannes de rechargement, y compris tous les types de cartouches de combustible.

4.6.2 Les parties en fonctionnement et à l'épreuve de la pression des ensembles vanne d'arrêt et vanne de détente doivent durer pendant la durée de vie du produit définie par le fabricant dans les conditions normales.

4.6.3 Les vannes doivent comporter des dispositifs pour empêcher la fuite de combustible au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible, et du stockage de la cartouche de combustible.

4.6.4 Les vannes ne doivent pas être sensibles à une manœuvre involontaire ou à une manœuvre manuelle par un utilisateur n'utilisant pas d'outils, qui entraîne une fuite de combustible. La conformité doit être vérifiée à l'aide du calibre d'essai 11 de l'IEC 61032, *Protection des personnes et des matériels par les enveloppes – Calibres d'essai pour la vérification*, et d'une force de 9,8 N.

4.6.5 Il ne doit pas y avoir de fuite de combustible ni de pertes de vapeur de combustible au cours du stockage, de la connexion, de la déconnexion ou du transfert du combustible de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible.

4.7 Matériaux et construction – système

4.7.1 La quantité maximale de combustible stocké dans le bloc d'alimentation électrique de la micropile à combustible ne doit pas être supérieure à 200 ml.

4.7.2 Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être conçu de telle sorte qu'une explosion ne puisse pas se produire, même en cas de fuite de combustible en provenance du système à micropile à combustible ou à l'intérieur de ce dernier. Les critères de conception de ces dispositifs (par exemple, débit de ventilation exigé) doivent être fournis par le fabricant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les dispositifs doivent être fournis soit par le fabricant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, soit par le fabricant du dispositif alimenté par le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.

4.7.3 Les composants et les matériaux à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être construits ou doivent utiliser des matériaux tels que la propagation du feu et l'inflammation soient atténuées. L'inflammabilité des matériaux doit être telle qu'un feu soutenu ne perdure pas après coupure du courant électrique et de l'alimentation en combustible et en oxydant. Ceci peut être démontré en choisissant des matériaux FV 0, FV 1 ou FV 2 conformes à l'IEC 60695-1-1 et à l'IEC 60695-11-10.

4.7.4 Il n'est pas exigé que les membranes des micropiles à combustible aient des caractéristiques assignées d'inflammabilité.

4.7.5 Les autres matériaux à l'intérieur de la micropile à combustible qui représentent moins de 30 % de la masse totale de la micropile à combustible sont considérés comme une quantité limitée et sont admissibles sans tenir compte de leurs caractéristiques assignées d'inflammabilité.

4.8 Sources d'inflammation

Pour éviter un danger de feu ou d'explosion à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, le fabricant doit soit éliminer la ou les sources d'inflammation accidentelles potentielles dans les zones où le combustible est présent (ou peut être potentiellement dégagé) ou doit assurer qu'une oxydation immédiate et contrôlée se produit par l'utilisation d'un réacteur catalytique.

Les sources d'inflammation accidentelles potentielles doivent être éliminées par un ou plusieurs des éléments suivants:

- Les températures en surface ne doivent pas dépasser 80 % de la température d'auto-inflammation, exprimée en degrés Celsius du gaz ou de la vapeur inflammable.
- Les équipements contenant des matériaux ou des composants capables de catalyser la réaction des fluides inflammables avec l'air doivent être capables d'arrêter la propagation de la réaction entre l'équipement et l'atmosphère inflammable environnante.
- Les matériels et/ou les composants électriques, s'ils sont soumis à un contact avec un combustible, doivent être adaptés à la zone dans laquelle ils sont installés.
- Le potentiel de décharge statique suffisant pour provoquer une inflammation doit être éliminé par un choix de matériaux appropriés et par une liaison equipotentielle et une mise à la terre correctes.

- Les composants électriques tels que les fusibles, les dispositifs de protection contre les surintensités, les capteurs, les vannes et solénoïdes électriques lorsqu'ils fonctionnent dans les conditions pour lesquelles ils sont conçus, ne doivent pas être à l'origine d'effets thermiques, d'arcs ou étincelles susceptibles de produire un dégagement inflammable de gaz.

L'oxydation immédiate et contrôlée doit être assurée par les éléments suivants:

- Les réacteurs catalytiques conçus pour contrôler l'oxydation sans risque sont acceptables. La température à l'intérieur de réacteurs de ce type peut être supérieure à la température d'auto-inflammation du fluide. Si le réacteur catalytique s'écarte des conditions de fonctionnement correctes, telles que définies par le fabricant, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être mis automatiquement dans un état sûr.

4.9 Enveloppes et stratégies d'acceptation

Une enveloppe contre le feu est exigée lorsque les températures des pièces, dans des conditions de défaut, peuvent être suffisantes pour l'inflammation.

4.9.1 Parties nécessitant une enveloppe contre le feu

Sauf lorsque la Méthode 2 de 4.7.1 de l'IEC 60950-1:2005 est utilisée exclusivement, ou comme permis en 4.7.2.2 de l'IEC 60950-1:2005, les parties suivantes sont considérées comme présentant un risque d'inflammation, et nécessitent par conséquent une enveloppe contre le feu:

- circuits de puissance ne satisfaisant pas aux exigences du Tableau 3 ou du Tableau 4 (circuits à puissance non limitée);
- composants dans les circuits alimentés par des sources à puissance limitée, tel que spécifié en 2.5 de l'IEC 60950-1:2005, mais non montés sur un matériau de classe d'inflammabilité V-1 ou V-0 (IEC 60695-11-10);
- composants à l'intérieur d'une unité d'alimentation ou un ensemble fournissant une énergie telle que spécifiée en 2.5 de l'IEC 60950-1:2005, y compris les dispositifs de protection contre les surintensités sur lesquels ne se produisent pas d'arcs, les impédances de limitation, les réseaux de régulation et tout le câblage jusqu'au point auquel les critères de sortie des sources à puissance limitée sont remplis.

Voir le Tableau 1 pour les exigences d'inflammabilité des matériaux.

La conformité au 4.7.1 de l'IEC 60950-1:2005 et au 4.7.2.2 de l'IEC 60950-1:2005 est vérifiée par examen et par évaluation des données fournies par le fabricant. Dans le cas où aucune donnée n'est fournie, la conformité est déterminée par des essais.

4.9.2 Parties ne nécessitant pas d'enveloppe contre le feu

Les parties suivantes ne nécessitent pas d'enveloppe contre le feu:

- Il n'est pas exigé que les moteurs aient des enveloppes contre le feu, s'ils sont conformes aux exigences applicables mentionnées en Annexe B de l'IEC 60950-1:2005.
- Composants électromécaniques conformes à 5.3.5 de l'IEC 60950-1:2005.
- Conducteurs et câbles à isolant PVC, TFE, PTFE, FEP, ETFE, PFA, néoprène ou polyimide.
- Composants, y compris les connecteurs, satisfaisant aux exigences de 4.7.3.2 de l'IEC 60950-1:2005, qui remplissent une ouverture dans une enveloppe contre le feu.
- Connecteurs dans des circuits alimentés par des sources à puissance limitée, conformes à 2.5 de l'IEC 60950-1:2005.

- Autres composants dans les circuits alimentés par des sources à puissance limitée, conformes à 2.5 de l'IEC 60950-1:2005, et montés sur des matériaux de classe d'inflammabilité V-1 ou V-0 (IEC 60695-11-10).
- Autres composants conformes à la Méthode 2 de 4.7.1 de l'IEC 60950-1:2005.
- Matériel, ou partie du matériel, ayant un interrupteur à contact temporaire que l'utilisateur doit activer en permanence, et dont le relâchement coupe toute alimentation du matériel ou de la partie du matériel.
- Les cartouches de combustible qui ne contiennent pas de circuits électriques capables de provoquer une inflammation dans des conditions de défaut ne nécessitent pas d'enveloppe contre le feu.
- La conformité au 4.7.1 de l'IEC 60950-1:2005 est vérifiée par examen et par évaluation des données fournies par le fabricant. Dans le cas où aucune donnée n'est fournie, la conformité est déterminée par des essais.

Tableau 1 – Résumé des exigences d'inflammabilité des matériaux

Partie		Exigences
Enveloppe contre le feu	Enveloppe	V-1 (IEC 60695-11-10), ou Essai A.2 de l'IEC 60950-1:2005, ou Essai au fil chauffant de l'IEC 60695-2-11 (si < 13 mm d'air des sources d'inflammation)
	Parties qui remplissent une ouverture	V-1 (IEC 60695-11-10), ou Essai A.2 de l'IEC 60950-1:2005, ou Normes IEC de composants applicables
À l'extérieur de l'enveloppe contre le feu	Composants et parties, y compris les enveloppes mécaniques et électriques	HB40 (IEC 60695-11-10) pour une épaisseur > 3 mm, ou HB75 (IEC 60695-11-10) pour une épaisseur < 3 mm, ou HBF (cellulaire) (ISO 9772), ou Essai au fil incandescent à 550 °C, de l'IEC 60695-2-11, ou voir 4.9.3 pour les exceptions
À l'intérieur de l'enveloppe contre le feu	Composants et parties, y compris les enveloppes mécaniques et électriques	V-2, ou HF-2 (cellulaire) (ISO 9772), ou Essai A.2 de l'IEC 60950-1: 2005-12, ou Normes IEC de composants applicables, ou voir 4.9.4 pour les exceptions
Emplacement quelconque	Assemblages de filtres à air	V-2 (IEC 60695-11-10), ou HF-2 (cellulaire) (ISO 9772), ou Essai A.2 de l'IEC 60950-1:2005, ou voir 4.7.3.5 de l'IEC 60950-1:2005

4.9.3 Matériaux pour les composants et les autres parties à l'extérieur des enveloppes contre le feu

4.9.3.1 Sauf indication contraire ci-dessous, les matériaux pour les composants et les autres parties (y compris les enveloppes mécaniques, les enveloppes électriques et les parties décoratives), situés à l'extérieur des enveloppes contre le feu, doivent être de classe d'inflammabilité HB75, si la plus petite épaisseur significative de ce matériau est < 3 mm, ou de classe d'inflammabilité HB40, si la plus petite épaisseur significative de ce matériau est > 3 mm, ou de classe d'inflammabilité HBF. Voir le Tableau 1 pour les exigences d'inflammabilité des matériaux.

NOTE Lorsqu'une enveloppe mécanique ou une enveloppe électrique sert aussi d'enveloppe contre le feu, les exigences pour les enveloppes contre le feu s'appliquent.

4.9.3.2 Les exigences pour les matériaux dans les assemblages de filtres à air sont données en 4.7.3.5 de l'IEC 60950-1:2005. Voir le Tableau 1 pour les exigences d'inflammabilité des matériaux.

4.9.3.3 Les connecteurs doivent être conformes à l'un des éléments ci-dessous:

- a) être constitués d'un matériau de classe d'inflammabilité V-2; ou
- b) satisfaire aux essais de l'Article A.2 de l'IEC 60950-1: 2005; ou
- c) satisfaire aux exigences sur l'inflammabilité de la norme de composants correspondante de l'IEC; ou
- d) être montés sur un matériau de classe d'inflammabilité V-1 ou V-0 (IEC 60695-11-10) et être de petite taille.

4.9.3.4 L'exigence applicable aux matériaux pour les composants et les autres parties spécifiant qu'ils doivent être de classe d'inflammabilité HB40, de classe d'inflammabilité HB75, ou de classe d'inflammabilité HBF, ne s'applique à aucun des cas suivants:

- a) Composants électriques qui ne présentent pas de danger de feu dans des conditions de fonctionnement anormales, lorsqu'ils sont soumis à l'essai conformément à 5.3.7 de l'IEC 60950-1:2005.
- b) Matériaux et composants situés à l'intérieur d'une enveloppe de volume inférieur ou égal à 0,06 m³, réalisée entièrement en métal et sans ouvertures de ventilation, ou à l'intérieur d'une unité hermétique contenant un gaz inerte.
- c) Composants satisfaisant aux exigences d'inflammabilité d'une norme IEC de composant applicable qui comprend de telles exigences.
- d) Composants électroniques, comme les circuits intégrés, les optocoupleurs, les condensateurs et autres petites parties, qui sont montés sur un matériau de classe d'inflammabilité V-1 ou V-0 (IEC 60695-11-10).
- e) Conducteurs, câbles et connecteurs à isolant PVC, TFE, PTFE, FEP, ETFE, PFA, néoprène ou polyimide.
- f) Colliers individuels (à l'exclusion des revêtements hélicoïdaux ou autres revêtements continus), rubans de laçage, attaches de câbles ou de torons, utilisés avec les faisceaux de câbles.
- g) Engrenages, cames, courroies, paliers et autres petites parties qui ne constitueraient qu'un apport négligeable de combustible dans un incendie, y compris les parties décoratives, les étiquettes, les pieds de montage, les couvercles de serrure, les boutons et les organes analogues.

4.9.3.5 La conformité est vérifiée par examen des données du matériel et du matériau et, si nécessaire, par un ou des essais appropriés de l'Annexe A de l'IEC 60950-1:2005.

4.9.4 Matériaux pour les composants et les autres parties à l'intérieur des enveloppes contre le feu

4.9.4.1 Les exigences pour les matériaux dans les assemblages de filtres à air sont données en 4.7.3.5 de l'IEC 60950-1:2005. Voir le Tableau 1 pour les exigences d'inflammabilité des matériaux.

4.9.4.2 À l'intérieur des enveloppes contre le feu, les matériaux des composants et autres parties (y compris les enveloppes mécaniques et électriques situées à l'intérieur des enveloppes contre le feu), doivent satisfaire à l'un des cas suivants:

- a) être de classe d'inflammabilité V-2, ou de classe d'inflammabilité HF-2; ou
- b) satisfaire à l'essai d'inflammabilité décrit dans l'Article A.2 de l'IEC 60950-1:2005; ou

- c) satisfaire aux exigences sur l'inflammabilité de la norme de composants correspondante de l'IEC, qui spécifie de telles exigences.
- d) Voir le Tableau 1 pour les exigences d'inflammabilité des matériaux.

4.9.4.3 Les exigences ci-dessus ne s'appliquent à aucun des cas suivants:

- composants électriques qui ne présentent pas de danger de feu dans des conditions de fonctionnement anormales, lorsqu'ils sont soumis à l'essai conformément à 5.3.7 de l'IEC 60950-1:2005;
- matériaux et composants situés à l'intérieur d'une enveloppe de volume inférieur ou égal à 0,06 m³, réalisée entièrement en métal et sans ouvertures de ventilation, ou à l'intérieur d'une unité hermétique contenant un gaz inerte;
- une ou plusieurs couches de matériaux d'isolation minces tels que du ruban adhésif, utilisé directement sur une surface quelconque à l'intérieur d'une enveloppe contre le feu, y compris la surface des parties transportant le courant, à condition que la combinaison du matériau d'isolation mince et de la surface d'application satisfasse aux exigences d'une classe d'inflammabilité V-2, ou d'une classe d'inflammabilité HF-2;

NOTE Lorsque le matériau d'isolation mince auquel il est fait référence dans l'exemption ci-dessus est sur la surface interne d'une enveloppe contre le feu, les exigences de 4.6.2 de l'IEC 60950-1:2005 continuent de s'appliquer à l'enveloppe contre le feu.

- composants électroniques, comme les circuits intégrés, les optocoupleurs, les condensateurs et autres petites parties, qui sont montés sur un matériau de classe d'inflammabilité V-1 ou V-0 (IEC 60695-11-10);
- conducteurs, câbles et connecteurs à isolant PVC, TFE, PTFE, FEP, ETFE, PFA, néoprène ou polyimide.
- colliers individuels (à l'exclusion des revêtements hélicoïdaux ou autres revêtements continus), rubans de laçage, attaches de câbles ou de torons, utilisés avec les faisceaux de câbles;
- conducteur conforme aux exigences pour VW-1 ou FT-1 ou plus, et qui est marqué ainsi;
- parties ci-après, à condition qu'elles soient séparées par au moins 13 mm d'air ou par une barrière solide en matériau de classe d'inflammabilité V-1 ou V-0 (IEC 60695-11-10), des parties électriques (autres que les conducteurs et câbles isolés) qui, dans des conditions de défaut, sont susceptibles d'engendrer une température qui pourrait provoquer une inflammation;
 - engrenages, cames, courroies, paliers et autres petites parties qui ne constitueraient qu'un apport négligeable de combustible dans un incendie, y compris les étiquettes, les pieds de montage, les couvercles de serrure, les boutons et les organes analogues;
 - les canalisations pour les circuits d'air ou de tout fluide, les réservoirs pour les poudres ou les liquides, et les parties en plastique cellulaire, à condition qu'ils soient de classe d'inflammabilité HB75, si la plus petite épaisseur significative du matériau est < 3 mm, ou de classe d'inflammabilité HB40, si la plus petite épaisseur significative du matériau est > 3 mm, ou de classe d'inflammabilité HBF.

4.9.4.4 La conformité est vérifiée par examen des données du matériel et du matériau et, si nécessaire, par un ou des essais appropriés de l'Annexe A de l'IEC 60950-1:2005.

4.9.5 Enveloppes mécaniques

4.9.5.1 Une enveloppe mécanique doit être suffisamment complète pour contenir ou détourner des parties qui, à cause d'une défaillance ou pour toute autre raison, pourraient se relâcher, se séparer ou être projetées à partir d'une partie mobile.

4.9.5.2 La conformité est vérifiée par examen de la construction et par des données disponibles et, si nécessaire, par les essais applicables de 4.2.2, 4.2.3, 4.2.4, et 4.2.7 de l'IEC 60950-1:2005, et les essais de type de l'Article 7 si applicable.

4.9.5.3 Après les essais décrits en 4.2.2, 4.2.3, 4.2.4 et 4.2.7 de l'IEC 60950-1:2005, l'échantillon doit continuer à satisfaire aux exigences de 2.1.1 et 4.4.1 de l'IEC 60950-1:2005. Il ne doit présenter aucun signe de perturbation des dispositifs de sécurité tels que coupe-circuits thermiques, dispositifs de protection contre les surintensités ou dispositifs de verrouillage.

4.9.5.4 La détérioration de la finition, les fissures, les bosses et les écaillages ne sont pas pris en considération s'ils n'affectent pas la sécurité de façon défavorable.

NOTE Si une enveloppe séparée ou une partie d'enveloppe est utilisée pour un essai, il peut être nécessaire de la réassembler dans le matériel dans le but de vérifier la conformité.

4.10 Protection contre les dangers d'incendie, d'explosion, de corrosivité et de toxicité

4.10.1 Les fluides inflammables, toxiques et corrosifs doivent être maintenus à l'intérieur d'un système de confinement fermé, comme dans une tuyauterie pour combustible, un réservoir, une cartouche de combustible ou une enveloppe similaire. La conformité doit être vérifiée par des essais de type, conformément à l'Article 7.

4.10.2 Un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible peut être équipé d'un dispositif permettant de détecter les niveaux de concentration des fluides, voir Tableau 7, et d'arrêter le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible avant que la limite de concentration ne soit dépassée.

4.10.3 Le câblage interne et l'isolation en général ne doivent pas être exposés au combustible, aux huiles, graisses ou substances similaires, à moins que l'isolation n'ait été évaluée pour un contact avec ces substances.

4.11 Protection contre les dangers électriques

Les tensions à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être dans les limites de la TBTS. Les déterminations doivent être réalisées conformément à 2.2 de l'IEC 60950-1:2005. Si les tensions internes dépassent 60 V en courant continu, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être examiné davantage, conformément à l'IEC 60950-1:2005. Les circuits qui dépassent la TBTS doivent satisfaire aux critères applicables aux circuits sous tension dangereuse y compris en ce qui concerne la distance électrique, et aux critères d'accessibilité à la réception et après des essais susceptibles de conduire à l'exposition de certaines parties, conformément à l'IEC 60950-1:2005.

Les composants des circuits sous tension dangereuse peuvent nécessiter également une évaluation complémentaire.

4.12 Construction de l'alimentation en combustible

4.12.1 Construction de la cartouche de combustible

Les cartouches de combustible doivent être conformes aux exigences suivantes.

4.12.1.1 Il ne doit pas y avoir de fuite de la cartouche de combustible dans la plage de températures comprise entre -40 °C et $+70\text{ °C}$. La conformité doit être déterminée par des essais de type conformément à 7.3.3 et 7.3.4.

4.12.1.2 Il ne doit pas y avoir de fuite de la cartouche de combustible à une pression manométrique interne de 95 kPa et à une pression normale de fonctionnement à 22 °C ou à deux fois la pression manométrique de la cartouche de combustible à 55 °C , en prenant celle des deux valeurs qui est la plus élevée. La conformité doit être déterminée par un essai de type conformément à 7.3.1.

4.12.1.3 Le volume de combustible maximal dans la cartouche de combustible ne doit pas dépasser 1 l.

4.12.1.4 Pour l'utilisation normale, le mauvais usage raisonnablement prévisible et le transport pour la vente d'une cartouche de combustible avec un bloc d'alimentation électrique de la micropile à combustible par un consommateur, des dispositifs doivent être prévus pour éviter une fuite de combustible avant, pendant et après la connexion ou le transfert de combustible vers le bloc d'alimentation électrique de la micropile à combustible. La conformité est vérifiée par 7.3.11.

4.12.1.5 Une cartouche de combustible doit résister à la corrosion dans son environnement d'utilisation.

4.12.1.6 Une cartouche de combustible doit comporter des dispositifs pour empêcher une mauvaise connexion qui entraînerait une fuite de combustible lorsqu'elle est installée dans un système à micropile à combustible. La conformité est vérifiée par l'essai de cycles de connexion, 7.3.11.

4.12.1.7 Les connecteurs d'alimentation en combustible prévus sur la cartouche de combustible doivent être construits de telle sorte qu'ils empêchent la fuite de combustible lorsqu'ils ne sont pas fixés sur une micropile à combustible au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible et du transport pour la vente. La conformité est vérifiée par l'essai de chute, 7.3.5 et l'essai de cycles de connexion, 7.3.11.

4.12.1.8 Dans le cas où une vanne régulatrice de pression ou un dispositif similaire sont prévus, une vanne régulatrice de pression de ce type doit satisfaire aux exigences de performance pour chaque essai de type. Cette vanne doit réussir tous les essais de type sans fuite.

4.12.1.9 La structure au niveau de la connexion à la cartouche de combustible ne doit pas permettre de fuite de combustible.

4.12.1.10 Une cartouche de combustible y compris l'interface entre la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible y compris la vanne doit présenter une construction suffisamment solide pour résister à une utilisation normale et à un mauvais usage raisonnablement prévisible généré par les vibrations, la chaleur, la pression, les chutes ou les chocs mécaniques, etc. La conformité est vérifiée par:

- les essais de pression différentielle, 7.3.1;
- l'essai de vibrations, 7.3.2;
- l'essai de cycles de températures, 7.3.3;
- l'essai d'exposition à température élevée, 7.3.4;
- l'essai de chute, 7.3.5;
- l'essai de charge de compression, 7.3.6;
- l'essai de stockage de longue durée, 7.3.9;
- l'essai de connexion à température élevée, 7.3.10;
- les essais de cycles de connexion, 7.3.11.

4.12.1.11 Les vannes de la cartouche de combustible doivent fonctionner comme prévu, sans l'utilisation d'outils et sans force excessive nécessaire pour la connexion ou la déconnexion.

4.12.2 Exigences de remplissage de la cartouche de combustible

La conception de la cartouche de combustible et la quantité de remplissage de combustible doivent permettre une libération du combustible sans fuite, à une température de cartouche

de combustible de 70 °C dans le cas d'une cartouche de combustible seule et lorsque la cartouche de combustible est limitée par le système à micropile à combustible ou par un dispositif d'essai comparable.

4.13 Protection contre les dangers mécaniques

4.13.1 Tuyauterie et canalisation autres que les conduites de combustible

Des exigences sont données ci-dessous pour la construction de la tuyauterie, des canalisations et des fixations, autres que les conduites de combustible, à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

4.13.1.1 Lorsque les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible sont conçus pour des pressions manométriques internes supérieures à 100 kPa, ils doivent être conçus, construits et soumis à l'essai conformément à l'ISO 15649.

4.13.1.2 Les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible conçus pour un fonctionnement à une pression manométrique inférieure à 100 kPa ou, conformément aux codes et normes locaux ou nationaux applicables des équipements sous pression non qualifiés comme systèmes sous pression, tels que les flexibles à eau basse pression, les canalisations en plastique, ou autres raccords vers les réservoirs atmosphériques ou basse pression et les conteneurs similaires, doivent être construits avec des matériaux appropriés, et leurs joints et fixations associés doivent être conçus et construits avec une force et une résistance aux fuites appropriées pour éviter les dégagements involontaires.

4.13.1.3 Les raccords-unions doivent être conçus pour être étanches en utilisant des méthodes d'étanchéisation résistant au fluide transporté et aux conditions ambiantes d'utilisation.

4.13.1.4 La construction des tuyauteries et canalisations doit présenter une capacité suffisante pour résister à la pression et à d'autres charges, et il n'y aura pas de danger de contamination ou de fuite du contenu des conduites. La conformité est déterminée par 7.3.1 et 7.3.6.

4.13.1.5 La construction des tuyauteries et canalisations doit avoir été conçue avec des mesures appropriées pour empêcher le gel, les cassures, la corrosion, etc. La conformité pour le gel est déterminée par 7.3.3. La conformité pour les cassures est présentée en 7.3.5.

4.13.2 Surface externe et limites de températures des composants

4.13.2.1 Généralités

Les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible ne doivent pas atteindre de températures excessives au cours d'un fonctionnement normal. La conformité doit être vérifiée en déterminant la température des différentes parties pendant le fonctionnement à la puissance de sortie assignée et à la température ambiante de fonctionnement assignée maximale spécifiées par le fabricant. Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible est mis en fonctionnement à la puissance de sortie assignée maximale jusqu'à ce que la température maximale d'équilibre soit atteinte. Au cours de l'essai, les coupe-circuits thermiques et les dispositifs de protection contre la surcharge ne doivent pas fonctionner. La température ne doit pas dépasser les valeurs données au Tableau 2.

4.13.2.2 Surfaces externes

Afin d'éliminer tout risque de brûlure provoquée par un contact avec le système à micropile à combustible ou avec le bloc d'alimentation électrique de la micropile à combustible, la température de l'enveloppe externe ne doit pas dépasser la valeur indiquée au Tableau 2.

4.13.2.3 Poignées, boutons, manettes et pièces similaires

L'utilisateur est destiné à toucher les poignées, boutons, manettes et pièces similaires, afin de faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La température des poignées, boutons, manettes et pièces similaires destinés à être touchés ne doit pas dépasser les valeurs présentées au Tableau 2.

4.13.2.4 Composants

4.13.2.4.1 Le Tableau 2 donne la température normale maximale pour divers composants externes. La température de ces composants ne doit pas dépasser les valeurs indiquées au Tableau 2.

4.13.2.4.2 Pour les composants et les câblages électriques intégrés dans le système à micropile à combustible qui ne sont pas présentés au Tableau 2, leurs températures ne doivent pas dépasser la température maximale pour laquelle les composants et les câblages sont assignés.

Tableau 2 – Limites de températures

Partie	Température °C
Enveloppe externe, poignées, boutons, manettes et organes analogues qui, dans des conditions d'utilisation normale, sont tenus:	
– métal	50
– porcelaine ou matière vitrifiée	60
– matière moulée, caoutchouc, ou bois	70
Parties et matériaux en contact direct avec des gaz ou vapeurs potentiellement inflammables	80 % de la température d'auto-inflammation du gaz ou de la vapeur potentiellement inflammable
Exception – Zones qui sont évaluées séparément, qui utilisent un processus faisant intervenir des températures élevées.	

4.13.3 Moteurs

4.13.3.1 Que le moteur fonctionne dans les conditions prévues ou au cours d'une condition anormale telle qu'un fonctionnement en surcharge ou avec rotor bloqué, sa température ne doit pas augmenter au point de pouvoir enflammer un dégagement de gaz inflammable.

4.13.3.2 Les parties du moteur telles que le balai de moteur, le dispositif de surcharge thermique voire un ou d'autres composants d'établissement et de coupure, qui agissent pour couper un circuit, même si la coupure est transitoire par nature, ne doivent pas provoquer de danger en produisant un arc ou un effet thermique capable d'enflammer un dégagement de gaz inflammable.

4.14 Construction des composants du dispositif électrique

4.14.1 Sources à puissance limitée

Les sources à puissance limitée doivent satisfaire à l'un des points suivants:

a) la puissance de sortie est limitée par construction, conformément au Tableau 3; ou

- b) une impédance limite la puissance de sortie, conformément au Tableau 3. Si un dispositif à coefficient de température positif est utilisé, il doit satisfaire aux essais spécifiés dans l'IEC 60730-1, Articles 15, 17, J.15 et J.17; ou
- c) un dispositif de protection contre les surintensités non générateur d'arcs est utilisé et la puissance de sortie est limitée, conformément au Tableau 4; ou
- d) un circuit de régulation limite la puissance de sortie, conformément au Tableau 3, à la fois dans les conditions normales de fonctionnement et après tout premier défaut (voir 1.4.14 de l'IEC 60950-1:2005) dans le circuit de régulation (circuit ouvert ou court-circuit); ou
- e) un circuit de régulation limite la puissance de sortie, conformément au Tableau 3, dans les conditions normales de fonctionnement, et un dispositif de protection contre les surintensités non générateur d'arcs limite la puissance de sortie, conformément au Tableau 4, après tout premier défaut (voir 1.4.14 de l'IEC 60950-1:2005) dans le circuit de régulation (circuit ouvert ou court-circuit). Si un dispositif de protection contre les surintensités non générateur d'arcs est utilisé, ce doit être un fusible approprié ou un dispositif électromécanique non réglable et non automatiquement réarmable.

La conformité est vérifiée par examen et par mesurage et, le cas échéant, par étude des données du fabricant pour les batteries. Les batteries doivent être totalement chargées lors des mesurages de V_{OC} et de I_{SC} conformément aux Tableaux 3 et 4.

Tableau 3 – Limites des sources à puissance limitée par construction

Tension de sortie – courant continu ^a (V_{OC}) V courant continu	Courant de sortie ^b (I_{SC}) A	Puissance apparente ^c (S) VA
≤ 20	$\leq 8,0$	$\leq 5 \times V_{OC}$
$20 < V_{OC} \leq 30$	$\leq 8,0$	≤ 100
$30 < V_{OC} \leq 60$	$\leq 150 / V_{OC}$	≤ 100
^a V_{OC} : Tension de sortie mesurée avec tous les circuits de charge déconnectés. Les tensions sont pour un courant continu lisse. ^b I_{SC} : Courant de sortie maximal avec charge non capacitive, comprenant un court-circuit, mesuré 60 s après application de la charge. ^c S : Puissance de sortie maximale en VA, quelle que soit la charge non capacitive, mesurée 60 s après application de la charge.		

**Tableau 4 – Limites des sources à puissance non limitée par construction
(Protection contre les surintensités exigée)**

Tension de sortie ^a (V_{oc}) V courant continu	Courant de sortie ^b (I_{sc}) A	Puissance apparente ^c (S) VA	Caractéristiques assignées de courant de la protection contre les surintensités ^d A
≤ 20	$\leq 1\,000 / V_{oc}$	≤ 250	$\leq 5,0$
$20 < V_{oc} \leq 30$			$\leq 100 / V_{oc}$
$30 < V_{oc} \leq 60$			$\leq 100 / V_{oc}$

a V_{oc} : Tension de sortie mesurée avec tous les circuits de charge déconnectés. Les tensions sont pour un courant continu lisse.

b I_{sc} : Courant de sortie maximal avec charge non capacitive, comprenant un court-circuit, mesuré 60 s après application de la charge. Les impédances de limitation de courant dans l'équipement restent dans le circuit pendant le mesurage, mais les dispositifs de protection contre les surintensités sont shuntés.

c S (VA): Puissance de sortie maximale en VA, quelle que soit la charge non capacitive, mesurée 60 s après application de la charge. Les impédances de limitation de courant dans l'équipement restent dans le circuit pendant le mesurage, mais les dispositifs de protection contre les surintensités sont shuntés.

NOTE Des mesurages sont effectués avec les dispositifs de protection contre les surintensités shuntés pour déterminer la quantité d'énergie qui est disponible pour causer une éventuelle surchauffe pendant le fonctionnement des dispositifs de protection contre les surintensités. Si le dispositif de protection contre les surintensités est un dispositif générateur d'arcs discret, une évaluation supplémentaire concernant son isolation par rapport aux vapeurs de gaz potentiellement inflammables doit être réalisée.

d Les valeurs du courant assigné du dispositif de protection contre les surintensités sont basées sur des fusibles et des disjoncteurs qui coupent le circuit en moins de 120 s avec un courant égal à 210 % de la valeur du courant spécifiée dans le Tableau 4.

4.14.2 Dispositifs utilisant des régulateurs électroniques

4.14.2.1 Systèmes de commande

Les logiciels systèmes et les circuits électroniques qui sont considérés comme les dispositifs de sécurité primaires tel que déterminé par l'analyse de sécurité selon 4.2 doivent être conformes à l'Annexe H de l'IEC 60730-1.

Les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible utilisant des régulateurs électroniques doivent être conformes aux points suivants:

- Au cours d'une utilisation normale, en cas de dysfonctionnement d'un seul régulateur, la sécurité ne doit pas être compromise,
- Au cours d'une utilisation normale, la sécurité ne doit pas être compromise dans les cas où une partie quelconque du circuit de commande est défaillante.

4.14.3 Conducteurs/câblage électriques

4.14.3.1 Les composants et le câblage électriques doivent être structurés de façon à réduire le plus possible les effets thermiques.

4.14.3.2 La protection des conducteurs ne doit pas être endommagée au cours de conditions normales de transport et d'utilisation, ou au cours de périodes de non-fonctionnement.

4.14.3.3 Le conducteur utilisé dans le câblage doit être aussi court que possible et, si nécessaire, des emplacements doivent être fournis avec l'isolation, protégés de la chaleur, immobilisés, ou fournis avec un autre traitement.

4.14.3.4 Dans le cas où des bornes ou des conducteurs de connexion exposés connectés sur l'extérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la

micropile à combustible sont fixés de manière incorrecte, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas ou fonctionne sans aucune anomalie.

4.14.3.5 Sauf dans les cas suivants, des bornes ou des conducteurs de connexion exposés connectés sur l'extérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent pouvoir être distingués par des nombres, des lettres, des symboles, des couleurs assignés, etc.

c) Les conducteurs électriques ou les bornes ont différentes formes physiques pour empêcher une connexion incorrecte.

d) Il n'y a que deux conducteurs ou bornes de connexion, et le fait d'interchanger ces conducteurs ou bornes n'a aucun effet sur le fonctionnement du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

4.14.3.6 Les passages empruntés par les conducteurs doivent être lisses et ne doivent pas présenter d'arêtes vives.

4.14.3.7 Les conducteurs électriques doivent être protégés de façon qu'ils n'entrent pas en contact avec des aspérités, ou qu'ils ne soient pas soumis à des pincements au cours de l'assemblage, et phénomènes similaires, susceptibles d'endommager l'isolation des conducteurs.

4.14.3.8 Les conducteurs isolés qui passent à travers des trous doivent être protégés pour éviter l'abrasion ou les dommages liés à la découpe. La conformité est vérifiée par examen.

4.14.3.9 Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible fonctionnant dans les conditions prévues, la température du matériau de câblage, y compris le câblage imprimé sur les cartes de circuits, ne doit pas augmenter au point de pouvoir enflammer un dégagement de gaz inflammable.

4.14.3.10 Dans le cas d'un fonctionnement du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible dans les conditions anormales de fonctionnement d'une surcharge électrique, le câblage imprimé sur les cartes de circuits «ouverts» ne doit pas produire d'arc ni d'effet thermique capables d'enflammer un dégagement de gaz inflammable.

4.14.4 Zone de la borne de sortie

La zone de la borne de sortie doit être conçue pour empêcher un contact accidentel avec les mains. Cette restriction ne s'applique pas aux types suivants de zones de bornes de sortie:

a) Une zone de borne de sortie pour laquelle, lorsqu'elle est fixée, il n'y a aucun risque de contact humain accidentel.

b) Une zone de borne de sortie pour laquelle la tension et le courant de sortie sont limités par construction, conformément au Tableau 3; ou un dispositif de protection contre les surintensités limite la sortie, conformément au Tableau 4.

4.14.5 Composants électriques et fixations

4.14.5.1 Les composants électriques et les fixations doivent avoir des caractéristiques électriques assignées suffisantes pour être utilisés dans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.

4.14.5.2 Les batteries utilisées dans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doivent être conformes aux normes de sécurité applicables suivantes:

IEC 60086-4, IEC 60086-5, IEC 62133 et IEC 62281.

4.14.6 Protection

4.14.6.1 Objectif des dispositifs de protection

Un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible doit suspendre automatiquement et en toute sécurité le fonctionnement du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible lorsqu'une situation se produit, perturbant le fonctionnement en continu. De plus, une fonction de protection doit être fournie avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible si nécessaire. En outre, cette fonction de protection doit pouvoir fonctionner à la fois lors du démarrage et de l'arrêt du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

4.14.6.2 Protection contre les accidents dus aux courts-circuits

Une fonction doit être prévue pour suspendre le fonctionnement en toute sécurité ou pour fournir une protection en réponse à une charge en court-circuit.

4.14.6.3 Protection contre la surcharge électrique

Les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible doivent être conçus de manière à réduire le danger de feu à la suite d'une condition de surcharge électrique anormale.

5 Exigences et essais de fonctionnement anormal et de conditions de défaut

5.1 Généralités

- a) Chaque système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible doit être conçu de manière à ce que les risques de feu, de fuite ou tout autre danger, dus à une surcharge mécanique ou électrique ou à une défaillance, ou dus à un fonctionnement anormal ou à une utilisation négligente, soient limités autant que possible.
- b) Après un fonctionnement anormal ou un premier défaut, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit rester dans un état sûr.
- c) Il est permis d'utiliser des fils fusibles, des coupe-circuits thermiques, des dispositifs de protection contre les surintensités et des dispositifs analogues pour fournir une protection appropriée, si des vérifications ont été effectuées et qu'il s'est révélé qu'il n'y aurait pas de source d'inflammation.
- d) La conformité est vérifiée par examen et par les essais de 5.2.

5.2 Essais de conformité

- a) Avant le début de chaque essai, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit fonctionner normalement.
- b) Lorsqu'un composant ou un sous-ensemble est enfermé de telle sorte que la mise en court-circuit ou la déconnexion n'est pas possible, les essais peuvent être effectués sur des parties échantillons pourvues de câbles de connexion spéciaux. Si ceci n'est pas possible ou pas pratique, le composant ou le sous-ensemble dans son ensemble doit satisfaire aux essais.
- c) Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible est soumis aux essais en appliquant une condition de fonctionnement anormal ou de simple défaut qui peut se produire au cours d'une utilisation normale et d'un mauvais usage raisonnablement prévisible. L'analyse des dangers (voir 4.2) doit être utilisée comme recommandation dans l'identification des défauts clés à soumettre à essai. De plus, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible qui est équipé d'un couvercle de protection est soumis à l'essai

avec le couvercle en place dans les conditions normales de repos jusqu'à ce que l'état d'équilibre soit atteint.

- d) Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, les schémas des circuits, l'AMDE, l'analyse des dangers et les spécifications concernant les composants doivent être examinés pour déterminer quelles conditions de défaut peuvent se produire. Exemples:
 - 1) les courts-circuits et circuits ouverts des dispositifs à semiconducteurs et condensateurs;
 - 2) les défauts provoquant une dissipation continue dans les résistances prévues pour une dissipation intermittente;
 - 3) les défauts internes dans les circuits intégrés provoquant une dissipation excessive.

5.3 Critères de réussite

Au cours des essais de simulation des conditions de fonctionnement anormal et de défaut:

- a) Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite et aucune perte de vapeur de combustible.
- b) Le système à pile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne doit pas émettre de métal fondu.
- c) Les pistes de circuits conçues pour s'ouvrir intentionnellement d'une façon répétitive dans les circuits non propagateurs de flammes doivent être conformes à l'IEC 60079-15, ou doivent être isolées des zones de combustibles.
- d) Les enveloppes ne doivent pas se déformer au point de permettre un accès aux parties dangereuses.
- e) Les températures des systèmes d'isolation thermique des moteurs, des transformateurs et autres composants d'enroulements ne doivent pas dépasser 150 °C (302 °F) pour la classe A, 165 °C (329 °F) pour la classe E, 175 °C (347 °F) pour la classe B, 190 °C (374 °F) pour la classe F et 210 °C (410 °F) pour les matériaux de classe H. Si la défaillance de l'isolation ne permet pas d'atteindre des niveaux d'énergie dangereux, une température maximale de 300 °C (572 °F) est autorisée. Des températures supérieures sont autorisées pour une isolation en verre ou céramique.
- f) Les températures et les arcs qui peuvent se produire ne doivent pas être une source d'inflammation potentielle. S'il est considéré qu'ils peuvent devenir une source d'inflammation potentielle, d'autres moyens doivent être prévus pour empêcher l'apparition d'arcs ou de températures élevées;
- g) Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées.
- h) La survenue d'une explosion doit être vérifiée visuellement pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

5.4 Défauts simulés et conditions anormales pour les circuits à puissance limitée et les circuits TBTS

- a) Lorsqu'il est exigé d'appliquer des défauts simulés ou des conditions de fonctionnement anormal, ceux-ci doivent être appliqués un par un et l'un après l'autre.
- b) Les défauts qui sont la conséquence directe d'un défaut simulé ou d'une condition de fonctionnement anormal sont considérés comme une partie de ce défaut simulé ou de la condition de fonctionnement anormal.
- c) Lors de l'application de défauts simulés ou de conditions de fonctionnement anormal, les accessoires, fournitures et produits consommables doivent être mis en place s'il est vraisemblable qu'ils ont un effet sur le résultat de l'essai.
- d) Lors de l'application de défauts simulés ou de conditions de fonctionnement anormal, il convient de tenir compte des dispositifs de protection contre les surintensités sur lesquels ne se produisent pas d'arcs, fournis en tant que partie de la protection, pour le produit final, contre les surintensités et les courts-circuits.

- e) Il faut également prendre en compte les parties sur lesquelles se forment des arcs dans le produit final, si l'application du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible peut émettre des vapeurs potentiellement inflammables au cours d'un fonctionnement normal ou anormal.
- f) Lorsqu'il est fait référence spécifiquement à un premier défaut, le premier défaut est constitué d'une seule défaillance d'une isolation ou d'une seule défaillance d'un composant.

5.5 Fonctionnement anormal – composants électromécaniques

Lorsqu'un danger risque de survenir, la vérification de la conformité des composants électromécaniques autres que les moteurs est effectuée par les essais de défauts suivants:

- g) Les mouvements mécaniques doivent être bloqués dans la position la plus défavorable, alors que le composant est normalement alimenté.
- h) Dans le cas d'un composant normalement mis sous tension par intermittence, un défaut doit être simulé dans le circuit de commande pour entraîner la mise sous tension permanente du composant.
- i) La durée de chaque essai doit être conforme à ce qui suit:
 - 1) Pour les composants du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible dont le défaut de fonctionnement n'est pas évident pour l'utilisateur, l'essai doit être poursuivi aussi longtemps que nécessaire pour obtenir l'état d'équilibre ou jusqu'à l'interruption du circuit par suite d'autres conséquences des conditions de défaut simulées, selon ce qui se produit en premier lieu.
 - 2) Pour les autres composants du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, la durée d'essai doit être de 5 min ou jusqu'à l'interruption du circuit par suite d'une défaillance du composant (destruction thermique par exemple).

5.6 Fonctionnement anormal des systèmes à micropile à combustible ou des blocs d'alimentation électrique de micropile à combustible avec batteries intégrées

Une batterie rechargeable, chargée conformément à la conception du fabricant, et intégrée au système à micropile à combustible ou au bloc d'alimentation électrique de la micropile à combustible, ou recommandée par le fabricant pour être utilisée avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, doit être utilisée pour chacun des essais suivants:

- a) Pour évaluer la sécurité de la charge d'une batterie rechargeable, une batterie est chargée pendant une période de 7 h, conformément à chacune des conditions suivantes:
 - 1) Avec le circuit de charge de batterie réglé sur sa vitesse de chargement maximale (si un réglage de ce type existe), suivi de tout premier défaut sur un composant, susceptible de survenir dans le circuit de charge, et qui donnerait lieu à une surcharge de la batterie. La batterie est chargée pendant 7 h. La batterie est ensuite soumise à une décharge rapide en créant un défaut de circuit ouvert ou un court-circuit à un dispositif de limitation de courant ou de limitation de tension dans le circuit de charge de la batterie en essai.
 - 2) Avec tout premier défaut sur un composant susceptible de survenir, et qui donnerait lieu à une charge en polarité inverse de la batterie. La batterie est chargée pendant 7 h. La batterie est ensuite soumise à une décharge rapide en créant un défaut de circuit ouvert ou un court-circuit à un dispositif de limitation de courant ou de limitation de tension dans le circuit de charge de la batterie en essai.
- b) À l'issue des essais ci-dessus, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être soumis à des essais de rigidité diélectrique, conformément aux recommandations fournies dans l'IEC 60950-1:2005.
- c) Ces essais défaillants de la batterie ne doivent pas avoir comme résultat une des conséquences suivantes:

- 1) des fuites chimiques ou de combustible de la batterie, du système à micropile à combustible, du bloc d'alimentation électrique de la micropile à combustible ou de la cartouche de combustible, provoquées par des fissures, des ruptures ou l'éclatement d'une enveloppe; ou
- 2) l'explosion de la batterie ou du système à micropile à combustible, du bloc d'alimentation électrique de la micropile à combustible, ou de la cartouche de combustible, si une telle explosion risque de blesser un utilisateur.
- 3) l'émission de flammes ou l'expulsion de métal fondu vers l'extérieur du système à micropile à combustible, du bloc d'alimentation électrique de la micropile à combustible, ou de la cartouche de combustible.
- 4) l'inflammation du système à micropile à combustible, du bloc d'alimentation électrique de la micropile à combustible, ou de la cartouche de combustible ou du combustible contenu à l'intérieur de cette dernière.

5.7 Fonctionnement anormal – simulation de défauts d'après l'analyse des dangers

Les défauts suivants doivent être simulés:

- a) Toutes les conditions anormales jugées nécessaires, d'après l'Article 4 pour évaluer les paramètres de protection prévus pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, par exemple protection contre les températures excessives, courts-circuits, tension de la pile à combustible.
- b) Court-circuit, déconnexion ou surcharge dans tous les composants et les parties concernés, sauf s'ils sont contenus dans une enveloppe contre le feu qui satisfait à toutes les exigences relatives aux enveloppes contre le feu, y compris en ce qui concerne les matériaux, voir 4.9.1 et 4.9.4.

NOTE Une condition de surcharge est une condition quelconque entre la charge normale et la condition de courant maximal, jusqu'au court-circuit.

- c) Températures supérieures aux circuits de protection contre les températures excessives, pour assurer la sécurité du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

6 Instructions et avertissements pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

6.1 Généralités

Tous les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible, doivent être accompagnés d'informations de sécurité appropriées (instructions, avertissements, ou les deux), indiquant le transport sûr prévu, l'utilisation, le stockage, la maintenance et la mise au rebut du produit.

6.2 Marquages minimaux exigés sur la cartouche de combustible

Au minimum, la cartouche de combustible doit porter les marquages suivants:

- a) CONTENU INFLAMMABLE ET TOXIQUE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) GARDER HORS DE PORTÉE DES ENFANTS.
- d) NE PAS EXPOSER À DES TEMPÉRATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES OU À DES SOURCES D'INFLAMMATION.
- e) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- f) EN CAS D'INGESTION DE COMBUSTIBLE OU DE CONTACT AVEC LES YEUX, CONSULTER UN MÉDECIN.

- g) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT.
- h) COMPOSITION ET QUANTITÉ DE COMBUSTIBLE.
- i) TEXTE OU MARQUAGE INDIQUANT QUE LA CARTOUCHE DE COMBUSTIBLE EST CONFORME A L'IEC 62282-6-100.

6.3 Marquages minimaux exigés sur le système à micropile à combustible

De plus, au minimum, le système à micropile à combustible doit également porter les marquages suivants:

- a) CONTENU INFLAMMABLE ET TOXIQUE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) NE PAS EXPOSER A DES TEMPÉRATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES OU À DES SOURCES D'INFLAMMATION.
- d) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- e) EN CAS D'INGESTION DE COMBUSTIBLE OU DE CONTACT AVEC LES YEUX, CONSULTER UN MÉDECIN.
- f) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT.
- g) COMPOSITION DU COMBUSTIBLE.
- h) CAPACITÉ MAXIMALE DE COMBUSTIBLE DANS LE RÉSERVOIR INTERNE, SI APPLICABLE.
- i) TEXTE OU MARQUAGE INDIQUANT QUE LE SYSTÈME A MICROPILE A COMBUSTIBLE EST CONFORME A L'IEC 62282-6-100.
- j) SORTIE ÉLECTRIQUE (TENSION, COURANT, PUISSANCE ASSIGNÉE).

6.4 Informations supplémentaires exigées sur la cartouche de combustible, ou sur les informations écrites d'accompagnement, ou sur le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible

Les instructions d'utilisation doivent inclure:

- a) instructions et avertissements de sécurité;
- b) texte ou marquages sur le système à micropile à combustible, indiquant que le système à micropile à combustible est conforme à l'IEC 62282-6-100;
- c) tous les systèmes à micropiles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible doivent identifier la ou les cartouches de combustible qui sont acceptables pour une utilisation avec les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible;
- d) températures minimales et maximales de fonctionnement et de stockage.

6.5 Documentation technique

La documentation technique doit inclure un manuel d'information utilisateur qui doit comprendre des instructions de sécurité et les éléments suivants:

- a) des informations pédagogiques qui forment l'utilisateur final concernant l'utilisation, le fonctionnement et la mise au rebut corrects de la cartouche de combustible, du bloc d'alimentation électrique de la micropile à combustible et/ou du système à micropile à combustible;
- b) des informations qui identifient le fabricant du bloc d'alimentation électrique de la micropile à combustible et/ou du système à micropile à combustible, y compris la raison sociale, l'adresse, le numéro de téléphone et le site web;

- c) tous les avertissements et toutes les instructions apposés sur le système à micropile à combustible, le bloc d'alimentation électrique de la micropile à combustible ou sur la cartouche de combustible doivent être énoncés dans le manuel. Des informations supplémentaires expliquant de façon plus détaillée ou mettant en évidence ces avertissements et instructions peuvent être fournies dans le manuel;
- d) des instructions selon lesquelles le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être utilisé dans une zone bien ventilée.

Les lois locales peuvent s'appliquer à ces exigences. Consulter les organismes nationaux individuellement pour des informations détaillées.

Le fabricant du système à micropile à combustible, du bloc d'alimentation électrique de la micropile à combustible et/ou des cartouches de combustible doit spécifier le type et les caractéristiques correspondantes du combustible et, si applicable, la qualité et les caractéristiques correspondantes du combustible et de l'eau à utiliser avec le système à micropile à combustible. Ces informations doivent être indiquées dans la documentation fournie avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.

Les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible doivent spécifier la ou les cartouches de combustible qui sont destinées à être utilisées avec eux. Ces informations doivent être indiquées dans la documentation fournie avec le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible.

7 Essais de type pour les systèmes à micropile à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

7.1 Généralités

- a) Les essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible doivent permettre de vérifier que ces systèmes à micropiles à combustible, blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible sont sûrs pour une utilisation normale.
- b) Le Tableau 5 énumère les essais de type qui doivent être effectués.

Tableau 5 – Liste des essais de type

Référence de l'essai	Entité d'essai	Échantillon d'essai
7.3.1	Essais de pression différentielle	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.2	Essai de vibrations	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.3	Essai de cycles de températures	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.4	Essai d'exposition à température élevée	Cartouche de combustible Cartouche de combustible remplie partiellement
7.3.5	Essai de chute	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.6	Essai de charge de compression	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.7	Essai de court-circuit externe	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.8	Essai de température de surface, de composant et de gaz d'échappement	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.9	Essai de stockage de longue durée	Cartouche de combustible Cartouche de combustible remplie partiellement
7.3.10	Essai de connexion à température élevée	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible remplie partiellement et bloc d'alimentation électrique de la micropile à combustible
7.3.11	Essai de cycles de connexion	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible
7.3.12	Essai d'émission	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Échantillon d'essai: Le nombre d'échantillons doit être au moins de six (6) cartouches de combustible, neuves ou partiellement remplies, comme spécifié pour les essais individuels ci-dessus, ou au moins de trois (3) systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible pour chaque essai de type. Séquence d'essai: Les essais 7.3.2 et 7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes cartouches de combustible. Les essais 7.3.1, 7.3.2 et 7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible. Réutilisation des échantillons: Les cartouches de combustible et les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible peuvent être réutilisés à l'initiative du fabricant, si ceci ne compromet pas l'essai individuel.		

- c) Sauf exigence explicite contraire dans cet article, les conditions de laboratoire sont spécifiées dans le Tableau 6.

Tableau 6 – Conditions normalisées de laboratoire

Élément	Condition
Température de laboratoire	La température de laboratoire est la «température ambiante» (condition de température normalisée, 22 °C ± 5 °C)
Atmosphère de la pièce du laboratoire; pour l'essai du système à micropile à combustible et du bloc d'alimentation électrique de la micropile à combustible uniquement	L'atmosphère de la pièce du laboratoire ne contient pas plus de 0,2 % de dioxyde de carbone et pas plus de 0,002 % de monoxyde de carbone. L'atmosphère de la pièce du laboratoire contient au moins 18 %, mais pas plus de 21 %, d'oxygène.

- d) Le système à micropile à combustible, le bloc d'alimentation électrique de la micropile à combustible et/ou la cartouche de combustible doivent être conditionnés à une température de laboratoire normalisée de 22 °C ± 5 °C pendant au moins 3 h avant la réalisation de chaque essai.
- e) Avertissement: Ces essais de type utilisent des procédures qui peuvent entraîner des dommages si des précautions appropriées ne sont pas prises. Il convient que les essais ne soient effectués que par des techniciens qualifiés et expérimentés utilisant une protection appropriée.

7.2 Mesurage des fuites de méthanol et procédure de mesure

Le mesurage des fuites de méthanol doit être effectué en principe conformément à la procédure présentée respectivement dans les Figures 2 à 7. Les exceptions sont indiquées dans les différents paragraphes.

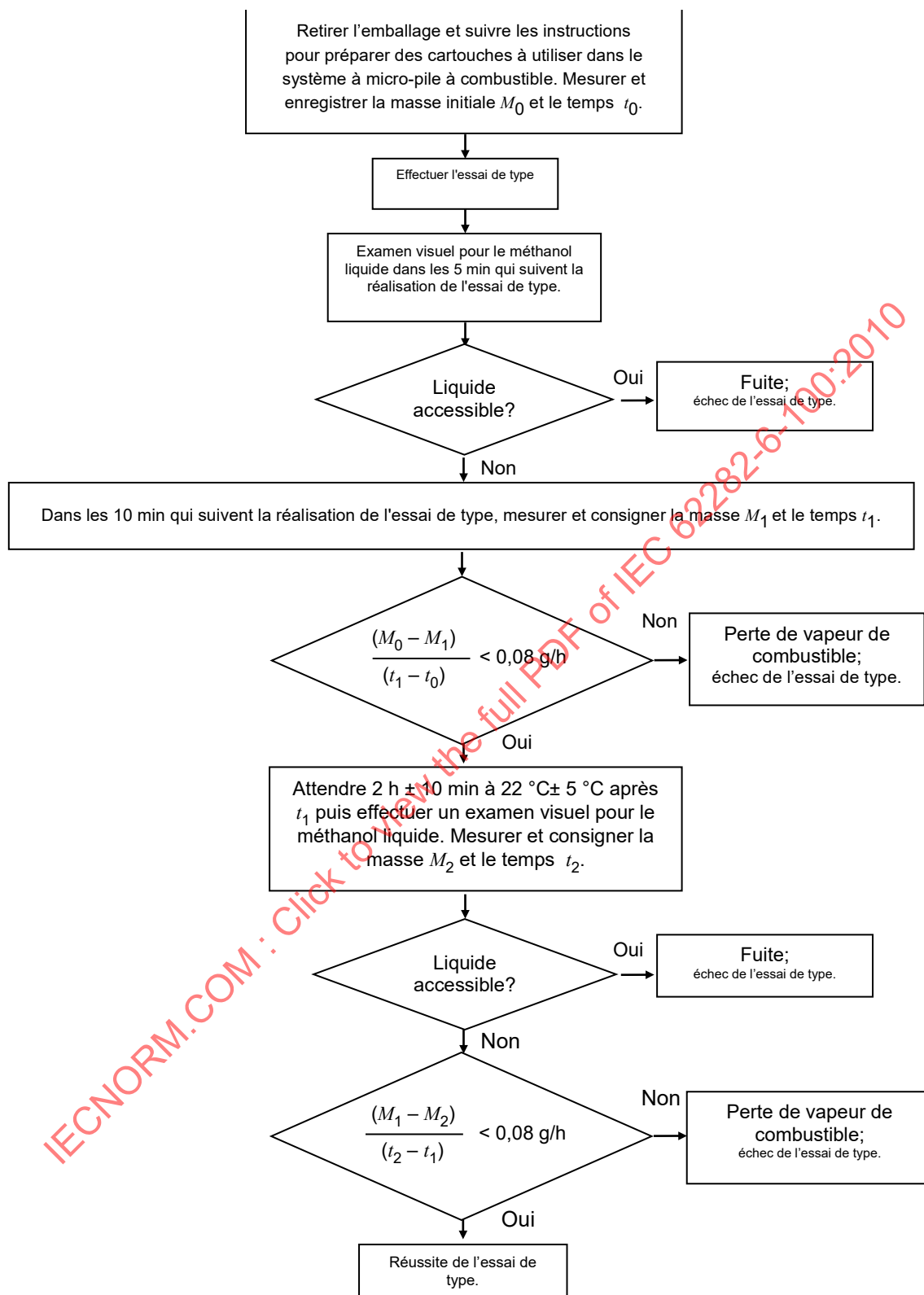


Figure 2 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour les essais de pression différentielle, de vibrations, de chutes et de charge de compression

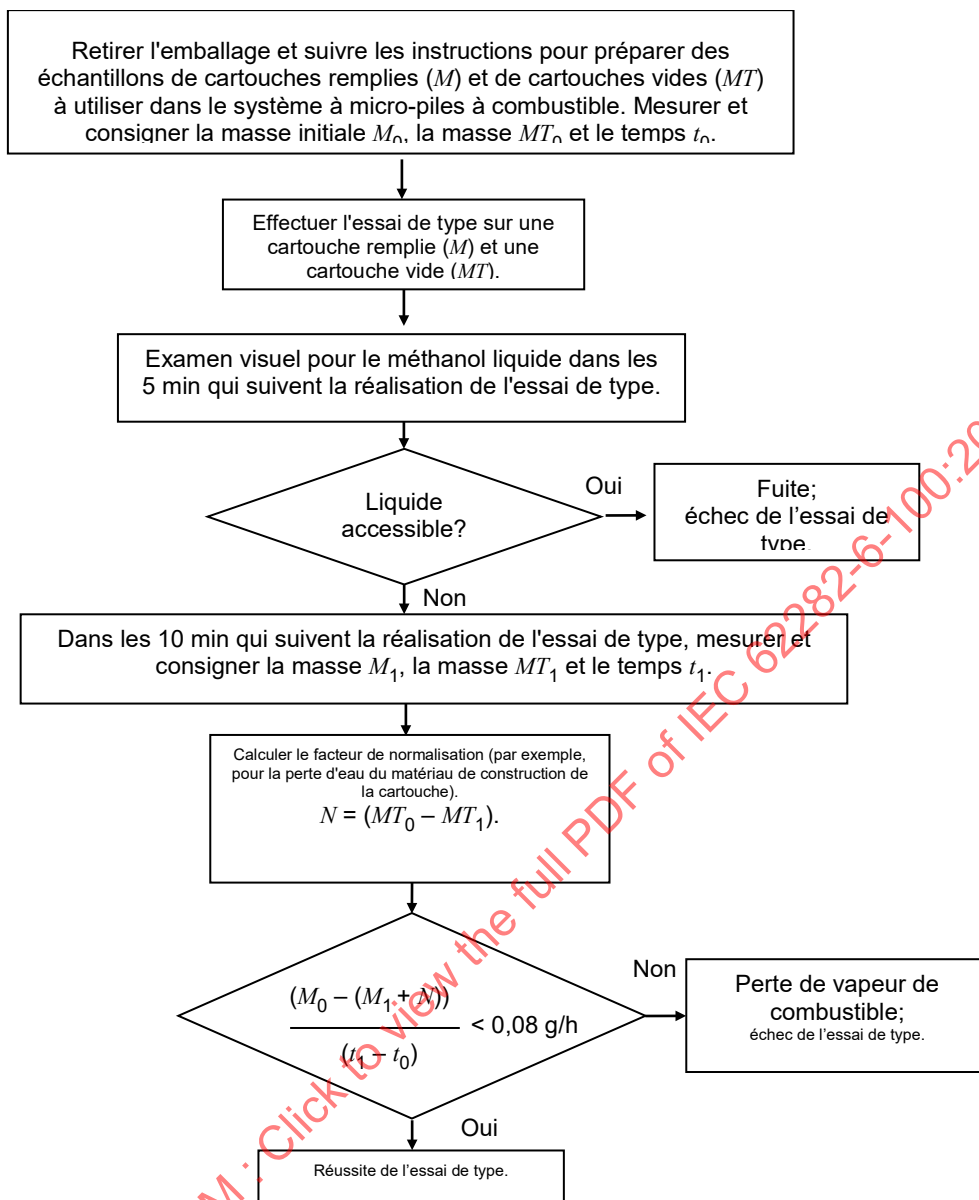


Figure 3 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour l'essai de cycles de températures et l'essai d'exposition à température élevée

L'intervalle de temps maximal $t_1 - t_0$ doit être établi, de telle sorte que pas plus de la moitié du combustible ne soit perdue si la fuite de combustible se produisait au taux de perte de masse maximal admissible.

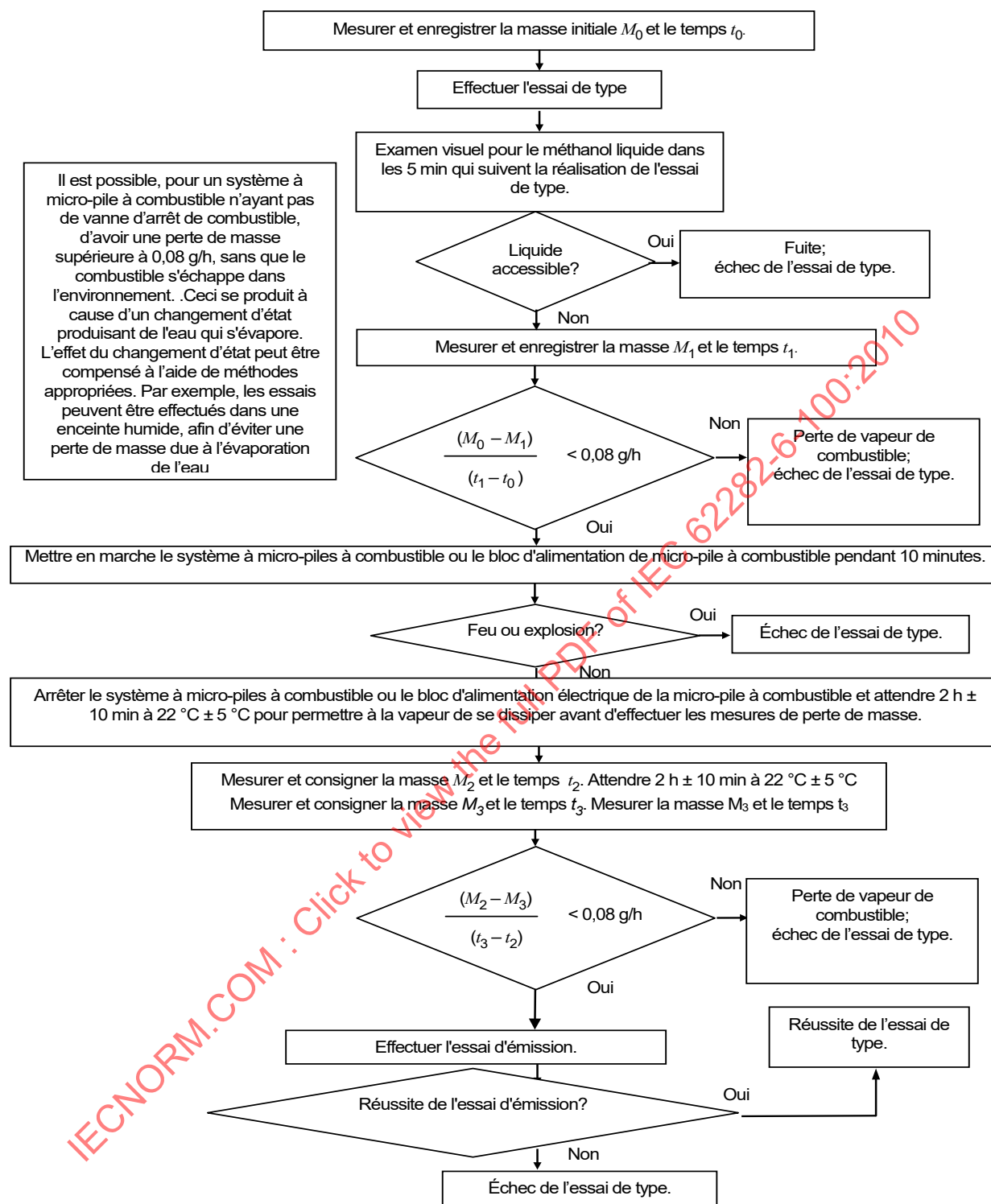


Figure 4 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour les essais de pression différentielle, de vibrations, de cycles de températures, de chute et de charge de compression

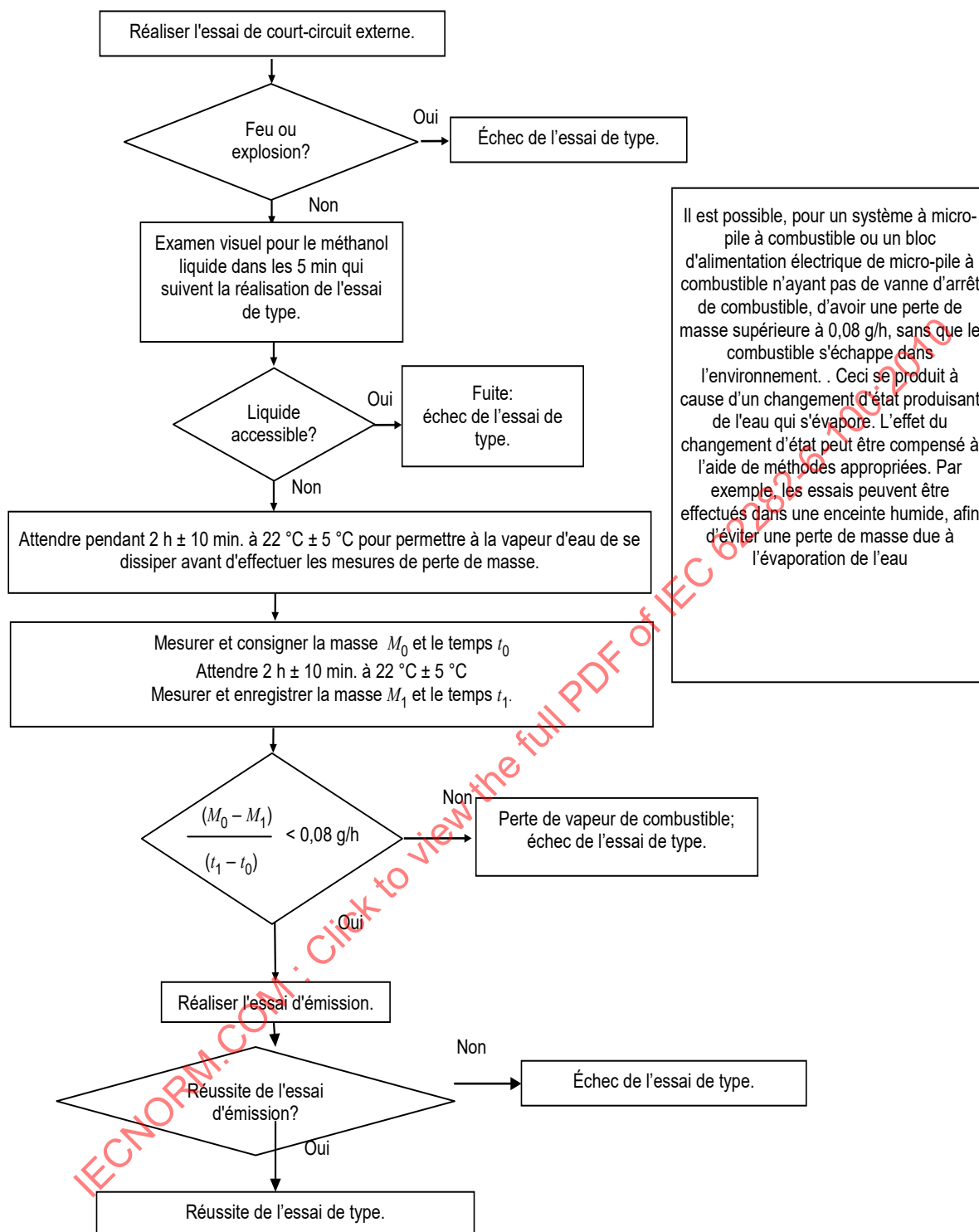


Figure 5 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai de court-circuit externe

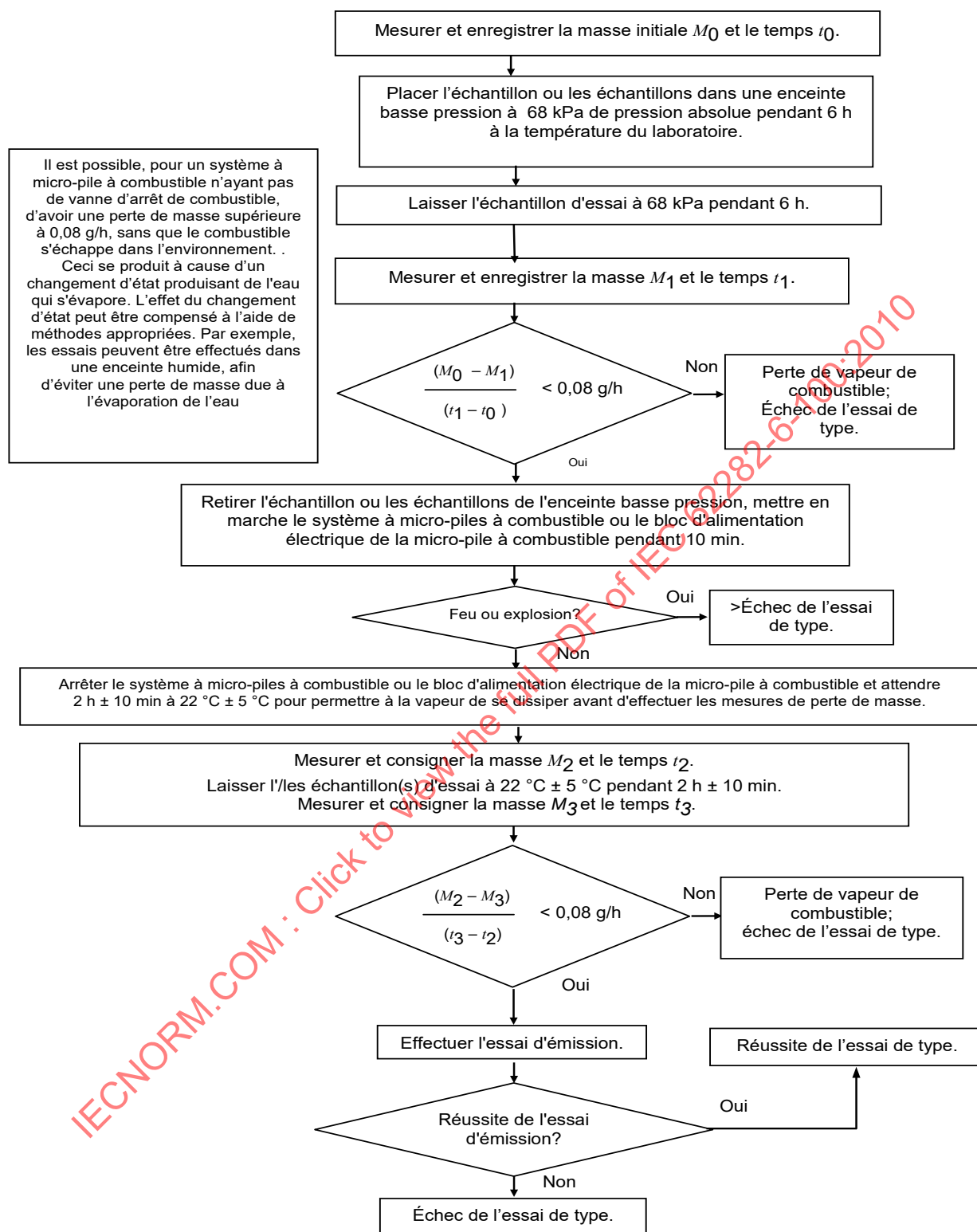


Figure 6 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai à basse pression externe à 68 kPa

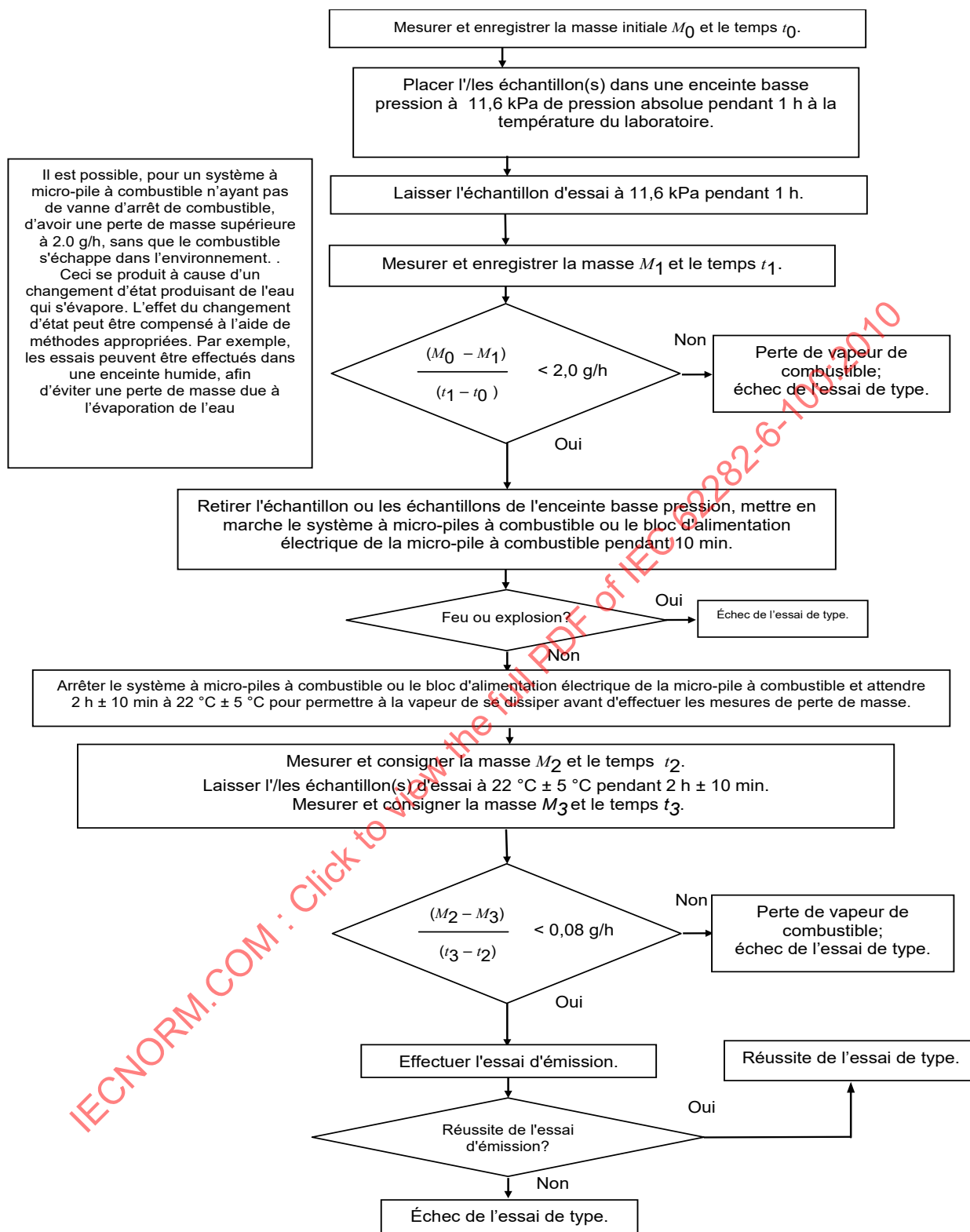


Figure 7 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai à basse pression externe à 11,6 kPa

7.3 Essais de type

7.3.1 Essais de pression différentielle

7.3.1.1 Généralités

Certaines parties de cet essai sont conformes à 4.12.1.2 utilisé pour confirmer qu'il ne doit pas y avoir de fuite au niveau de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. Deux options d'essai sont proposées, en fonction des conditions de pression de limite donnant la valeur la plus élevée:

- a) Si la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C donne une valeur supérieure à deux fois la pression manométrique de la cartouche de combustible à 55 °C, le 7.3.1.2 ou le 7.3.1.3 peut être utilisé pour vérifier la conformité à 4.12.1.2.
- b) Si deux fois la pression manométrique de la cartouche de combustible à 55 °C donne une valeur supérieure à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, le 7.3.1.2 doit être utilisé pour vérifier la conformité à 4.12.1.2.

7.3.1.2 Essai de mise sous pression interne de la cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement et vanne de la cartouche de combustible.
- b) **Objet:** simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**

Pour l'essai de mise sous pression interne, le corps de la cartouche de combustible et la vanne de la cartouche de combustible doivent être soumis à l'essai séparément.

- 1) À l'aide d'un milieu liquide adapté comme l'eau, mettre sous pression le corps de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
 - 2) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
 - 3) À l'aide d'un milieu liquide adapté comme l'eau, mettre sous pression la vanne fermée de la cartouche de combustible à une pression égale soit à la pression manométrique de 95 kPa plus la pression normale de service à 22 °C de la cartouche, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
 - 4) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
- d) **Critères de réussite:** Aucune fuite du milieu d'essai liquide accessible et aucune chute soudaine de pression au cours de l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et la vanne de la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue.

7.3.1.3 Essai de la cartouche de combustible à basse pression externe

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.

- b) **Objet:** simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 5) Effectuer cet essai conformément à la Figure 2.
 - 6) L'échantillon doit être placé dans une chambre à vide, et la pression dans la chambre à vide doit être réduite à 95 kPa en dessous de la pression atmosphérique normale.
 - 7) Maintenir le vide pendant 30 min.
- d) **Critères de réussite:** Ni feu ni flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible et aucune perte de vapeur de combustible. Voir Figure 2. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. La présence de feu ou de flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

7.3.1.4 Essais de pression différentielle du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

7.3.1.4.1 Essai à basse pression externe à 68 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

Cet essai est exigé pour tous les systèmes à piles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
 - 8) Effectuer cet essai conformément à la Figure 6.
 - 9) Les échantillons d'essai doivent être stockés à basse pression externe à 68 kPa de pression absolue pendant 6 h à la température ambiante du laboratoire. La fuite doit être mesurée en se basant sur la procédure décrite à la Figure 6.
 - 10) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite de liquide accessible. Voir Figure 6. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. L'essai d'émission doit satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, le résultat de l'essai d'émission est acceptable. Pendant l'essai de 6 h à 68 kPa de pression externe absolue, la perte de vapeur de combustible doit être inférieure à 0,08 g/h.

7.3.1.4.2 Essai à basse pression externe à 11,6 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

Cet essai est exigé pour tous les systèmes à piles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
 - 11) Effectuer cet essai conformément à la Figure 7.
 - 12) Les échantillons d'essai doivent être stockés à basse pression externe à 11,6 kPa de pression absolue pendant 1 h à la température ambiante du laboratoire. La fuite doit être mesurée en se basant sur la procédure décrite à la Figure 7, avec pour critères de réussite OUI/NON une perte de vapeur de combustible à 11,6 kPa inférieure à 2,0 g/h en ne dépassant pas 25 % de la limite inférieure d'inflammabilité (LII).
 - 13) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite de liquide accessible. Voir Figure 7. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. L'essai d'émission doit satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, le résultat de l'essai d'émission est acceptable. Pendant l'essai de 1 h à 11,6 kPa de pression externe absolue, la perte de vapeur de combustible doit être inférieure à 2,0 g/h.

7.3.2 Essai de vibrations

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible remplie partiellement, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible utilisé en 7.3.1.
- b) **Objet:** simuler les effets des vibrations au cours de conditions normales de transport, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure 2 pour la cartouche de combustible et conformément à la Figure 4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) L'échantillon d'essai doit être fixé solidement à la plate-forme du générateur de vibrations, sans déformer l'échantillon, et de manière à émettre correctement les vibrations.
 - 3) Les vibrations doivent être de forme d'onde sinusoïdale avec un balayage logarithmique entre 7 Hz et 200 Hz et de nouveau à 7 Hz, traversé en 15 min.
 - 4) Ce cycle doit être répété 12 fois pendant 3 h au total pour chacune des trois positions de montage perpendiculaires des échantillons d'essai.

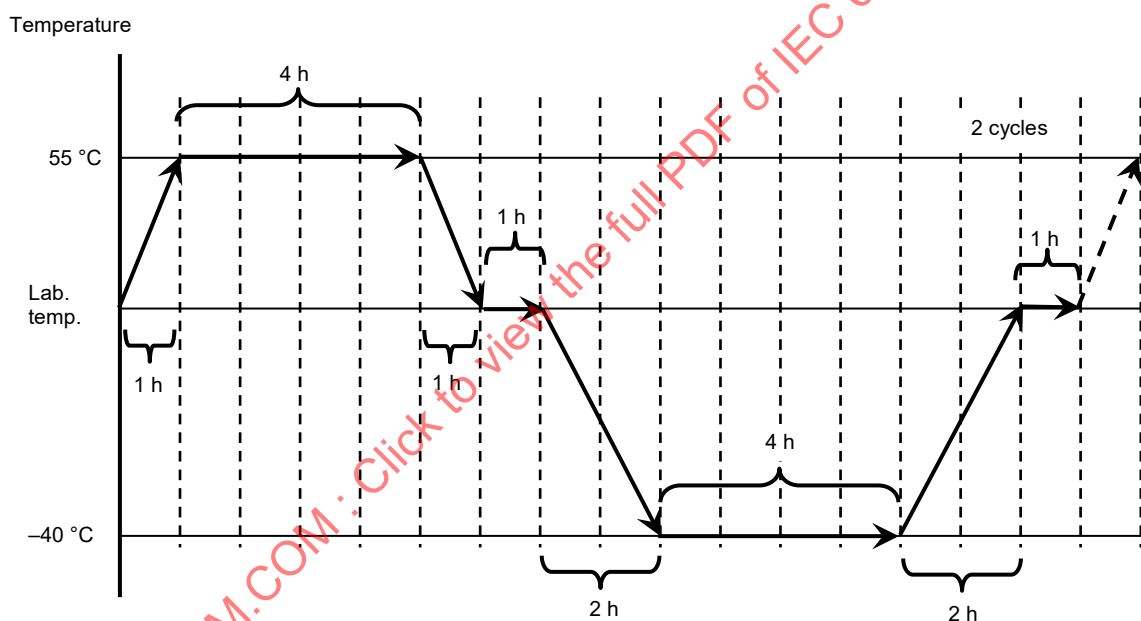
- 5) Le balayage en fréquence logarithmique se déroule comme suit: à partir de 7 Hz, une accélération de crête de $1 g_n$ est maintenue jusqu'à ce que la valeur de 18 Hz soit atteinte. L'amplitude est ensuite maintenue à 0,8 mm (excursion totale de 1,6 mm) et la fréquence est augmentée jusqu'à ce qu'une accélération de crête de $8 g_n$ se produise (environ 50 Hz). Une accélération de crête de $8 g_n$ est ensuite maintenue jusqu'à ce que la fréquence soit portée à 200 Hz.
- 6) Effectuer l'essai d'émission pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible ni aucune perte de vapeur de combustible. La fuite et la perte de vapeur doivent être mesurées en se basant sur la Figure 2 pour la cartouche de combustible et sur la Figure 4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.

7.3.3 Essai de cycles de températures

- a) **Échantillon d'essai:** cartouche de combustible utilisée en 7.3.2, cartouche de combustible remplie partiellement utilisée en 7.3.2, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant utilisé en 7.3.2, ou système à micropile à combustible utilisé en 7.3.2.
- b) **Objet:** simuler les effets d'une exposition à basse température et à température élevée et les effets de variations extrêmes de températures.
- c) **Procédure d'essai:**
 - 7) Effectuer ces essais conformément à la Figure 3 pour la cartouche de combustible et conformément à la Figure 4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 8) Pour une cartouche de combustible, deux orientations de cartouches de combustible doivent être soumises à l'essai – vanne vers le haut et vanne vers le bas. Pour un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible, il n'est pas nécessaire de vérifier par essai plus d'une orientation.
 - 9) Voir Figure 8 pour le profil de température à utiliser.
 - 10) Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, et augmenter la température de l'enceinte de la température de laboratoire à $55\text{ °C} \pm 2\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$, et la maintenir à $55\text{ °C} \pm 2\text{ °C}$ pendant au moins 4 h.
 - 11) Diminuer la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$, puis diminuer la température de l'enceinte à $-40\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$, et la maintenir à $-40\text{ °C} \pm 5\text{ °C}$ pendant au moins 4 h.
 - 12) Augmenter la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$.
 - 13) Le processus ci-dessus doit être réalisé deux fois.
 - 14) Après 1 h à $22\text{ °C} \pm 5\text{ °C}$, la fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 3 (pour la cartouche de combustible) et d'après la procédure décrite à la Figure 4 (pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible).

15) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.

- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible ni aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées en se basant sur la Figure 3 pour la cartouche de combustible et sur la Figure 4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.



Anglais	Français
Temperature	Température
Lab. temp.	Température du laboratoire

Figure 8 – Cycles de températures

7.3.4 Essai d'exposition à température élevée

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets d'une cartouche de combustible laissée dans des environnements à température élevée.
- c) **Procédure d'essai:**
- 1) Deux orientations doivent être soumises à l'essai – vanne vers le haut et vanne vers le bas.

- 2) Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, à une température de $70\text{ °C} \pm 2\text{ °C}$, et laisser la température de l'enceinte revenir à $70\text{ °C} \pm 2\text{ °C}$, et maintenir cette température pendant au moins 4 h avec l'échantillon dans l'enceinte.
- 3) Retirer l'échantillon d'essai à la température de laboratoire.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 3 pour une cartouche de combustible. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

7.3.5 Essai de chute

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible remplie partiellement, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets d'une chute involontaire, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) L'échantillon d'essai doit chuter sur une surface horizontale se composant de bois dur d'au moins 13 mm d'épaisseur monté sur deux couches de contreplaqué, chacune d'une épaisseur de 18 mm à 20 mm, le tout sur un sol en béton ou en matériau équivalent non élastique, à partir d'une hauteur prédéterminée.
 - 2) La hauteur de chute doit être de:
 - i) $1\,200\text{ mm} \pm 10\text{ mm}$: dans le cas d'un bloc d'alimentation électrique de la micropile à combustible et/ou d'un système à micropile à combustible.
 - ii) $1\,500\text{ mm} \pm 10\text{ mm}$: dans le cas d'une cartouche de combustible contenant plus de 200 ml.
 - iii) $1\,800\text{ mm} \pm 10\text{ mm}$: dans le cas d'une cartouche de combustible contenant jusqu'à 200 ml.
 - 3) Pour les essais de la cartouche de combustible, l'essai de chute doit être effectué dans quatre orientations de chute avec le même échantillon.
 - 4) Pour le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible, un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible peut être utilisé pour chacune des quatre orientations de chute, ou plusieurs systèmes à micropiles à combustible ou blocs d'alimentation électrique de micropiles à combustible peuvent être utilisés pour les chutes suivantes, à l'initiative du fabricant.
 - 5) Les orientations de chute doivent être les suivantes:
 - i) vanne vers le haut
 - ii) vanne vers le bas
 - iii) deux autres orientations perpendiculaires
 - 6) Pour les essais du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite et aucune perte de vapeur de combustible. La fuite et la perte de vapeur doivent être mesurées en se basant sur la Figure 2 pour la cartouche de combustible et sur la Figure 4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à

micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible est toujours en état de fonctionnement, les circuits de protection spécifiés par l'AMDE en tant que parties des systèmes de sécurité doivent toujours être pleinement fonctionnels. Il ne doit pas y avoir d'exposition des parties dangereuses.

7.3.6 Essai de charge de compression

7.3.6.1 Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur le bloc d'alimentation électrique de la micropile à combustible, ou le système à micropile à combustible.
- c) **Procédure d'essai:**
 - 1) L'échantillon d'essai du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer sur l'échantillon une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$.
 - 2) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).
 - 3) Une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 4) L'essai doit en général être effectué dans trois orientations perpendiculaires. Si l'échantillon n'est pas stable de lui-même, il n'est pas nécessaire qu'il soit soumis à l'essai dans cette orientation.
 - 5) Effectuer l'essai d'émission conformément à 7.3.12, après l'essai de charge de compression.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 4. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. La présence de feu ou de flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions provenant des systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la

micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.

7.3.6.2 Cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur la cartouche de combustible.
- c) **Procédure d'essai:**
 - 1) L'échantillon d'essai de la cartouche de combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer à l'échantillon une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$.
 - 2) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).
 - 3) Une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 4) Les orientations de la cartouche de combustible doivent être choisies d'après les positions de repos en principe stables lors de chutes accidentelles (par exemple, les orientations ayant les centres de gravité les plus bas par rapport à la surface de repos). Il est acceptable de soumettre aux essais une seule surface d'une cartouche de combustible prismatique qui soit suffisamment cubique et la surface incurvée d'une cartouche de combustible cylindrique avec une longueur d'axe longitudinal supérieure à deux fois le diamètre.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 2. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

7.3.7 Essai de court-circuit externe

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets d'un court-circuit externe.
- c) **Procédure d'essai:**
 - 1) L'essai de court-circuit externe doit être effectué séparément et respectivement à la fois sur les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible en fonctionnement [DISPOSITIF EN POSITION «ON»] et sur les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible en état de non-fonctionnement [DISPOSITIF EN POSITION «OFF»].
 - 2) Chaque échantillon d'essai doit être court-circuité en reliant les bornes positive et négative du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible avec des conducteurs ayant une charge de résistance maximale de $0,1 \Omega$ pendant au moins 5 min.
 - 3) Effectuer l'essai d'émission conformément à 7.3.12 après chaque essai de court-circuit externe.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la

Figure 5. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

Les surfaces externes ne doivent pas dépasser les températures du Tableau 2, pendant ou après les essais de court-circuit externe.

Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.

NOTE L'essai de court-circuit externe peut être effectué de manière séquentielle avec l'essai de température de surface, de composant et de gaz d'échappement, en utilisant le même échantillon.

7.3.8 Essai de température de surface, de composant et de gaz d'échappement

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** éliminer tout risque de brûlure provoquée par un contact avec l'enveloppe d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible et éliminer tout risque de brûlure provoquée par un gaz d'échappement provenant des aérations, ainsi que vérifier la conformité avec les caractéristiques assignées de température des composants.
- c) **Procédure d'essai:**
 - 4) Les températures doivent être mesurées jusqu'à leur stabilisation à ± 2 °C pendant 5 min.
 - 5) Cet essai doit être effectué à la température de fonctionnement ambiante assignée indiquée par le fabricant.
 - 6) La température de la surface nue des blocs d'alimentation électrique de micropiles à combustible ou des systèmes à micropiles à combustible fonctionnant à la puissance de sortie assignée doit être mesurée à l'aide de caméra(s) infrarouge(s), de thermocouples, ou autres dispositifs appropriés.
 - 7) Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être positionné pour un fonctionnement normal, de telle sorte que les gaz d'échappement ne soient pas obstrués.
 - 8) La température des gaz d'échappement doit être mesurée à une distance de 1 cm de la ventilation d'évacuation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible fonctionnant à la puissance de sortie assignée.
- d) **Critères de réussite:** La température de surface des différentes parties facilement accessibles du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile ne doit pas dépasser la valeur indiquée dans le Tableau 2, en fonction du matériau. La température à 1 cm de la ventilation d'évacuation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible en fonctionnement doit être inférieure à 70 °C. Au cours de l'essai, les coupe-circuits thermiques et les dispositifs de protection contre la surcharge ne doivent pas fonctionner.

Pour les composants et le câblage électrique à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible qui ne font pas l'objet du Tableau 2, leur température ne doit pas dépasser la température maximale pour laquelle les composants et le câblage sont assignés. Les composants relatifs à la sécurité doivent être identifiés par l'AMDE.

NOTE Cet essai peut être réalisé de manière séquentielle avec l'essai de court-circuit externe, en utilisant le même échantillon.

7.3.9 Essai de stockage de longue durée

7.3.9.1 Généralités

7.3.9.2 (Option 1), 7.3.9.3 (Option 2) ou 7.3.9.4 (Option 3) peut être utilisé.

7.3.9.2 Option 1 – Mesurage du poids en continu

a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.

b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.

c) **Procédure d'essai** (Voir Figure 9):

- 1) Utiliser un dynamomètre (dispositif de pesage électronique continu) conçu et étalonné pour une utilisation à $50\text{ °C} \pm 2\text{ °C}$ à l'intérieur de l'enceinte de température.
- 2) Placer le dynamomètre dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$. Placer la cartouche de combustible sur la partie supérieure du dynamomètre, de sorte que toute la masse soit appliquée sur le dynamomètre. Un dispositif de fixation peut être utilisé pour contrôler la position de la cartouche de combustible, pour garantir que toute la masse est appliquée sur le dynamomètre.
- 3) Connecter un affichage numérique sur le dynamomètre et collecter les données manuellement ou automatiquement. Il convient de collecter les données avec un degré de confiance élevé, pour assurer que la perte de vapeur de combustible ne dépasse pas 0,08 g/h.
- 4) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
- 5) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours.
- 6) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{initiale} et enregistrer le temps t_i . Si le taux de perte de masse moyenne est inférieur à 0,08 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de vapeur de combustible.

i) Perte de vapeur de combustible
$$= \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$$

ii) $\Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/j} = 672 \text{ h}$.

iii) M_{initiale} = masse initiale de la cartouche de combustible.

iv) M_{finale} = masse finale de la cartouche de combustible.

- 7) Si la cartouche de combustible est vide avant la fin de l'essai, le taux de perte de masse doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que la cartouche de combustible ne soit vide. L'essai est réussi si la perte de vapeur de combustible est inférieure à 0,08 g/h.

i) Perte de vapeur de combustible
$$= \frac{M_{\text{initiale}} - M_{\text{dernière}}}{\Delta t_{\text{dernier}}}$$

ii) $\Delta t_{\text{dernier}}$ = le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.

iii) M_{initiale} = masse initiale de la cartouche de combustible.

- iv) $M_{\text{dernière}}$ = le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible et aucune fuite de liquide. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 9. Si la perte de vapeur de combustible de la cartouche de combustible est inférieure aux critères de 0,08 g/h de perte de vapeur de combustible, alors l'échantillon d'essai satisfait à l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

7.3.9.3 Option 2 – Mesurages périodiques du poids

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai** (Voir Figure 9):

- 1) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
- 2) Placer la cartouche de combustible dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$. Il convient de recueillir les mesurages du poids avec un degré de confiance élevé, afin de déterminer si la perte de vapeur de combustible est inférieure à 0,08 g/h, avec une fréquence minimale d'une fois tous les trois jours.
- 3) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours.
- 4) La durée pendant laquelle les échantillons d'essai sont retirés de l'enceinte pour le mesurage ne doit pas être incluse dans la durée pendant laquelle l'échantillon d'essai doit être soumis à l'essai (28 jours). Il convient d'ajouter une durée supplémentaire pour que l'échantillon d'essai soit à la température d'essai ($50\text{ °C} \pm 2\text{ °C}$), à chaque fois que l'échantillon d'essai est retiré de l'enceinte. Il convient que les échantillons d'essai ne soient stabilisés à la température ambiante du laboratoire que si la perte de masse est affectée.
- 5) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,08 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de vapeur de combustible.

$$\text{i) Perte de vapeur de combustible} = \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initiale}} = \text{masse initiale de la cartouche de combustible.}$$

$$\text{iv) } M_{\text{finale}} = \text{masse finale de la cartouche de combustible.}$$

- 6) Si la cartouche de combustible est vide avant la fin de l'essai, le taux de perte de masse doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que la cartouche de combustible ne soit vide. L'essai est réussi si la perte de vapeur de combustible est inférieure à 0,08 g/h.

$$\text{i) Perte de vapeur de combustible} = \frac{M_{\text{initiale}} - M_{\text{dernière}}}{\Delta t_{\text{dernier}}}$$

- ii) $\Delta t_{\text{dernier}}$ = le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) $M_{\text{dernière}}$ = le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible et aucune fuite de liquide. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 9. Si le taux de perte de vapeur de combustible de la cartouche de combustible est inférieur au critère de 0,08 g/h de perte de vapeur de combustible, alors l'échantillon d'essai satisfait à l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

7.3.9.4 Option 3 – un seul mesurage du poids

Cette option est destinée aux cartouches de combustible avec des taux de fuite très faibles.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai** (Voir Figure 9):
 - 1) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
 - 2) Placer les cartouches de combustible dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$. Après 28 jours, les cartouches de combustible sont retirées de l'enceinte pour le mesurage. Il convient que les échantillons d'essai soient stabilisés à la température ambiante du laboratoire si la perte de masse est affectée. Le mesurage de la masse est ensuite effectué.
 - 3) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,08 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de vapeur de combustible.
 - i) Perte de vapeur de combustible $= \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$
 - ii) $\Delta t = t_f - t_i = 28\text{ jours} \times 24\text{ h/jour} = 672\text{ h}$.
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) M_{finale} = masse finale de la cartouche de combustible.
 - 4) Si la cartouche de combustible est vide après 28 jours, alors l'essai de type conformément à 7.3.9.2 Option 1 ou à 7.3.9.3 Option 2 doit être effectué.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible et aucune fuite de liquide. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 9. Si le taux de perte de vapeur de combustible de la cartouche de combustible est inférieur au critère de 0,08 g/h de perte de vapeur de combustible, alors l'échantillon d'essai satisfait à l'essai de perte de vapeur de combustible. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et

rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

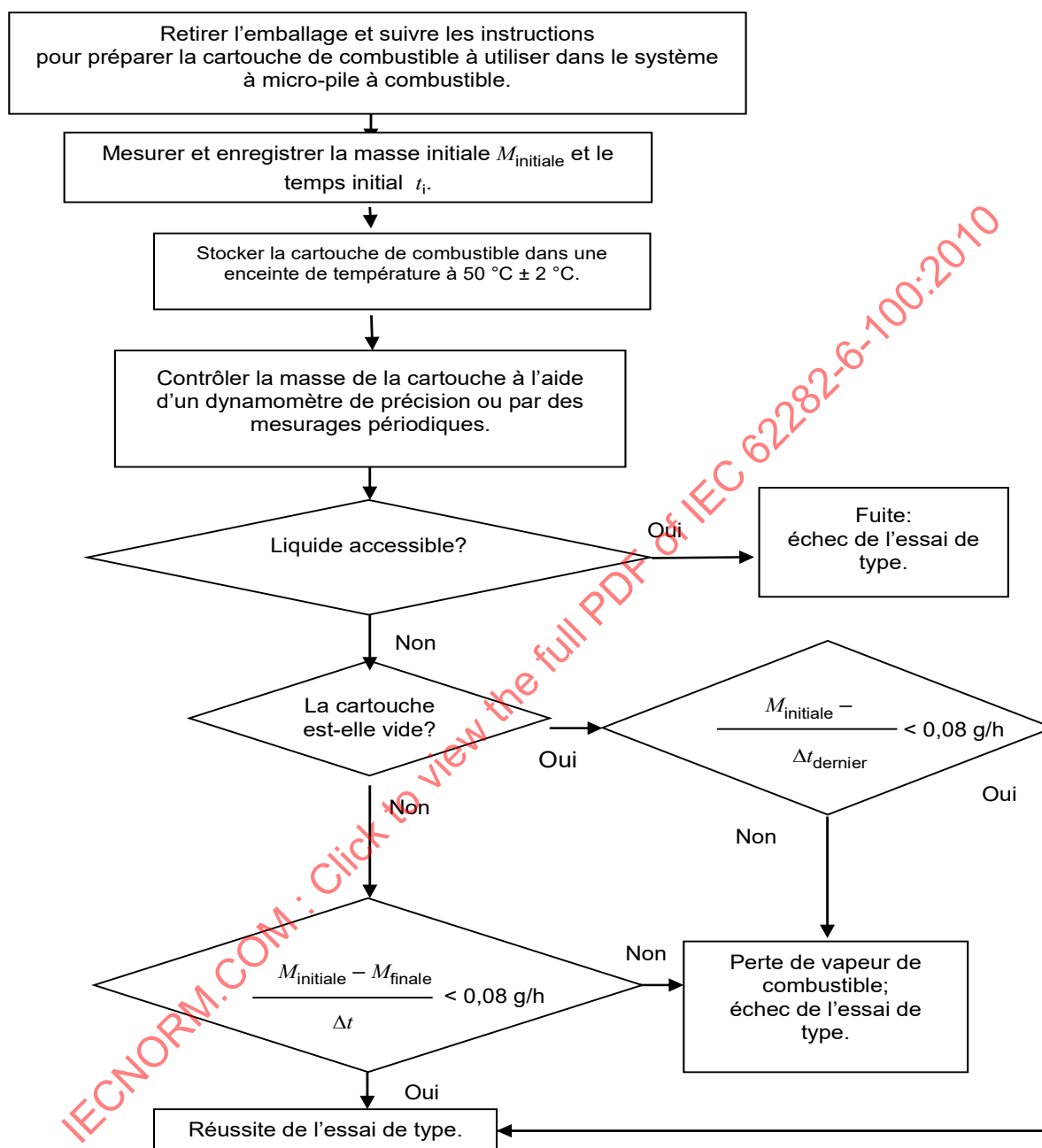


Figure 9 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour l'essai de stockage de longue durée

7.3.10 Essai de connexion à température élevée

- Échantillon d'essai:** cartouche de combustible inutilisée, ou cartouche de combustible remplie partiellement et bloc d'alimentation électrique de la micropile à combustible, ou une installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible.
- Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne

du bloc d'alimentation électrique de la micropile à combustible, la cartouche de combustible étant à une température élevée, et garantir l'absence de fuite, de feu et d'explosion.

c) **Procédure d'essai:**

- 1) Placer l'échantillon d'essai de la cartouche de combustible dans une enceinte d'essai à température contrôlée, c'est-à-dire à une température de $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 4 h.
- 2) Le bloc d'alimentation électrique de la micropile à combustible ou l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible sont maintenus à la température ambiante du laboratoire.
- 3) Retirer l'échantillon d'essai de l'enceinte et connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible, dans les 5 min qui suivent le retrait de l'enceinte.
- 4) Vérifier s'il y a des fuites lors de la connexion.
- 5) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.

- d) **Critères de réussite:** Pas de fuite, pas de feu ni flamme, et pas d'explosion. Si, en utilisant une force normale, la cartouche de combustible ne peut pas être connectée, et qu'aucune fuite, aucun feu et aucune explosion ne se produisent, ceci est acceptable. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou la vanne du bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du bloc d'alimentation électrique de la micropile à combustible.

7.3.11 Essais de cycles de connexion

7.3.11.1 Cartouche de combustible

7.3.11.1.1 Cartouche insérable, cartouche externe ou cartouche fixée

- a) **Échantillon d'essai:** cartouche insérable, cartouche externe ou cartouche fixée inutilisée, et bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux instructions du fabricant ou installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible et alimentée en combustible conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites lors de la connexion.
 - 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 4) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
 - 5) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.

- 6) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 7) Connecter et déconnecter la cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
 - 8) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 9) Connecter et déconnecter la cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
 - 10) Renverser la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif, et rechercher des signes de fuite.
 - 11) Connecter la cartouche de combustible et faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 12) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 13) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- d) **Critères de réussite:** Pas de fuite, pas de feu ni flamme, et pas d'explosion. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou la vanne du bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du bloc d'alimentation électrique de la micropile à combustible.

7.3.11.1.2 Cartouche satellite

- a) **Échantillon d'essai:** cartouche de combustible satellite inutilisée, et bloc d'alimentation électrique de la micropile à combustible ou installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible alimentée en combustible, conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites lors de la connexion et amorcer ou simuler le débit de combustible.
 - 2) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
 - 3) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
 - 4) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 5) Connecter et déconnecter la première cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.

- 6) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 7) Connecter et déconnecter la cartouche de combustible trois autres fois pour un total de 10 connexions et déconnexions.
 - 8) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 9) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible et amorcer ou simuler le débit de combustible.
 - 10) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
 - 11) Répéter les étapes 1 à 10 quatre autres fois pour un total de 55 cycles, en attendant 1 h entre chaque série de 11 cycles.
- d) **Critères de réussite:** Pas de fuite, pas de feu ni flamme, et pas d'explosion. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou la vanne du bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du bloc d'alimentation électrique de la micropile à combustible.

7.3.11.2 Bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** au moins deux cartouches de combustible inutilisées et 98 autres cartouches de combustible ou installations d'essai fixes comportant des vannes de cartouches de combustible supplémentaires et un bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie et du matériau de la vanne de la cartouche de combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite, à la fois lors de l'utilisation initiale et après un vieillissement adapté de la connexion du bloc d'alimentation électrique de la micropile à combustible.

La première cartouche de combustible (#1) et la dernière cartouche de combustible (#100) sont examinées; les 980 cycles restants sont uniquement destinés à faire vieillir le bloc d'alimentation électrique de la micropile à combustible.

Dans le cas d'un bloc d'alimentation électrique de la micropile à combustible qui utilise une cartouche satellite, il doit être soumis à l'essai conformément à la procédure ci-dessous en simulant le débit de combustible entre la cartouche satellite et le bloc d'alimentation électrique de la micropile à combustible.

c) **Procédure d'essai:**

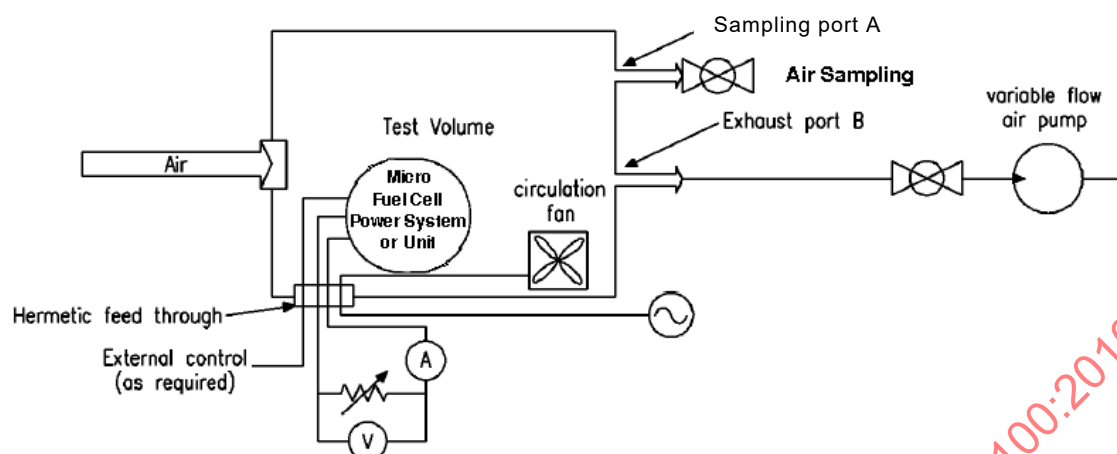
- 1) Connecter la première cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites lors de la connexion.
- 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 4) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- 5) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.

- 6) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 7) Connecter et déconnecter la première cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 8) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 9) Connecter et déconnecter la première cartouche de combustible trois autres fois pour un total de 10 connexions et déconnexions.
- 10) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 11) Connecter la première cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites lors de la connexion.
- 12) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 13) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 14) Déconnecter la première cartouche de combustible et vérifier s'il y a des fuites.
- 15) Pour un vieillissement de la connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible, suivre les étapes suivantes:
 - v) En utilisant soit des cartouches de combustible soit une installation d'essai fixe comportant des vannes de cartouche de combustible, lancer des cycles de connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible pour un total de 980 cycles de connexions et déconnexions.
 - vi) Simuler le débit de combustible après chaque série de 50 cycles de connexion/déconnexion.
 - vii) Le renversement du bloc d'alimentation électrique de la micropile à combustible, ou des cartouches de combustible n'est pas nécessaire, mais si une fuite est détectée, l'essai échoue.
 - viii) Après ce vieillissement, une dernière cartouche de combustible inutilisée est soumise à l'essai.
- 16) Connecter la dernière cartouche de combustible inutilisée au bloc d'alimentation électrique de la micropile à combustible et vérifier s'il y a des fuites lors de la connexion.
- 17) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 18) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 19) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- 20) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
- 21) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 22) Connecter et déconnecter la dernière cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 23) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.

- 24) Connecter et déconnecter la dernière cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
 - 25) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 26) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible et vérifier s'il y a des fuites lors de la connexion.
 - 27) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 28) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 29) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- d) **Critères de réussite:** Pas de fuite, pas de feu ni flamme, et pas d'explosion. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du bloc d'alimentation électrique de la micropile à combustible.

7.3.12 Essai d'émission

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) du système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible – qui est alimenté en méthanol – les émissions de monoxyde de carbone (CO), de dioxyde de carbone (CO₂) et de composés organiques tels que le méthanol, le formaldéhyde, l'acide formique et le formiate de méthyle, doivent être maintenues à un niveau inférieur aux valeurs spécifiées. Le fait de maintenir ces limites empêche non seulement une exposition déconseillée, mais garantit aussi le maintien d'une alimentation adéquate en oxygène dans l'environnement de fonctionnement.

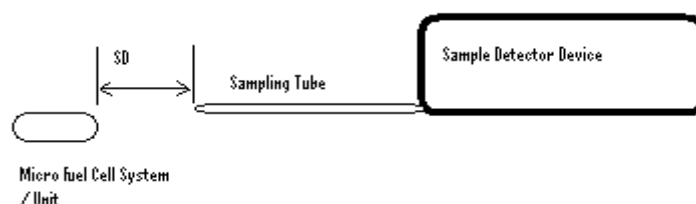


Anglais	Français
Sampling port A	Orifice d'échantillonnage A
Test volume	Volume d'essai
Micro fuel cell power system or unit	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Circulation fan	Ventilateur de brassage
Hermetic feed through	Passage hermétique
External control (as required)	Commande extérieure (si exigée)
Exhaust port A	Orifice d'évacuation A
Air sampling	Échantillonnage de l'air
Variable flow air pump	Pompe à air à débit variable

Figure 10 – Appareillage d'essai du taux d'émission opérationnel

- c) **Appareillage d'essai:** Un exemple d'appareillage d'essai du taux d'émission opérationnel est représenté à la Figure 10. La configuration représentée à la Figure 10 sert à la vérification par essai du taux d'émission de tous les systèmes à micropiles à combustible ou blocs d'alimentation électrique de micropiles à combustible. Les essais de taux d'émission conformément à 7.3.12 d) 1) sont exigés pour tous les types de systèmes à micropiles à combustible et de blocs d'alimentation électrique des micropiles à combustible.

Pour les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur (tels que les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible utilisés pour alimenter des téléphones cellulaires, des jeux tenus à la main, etc.), des essais complémentaires conformes à 7.3.12 d) 2) sont exigés pour vérifier que les concentrations des émissions dans le voisinage de la bouche ou du nez d'un utilisateur sont maintenues dans des limites appropriées. Ces essais de concentrations d'émissions doivent être réalisés dans une grande salle ouverte en utilisant un appareillage d'essai de concentration d'émission différent. Un exemple d'appareillage d'essai de la concentration d'émission opérationnel est représenté à la Figure 11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD – *separation distance*) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé) pour les essais de la limite de concentration des émissions.



Anglais	Français
Sampling tube	Tube d'échantillonnage
Sample detector device	Dispositif de détection d'échantillon
Micro fuel cell system/unit	Système à micropile à combustible / bloc d'alimentation de la micropile à combustible

Figure 11 – Appareillage d'essai de la concentration d'émission opérationnel

Les gaz d'émission peuvent être composés de matières organiques toxiques, telles que le méthanol, le formaldéhyde, l'acide formique et le formiate de méthyle, qui peuvent être évacuées d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible.

Pour analyser ces matières organiques, un chromatographe en phase gazeuse avec un détecteur à ionisation de flamme (GC/FID – *gas chromatograph/flame ionization detector*) ou avec un spectromètre de masse (GC/MS – *gas chromatograph/mass spectrometer*) ou un système de chromatographie liquide à haute performance (HPLC – *high-performance liquid chromatography*), doivent être utilisés en absorbant les gaz d'émission sur le tube à adsorption fixé sur l'orifice d'échantillonnage A de l'enceinte d'essai, ou directement sur un analyseur à travers l'orifice d'échantillonnage A de la Figure 10. Toutefois, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus.

La concentration de CO et de CO₂ peut être mesurée par un analyseur à absorption infrarouge non dispersif. Ces appareils de mesure analytiques doivent être conformes à l'ISO 16000-3, à l'ISO 16000-6 et à l'ISO 16017-1. Cependant, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus, en utilisant les normes mentionnées ci-dessus.

d) Procédure d'essai:

- 1) Pour tous les systèmes à micropiles à combustible et les blocs d'alimentation électrique de micropiles à combustible – aussi bien ceux destinés à être utilisés très près de la bouche ou du nez d'un consommateur que ceux qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur – l'essai suivant d'échantillonnage du taux d'émission doit être réalisé.
 - i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure 10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «DISPOSITIF EN POSITION «ON»».
 - ii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
 - iii) Les émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à

la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure 10.

- iv) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon
- v) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure 10, tout en mesurant et enregistrant simultanément le débit à travers l'enceinte d'essai. Le débit à travers l'enceinte d'essai peut être calculé à partir de la somme du débit de la pompe à air à débit variable et du débit d'échantillon à travers l'orifice d'échantillonnage de l'air A ou en mesurant le débit d'air d'admission à l'enceinte d'essai.
- vi) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau 7.
- vii) Calculer le taux d'émission des composés chimiques concernés émis en multipliant la concentration stabilisée maximale de chaque constituant par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit en régime établi de la pompe à air à débit variable à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux d'émission.

Voir ci-dessous:

$$ER = (F_P + F_S) \times C$$

ou

$$ER = (F_i) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre normalisé;

- viii) Comparer le taux maximal d'émission mesuré avec le Tableau 7. Si le taux d'émission n'est pas inférieur à la limite de taux d'émission dans le Tableau 7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite 7.3.12 e) 1) i) et 7.3.12 e) 2) i).
 - ix) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 2) Pour les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur, l'essai complémentaire suivant d'échantillonnage de concentration d'émissions doit être réalisé:
- i) Les essais de taux d'émission des systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible doivent être réalisés dans une grande salle ouverte. L'intention de cet essai est d'approcher et de

mesurer la concentration d'émission attendue près de la bouche ou du nez d'une personne en air calme. Un mannequin ou autre simulateur peut être utilisé pour améliorer la précision de l'essai. L'air à l'intérieur de la salle doit être échantillonné avant les essais afin d'assurer la précision et éviter les résultats erronés non conformes. Veiller à s'assurer que les matières dans la salle ou dans le système d'échantillonnage n'apportent pas d'émissions (c'est-à-dire, de contaminants) à l'essai. Avant les essais, il est recommandé de rechercher les traces de contamination dans le système sans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, pour éviter les résultats erronés non conformes.

- ii) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à la puissance assignée dans la grande salle ouverte lors de l'échantillonnage de concentrations d'émissions à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure 11. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai de concentration d'émission doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible, et avec l'interrupteur d'alimentation électrique en position «ON».
- iii) Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
- iv) Les concentrations des émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être échantillonnées à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure 11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé).
- v) La vitesse d'échantillonnage pour les mesurages de concentration d'émission très près doit être de 5 l par minute, ce qui représente la vitesse de respiration d'un être humain adulte.
- vi) Laisser le débit d'échantillon se stabiliser.
- vii) Échantillonner et enregistrer les émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de la pile à combustible qui se produisent à une distance représentative de la zone de respiration d'un consommateur.
- viii) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau 7.
- ix) Comparer les concentrations maximales mesurées avec le Tableau 7. Si les concentrations d'émission ne sont pas inférieures aux limites de concentration d'émission dans le Tableau 7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite 7.3.12 e) 2) ii).
- x) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.

e) **Critères de réussite:**

- 1) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau 7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau 7 lorsqu'il est soumis à l'essai conformément à 7.3.12 d) 1). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
- 2) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible à utiliser très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau 7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau 7 lorsqu'il est soumis à l'essai conformément à 7.3.12 d) 1). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
 - ii) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui ne sont pas destinés à être utilisés à étroite proximité de la bouche ou du nez d'un consommateur: En plus de la conformité à la limite de taux d'émission indiquée ci-dessus, la concentration maximale d'émission pour chacun des constituants concernés doit être inférieure à la limite de concentration d'émission indiquée dans le Tableau 7 lorsqu'elle est vérifiée par essai conformément à 7.3.12 d) 2). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.

Tableau 7 – Limites d'émissions

	Limite de concentration	Limite du taux d'émission ^a
Eau	Illimitée	Pas de limite
Méthanol	0,26 g/m ³	2,6 g/h
Formaldéhyde	0,000 1 g/m ³ ^b	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Acide formique	0,009 g/m ³	0,09 g/h
Formiate de méthyle	0,245 g/m ³	2,45 g/h

^a La limite du taux d'émission était basée sur la valeur 10 m³ ACH, choisie comme le produit du volume de référence par les renouvellements d'air par heure (ACH – *air changes per hour*), parce qu'elle couvre les environnements raisonnablement prévisibles dans lesquels les systèmes à micropiles à combustible sont utilisés. L'espace intérieur dans une petite voiture et le volume minimal par personne à bord d'un avion commercial sont fixés à 1 m³. L'ACH minimal utilisé à bord d'un avion de passagers est de 10 et le réglage de ventilation le plus faible dans les voitures est de 10 ACH. Les maisons et les bureaux peuvent présenter des niveaux d'ACH aussi bas que 0,5, mais le volume par personne est supérieur à 20 m³, et donc un produit de 10 est satisfaisant.

^b La limite fixée par l'OMS est de 0,000 1 g/m³. Les niveaux de fond sont de 0,000 03 g/m³. La limite d'émission ne peut pas faire passer le niveau de fond au-dessus de la limite fixée.

^c Un adulte assis a un taux d'émission de CO₂ de 30 g/h. Les taux d'émission des piles à combustible, mais aussi des adultes sont limités, de telle sorte que la concentration de CO₂ n'atteigne pas la limite de concentration sur huit heures fixée par l'OMS de 9 m³. Dans un environnement avec 10 m³ ACH, ceci limite la contribution de la pile à combustible à 60 g/h.

Annexe A (normative)

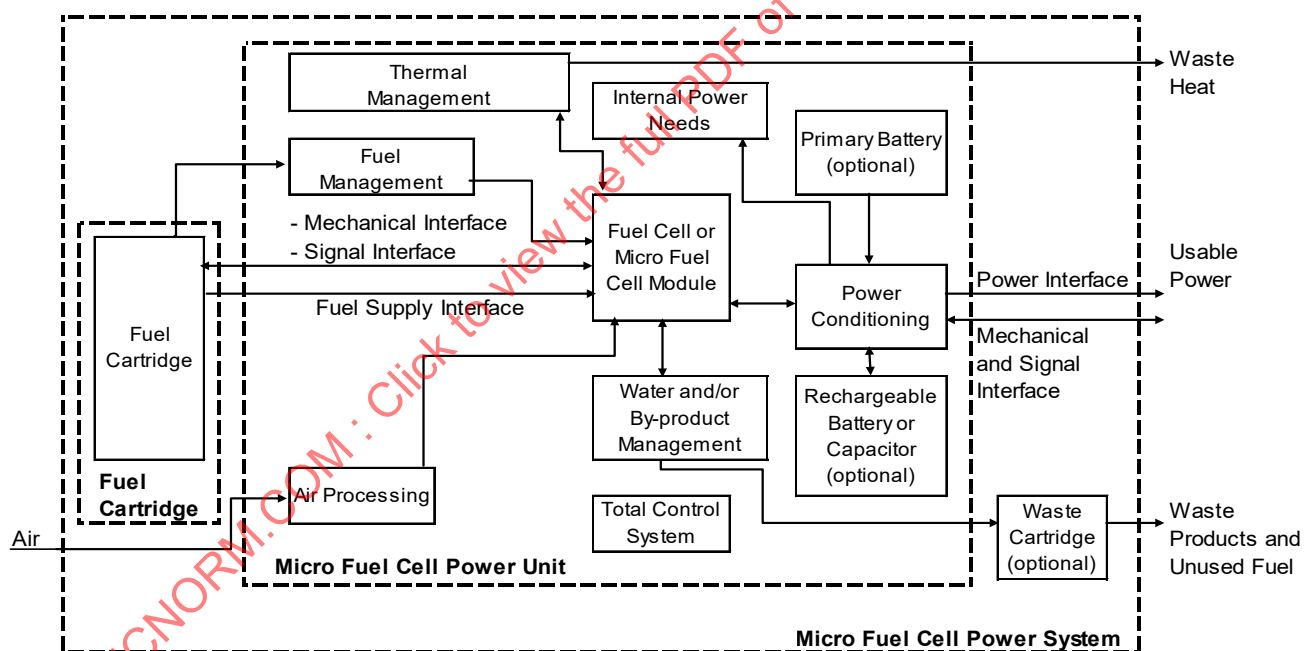
Systèmes à micropiles à combustible à l'acide formique

A.1 Domaine d'application

A.1.2 Combustibles et technologies traités dans la présente annexe

L'Annexe A traite des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible de l'acide formique en solutions aqueuses (à une concentration en acide formique inférieure à 85 % en poids). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à l'acide formique direct.

La Figure A.1 remplace la Figure 1 présentant un schéma de principe du système à micropile à combustible à l'acide formique à utiliser avec la présente annexe.



Anglais	Français
Air	Air
Air processing	Traitement de l'air
Fuel cartridge	Cartouche de combustible
Fuel cell or micro fuel cell module	Micropile à combustible ou module à micropiles à combustible
Water and/or by-product management	Gestion de l'eau et/ou des sous-produits
Fuel management	Gestion du combustible
Fuel supply interface	Interface de l'alimentation en combustible
Internal power needs	Besoins internes en énergie
Mechanical interface	Interface mécanique
Mechanical and signal interface	Interface mécanique et de signal

Anglais	Français
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de micropiles à combustible
Power conditioning	Conditionnement de l'énergie
Power interface	Interface de puissance
Primary battery (optional)	Pile électrique (facultatif)
Rechargeable battery or capacitor (optional)	Batterie rechargeable ou condensateur (facultatif)
Signal interface	Interface de signal
Thermal management	Gestion thermique
Total control system	Système global de commande
Usable power	Puissance utile
Waste cartridge (optional)	Cartouche usagée (facultatif)
Waste heat	Chaleur résiduelle
Waste products and unused fuel	Déchets et combustible inutilisé

Figure A.1 – Schéma de principe du système à micropile à combustible à l'acide formique – Remplace la Figure 1

A.1.3 Niveau de sécurité équivalent

Ce paragraphe remplace le 1.3.

- a) Les exigences de la présente norme ne sont pas destinées à limiter l'innovation. Le fabricant peut prendre en considération des combustibles, des matériaux, des conceptions ou des constructions qui ne sont pas spécifiquement traités dans la présente norme. Il convient d'évaluer ces alternatives selon leur aptitude à fournir des niveaux de sécurité équivalents à ceux définis dans la présente norme.
- b) Il est évident que tous les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible doivent être conformes aux exigences locales et nationales, y compris, entre autres, à celles relatives au transport, la protection des enfants, et le stockage, le cas échéant.
- c) Les ressemblances suivantes entre les systèmes à micropiles à combustible au méthanol et à l'acide formique sont présentées pour aider à mieux comprendre pourquoi les exigences relatives à l'acide formique sont semblables aux exigences relatives au méthanol avec le minimum de modifications.
 - 1) Les composants des systèmes à micropiles à combustible sont semblables (voir Figure 1 et Figure A.1).
 - 2) Les deux types de systèmes à micropiles à combustible utilisent des combustibles liquides et les deux systèmes à micropiles à combustible ont les critères «liquide non accessible» pour qu'il n'y ait pas de fuite (voir définitions à l'Article A.3).
 - 3) Les deux types de systèmes à micropiles à combustible peuvent avoir des composants à émissions gazeuses semblables, et doivent donc avoir des critères similaires pour le mesurage et l'analyse des émissions, et les mêmes considérations doivent être faites pour les niveaux de risques liés aux émissions.
 - 4) Les émissions de formaldéhyde et de formiate de méthyle rencontrées dans les systèmes à micropiles à combustible au méthanol ne sont pas présentes dans les systèmes à micropiles à combustible à acide formique. Les réactions théoriques avec l'acide formique et l'hydrogène peuvent produire du méthanol, du formiate de méthyle et du formaldéhyde, mais ces réactions ont des énergies d'activation très élevées, qui ne peuvent être atteintes qu'avec des combinaisons de températures élevées – typiquement supérieures à 200 °C), de pressions élevées – typiquement supérieures à 10 MPa – et en présence de catalyseurs d'hydrogénation tels que les oxydes des métaux de transition. Il n'est pas prévu de rencontrer ces conditions dans le système à micropile à combustible à acide formique, et par conséquent l'existence de ces trois

produits d'émission, à la suite de leur formation par une réaction de réduction, ne doit pas être prise en compte dans les systèmes à micropiles à combustible à l'acide formique. En raison des niveaux admissibles extrêmement faibles d'exposition humaine au formaldéhyde, le formaldéhyde est mesuré dans l'essai d'émission pour des besoins de validation.

- 5) Les émissions d'hydrogène et de dioxyde de carbone ne sont possibles que lorsque l'acide formique est exposé à des températures supérieures à 150 °C, ou lorsqu'il est en contact avec des catalyseurs de décomposition sans charge sur la pile à combustible. Il n'est pas prévu que les cartouches de combustible d'une micropile à combustible et les blocs d'alimentation électrique des micropiles à combustible à l'acide formique soient soumis à des températures si élevées. Les systèmes à micropiles à combustible à l'arrêt, mais fonctionnant correctement, doivent avoir des mécanismes à sûreté intégrée, pour empêcher un débit de combustible vers les catalyseurs. L'analyse des modes de défaillance et de leurs effets et les essais correspondants doivent assurer une protection contre des modes de défaillance de ce type et assurer l'existence de réductions de conception adaptées.
- 6) Étant donné que même avec le système à micropile à combustible à l'arrêt, des vapeurs de monoxyde de carbone et d'acide formique peuvent être produites à partir d'une cartouche de combustible à l'acide formique et d'un système à micropile à combustible, l'essai d'émission doit être effectué avec le système à micropile à combustible à l'arrêt (DISPOSITIF EN POSITION «OFF»), comme un essai supplémentaire.
- 7) Les vapeurs de dioxyde de carbone, de monoxyde de carbone, d'acide formique, d'hydrogène et d'eau sont toutes les émissions possibles qui peuvent provenir d'un système à micropile à combustible opérationnel (DISPOSITIF EN POSITION «ON»).
- 8) Un combustible à acide formique ayant une concentration inférieure à 85 % en poids est non inflammable; les avertissements concernant l'inflammabilité des combustibles ne s'appliquent donc pas aux systèmes à micropiles à combustible à acide formique.

A.3 Termes et définitions

Les termes et définitions ci-dessous remplacent les termes et définitions de l'Article 3 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe A. Tous les termes et définitions de l'Article 3 qui ne sont pas spécifiquement mentionnés ici s'appliquent aussi.

A.3.5

combustible

solution d'acide formique et d'eau ayant une concentration inférieure à 85 % d'acide formique en poids

A.3.8

combustible liquide dangereux (corrosif)

combustible à acide formique ayant un pH inférieur à 3,0 (un pH de 3,0 représente environ 0,35 % d'acide formique en poids dans l'eau)

A.3.10

réservoir interne

non applicable à la présente Annexe A

A.3.11

fuite

combustible liquide dangereux accessible à l'extérieur du système à micropile à combustible ou de la cartouche de combustible, ou indication de pH positive de l'acide formique liquide (voir A.3.37)

A.3.19**absence de perte de vapeur de combustible**

émission de combustible sous forme de vapeur provenant de la cartouche de combustible, du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible limitée à 0,018 g/h

Les termes supplémentaires et leurs définitions ci-dessous sont nécessaires pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe A en plus de ceux donnés dans l'Article A.3 et dans l'Article 3.

A.3.37**indication de pH positive de l'acide formique liquide**

indication positive de la présence d'acide (pH inférieur à 3,0) sur le papier pH (papier réactif acido-basique) fixé sur les zones de fuite possibles du système à micropile à combustible au cours de l'essai de type

A.3.38**dispositif**

soit le système à micropile à combustible (voir Figure A.1), soit un produit d'utilisateur final qui comporte un système à micropile à combustible comme son alimentation électrique

A.3.39**«DISPOSITIF EN POSITION «ON»»**

dispositif avec son interrupteur d'alimentation électrique en position «ON» et fonctionnant pour produire de l'énergie électrique ou incapable de produire de l'énergie électrique en raison d'une défaillance ou d'autres causes

A.3.40**«DISPOSITIF EN POSITION «OFF»»**

dispositif avec son interrupteur d'alimentation électrique en position «OFF» et ne produisant pas de l'énergie électrique.

A.4 Matériaux et construction des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible

A.4.12.1.3 *Cette exigence s'applique aux cartouches de combustible à l'acide formique et remplace l'exigence correspondante de 4.12.1.3. Toutes les autres exigences de l'Article 4 s'appliquent.*

Le volume maximal de combustible à l'acide formique dans la cartouche de combustible ne doit pas dépasser 1 l.

A.6 Instructions et avertissements pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible**A.6.2 Marquages minimaux exigés sur la cartouche de combustible**

Ces marquages remplacent les marquages exigés par le 6.2.

Au minimum, la cartouche de combustible doit porter les marquages suivants:

- a) CONTENU CORROSIF ET TOXIQUE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) GARDER HORS DE PORTÉE DES ENFANTS.
- d) NE PAS EXPOSER À DES TEMPERATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES.

- e) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- f) EN CAS D'INGESTION DE COMBUSTIBLE OU DE CONTACT AVEC LES YEUX, CONSULTER UN MÉDECIN.
- g) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT.
- h) COMPOSITION ET QUANTITÉ DE COMBUSTIBLE.
- i) TEXTE OU MARQUAGE INDIQUANT QUE LA CARTOUCHE DE COMBUSTIBLE EST CONFORME A L'IEC 62282-6-100.

A.6.3 Marquages minimaux exigés sur le système à micropile à combustible

Ces marquages remplacent les marquages exigés par le 6.3.

De plus, au minimum, le système à micropile à combustible doit également porter les marquages suivants:

- a) CONTENU CORROSIF ET TOXIQUE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) NE PAS EXPOSER À DES TEMPERATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES.
- d) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- e) EN CAS D'INGESTION DE COMBUSTIBLE OU DE CONTACT AVEC LES YEUX, CONSULTER UN MÉDECIN.
- f) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT
- g) COMPOSITION ET QUANTITÉ DE COMBUSTIBLE.
- h) CAPACITÉ MAXIMALE DE COMBUSTIBLE DANS LE RÉSERVOIR INTERNE, SI APPLICABLE.
- i) TEXTE OU MARQUAGE INDIQUANT QUE LE SYSTÈME À MICROPILE À COMBUSTIBLE EST CONFORME A L'IEC 62282-6-100.
- j) SORTIE ÉLECTRIQUE (TENSION, COURANT, PUISSANCE ASSIGNÉE).

A.7 Essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

A.7.1 Généralités

Ce paragraphe A.7.1 remplace le 7.1 pour la présente Annexe lors des essais relatifs aux systèmes à micropiles à combustible à l'acide formique, aux blocs d'alimentation électrique des micropiles à combustible à l'acide formique et aux cartouches de combustible à l'acide formique.

- a) Les essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible doivent permettre de vérifier que ces systèmes à micropiles à combustible, blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible sont sûrs pour une utilisation normale.
- b) Le Tableau A.5 énumère les essais de type qui doivent être effectués. *Le Tableau A.5 remplace le Tableau 5.*
- c) Sauf exigence explicite contraire dans cet article, les conditions de laboratoire sont spécifiées dans le Tableau A.6. *Le Tableau A.6 remplace le Tableau 6.*
- d) Le système à micropile à combustible, le bloc d'alimentation électrique de la micropile à combustible et/ou la cartouche de combustible doivent être conditionnés à une température de laboratoire normalisée de 22 °C ± 5 °C pendant au moins 3 h avant la réalisation de chaque essai.

- e) Avertissement: Ces essais de type utilisent des procédures qui peuvent entraîner des dommages si des précautions appropriées ne sont pas prises. Il convient que les essais ne soient effectués que par des techniciens qualifiés et expérimentés utilisant une protection appropriée.

Tableau A.5 – Liste des essais de type – Remplace le Tableau 5

Référence de l'essai	Entité d'essai	Échantillon d'essai
A.7.3.1	Essais de pression différentielle	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.2	Essai de vibrations	Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.3	Essai de cycles de températures	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.4	Essai d'exposition à température élevée	Cartouche de combustible Cartouche de combustible remplie partiellement
7.3.5	Essai de chute	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.6	Essai de charge de compression	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.7	Essai de court-circuit externe	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.8	Essai de température de surface, de composant et de gaz d'échappement	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
A.7.3.9	Essai de stockage de longue durée	Cartouche de combustible Cartouche de combustible remplie partiellement
7.3.10	Essai de connexion à température élevée	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible remplie partiellement et bloc d'alimentation électrique de la micropile à combustible
7.3.11	Essai de cycles de connexion	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible
A.7.3.12	Essai d'émission	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible

Le Tableau A.5 remplace le Tableau 5.

Échantillon d'essai: Le nombre d'échantillons doit être au moins de six (6) cartouches de combustible, neuves ou partiellement remplies, comme spécifié pour les essais individuels ci-dessus, ou au moins de trois (3) systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible pour chaque essai de type.

Séquence d'essai: Les essais 7.3.2 et 7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes cartouches de combustible. Les essais A.7.3.1, 7.3.2, et 7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes systèmes à micropile à combustible ou des mêmes blocs d'alimentation électrique de micropiles à combustible.

Réutilisation des échantillons: Les cartouches de combustible et les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible peuvent être réutilisés à l'initiative du fabricant, si ceci ne compromet pas l'essai individuel.

Tableau A.6 – Conditions normalisées de laboratoire – Remplace le Tableau 6

Élément	Condition
Température de laboratoire	La température de laboratoire est la «température ambiante» (condition de température normalisée, 22 °C ± 5 °C)
Atmosphère de la pièce du laboratoire; pour les essais du système à micropile à combustible et du bloc d'alimentation électrique de la micropile à combustible uniquement	L'atmosphère de la pièce du laboratoire ne contient pas plus de 0,2 % de dioxyde de carbone et pas plus de 0,002 % de monoxyde de carbone. L'atmosphère de la pièce du laboratoire contient au moins 18 %, mais pas plus de 21 %, d'oxygène.
Le Tableau A.6 remplace le Tableau 6.	

A.7.2 Mesurage des fuites d'acide formique et procédure de mesure

Ce paragraphe A.7.2 remplace le 7.2 pour la présente Annexe lors des essais relatifs aux systèmes à micropiles à combustible à l'acide formique, aux blocs d'alimentation électrique des micropiles à combustible à l'acide formique et aux cartouches de combustible à l'acide formique.

- a) *Le mesurage de la fuite d'acide formique doit être effectué en principe conformément aux procédures présentées dans les Figures A.2 à A.7. Ces figures et leurs procédures remplacent les figures correspondantes présentées en 7.2.*
- b) Comme outil supplémentaire de détection des fuites d'acide formique, le papier pH, fixé sur les zones de fuite possibles du système à micropile à combustible, doit être utilisé pour faciliter la vérification visuelle des fuites d'acide formique liquide (voir la définition "indication de pH positive de l'acide formique liquide"). Il s'agit d'une exigence supplémentaire dans l'Annexe A pour les piles à combustible à l'acide formique. Pour les essais opérationnels, il convient que les conduites d'air des produits réactifs vers le système à micropile à combustible et les orifices d'évacuation ne soient pas bloquées par le papier pH.

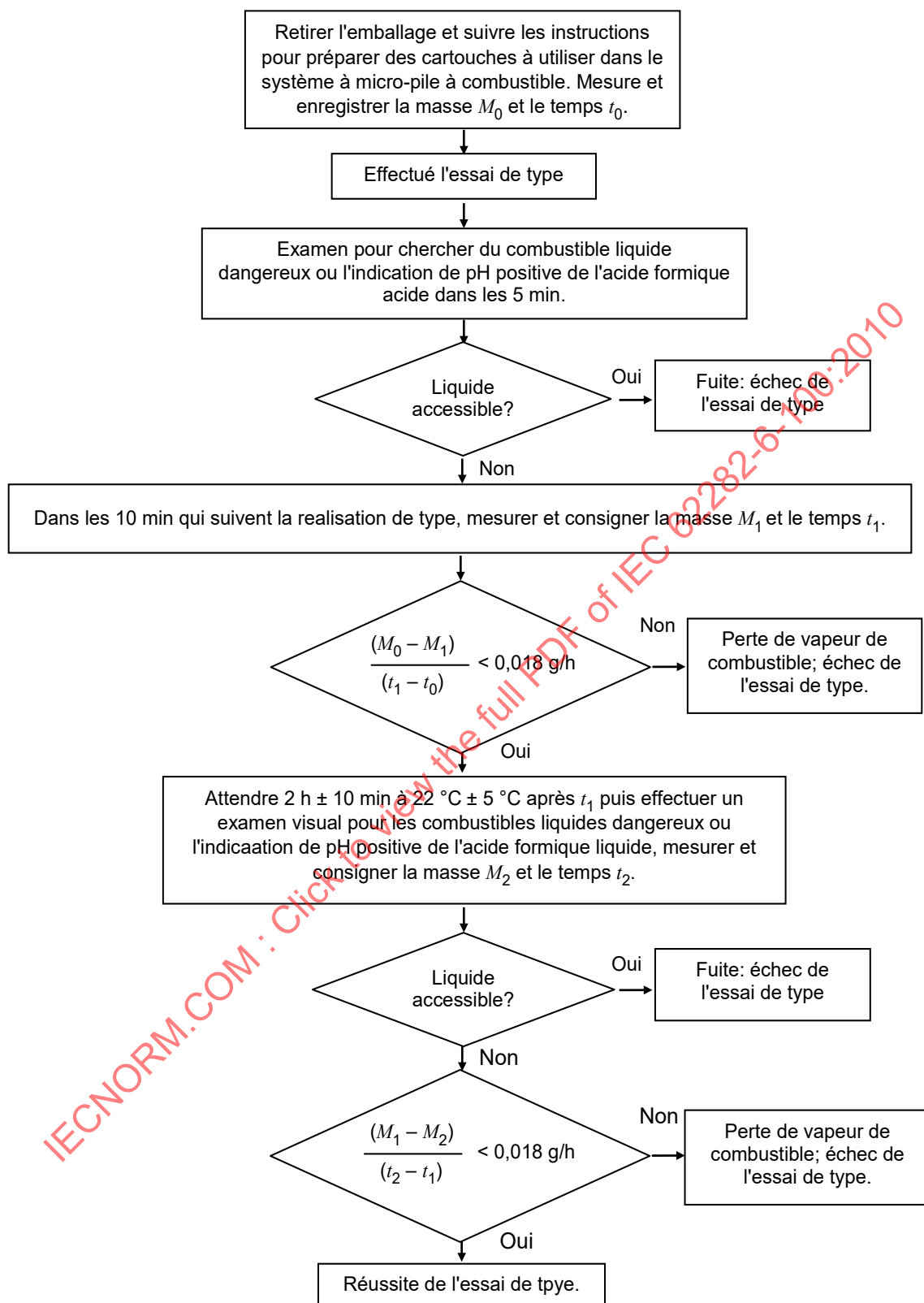


Figure A.2 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour les essais de pression différentielle, de vibrations, de chutes et de charge de compression – Remplace la Figure 2

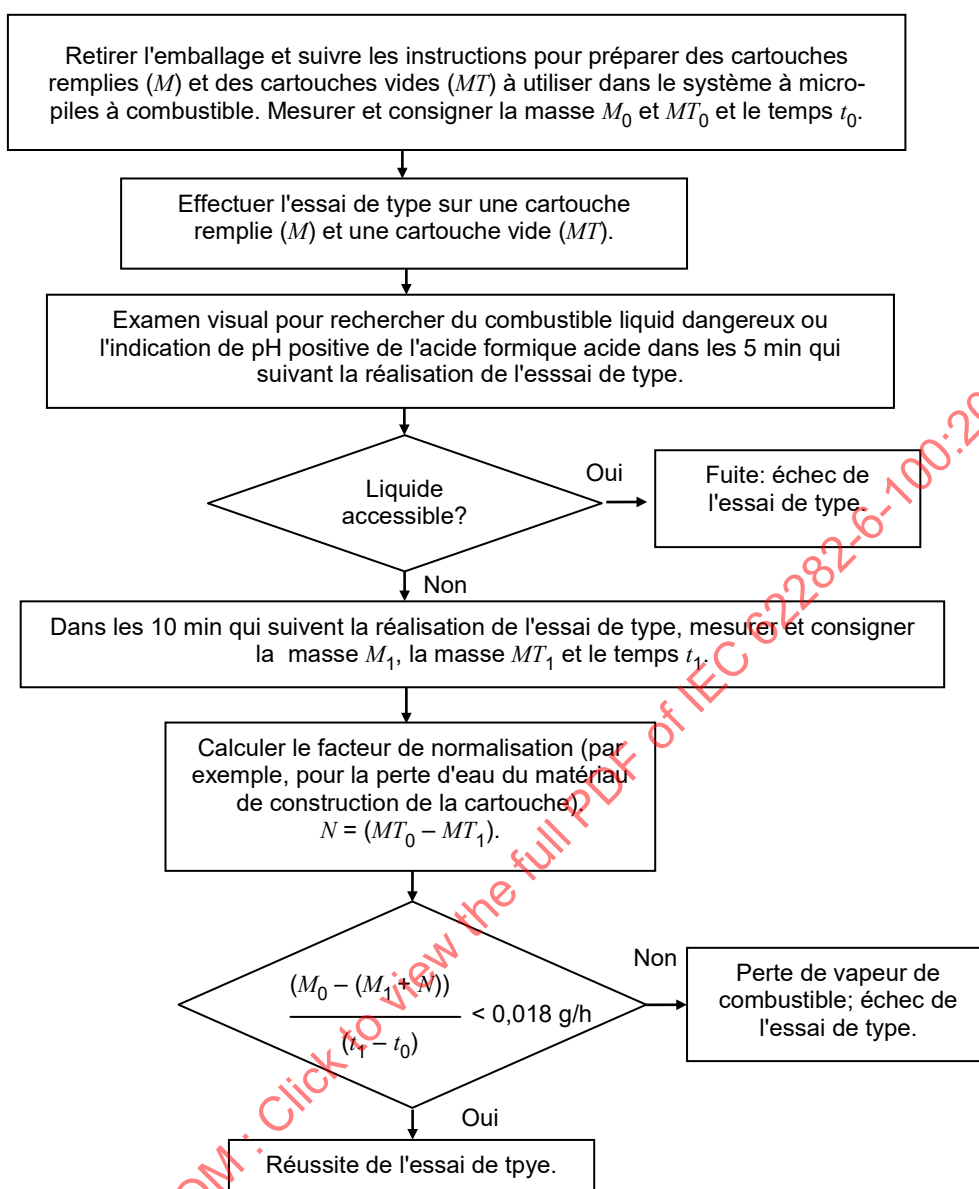


Figure A.3 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour l'essai de cycles de températures et l'essai d'exposition à température élevée – Remplace la Figure 3.

L'intervalle de temps maximal $t_1 - t_0$ doit être établi, de telle sorte que pas plus de la moitié du combustible ne soit perdue si la fuite de combustible se produisait au taux de perte de masse maximal admissible.

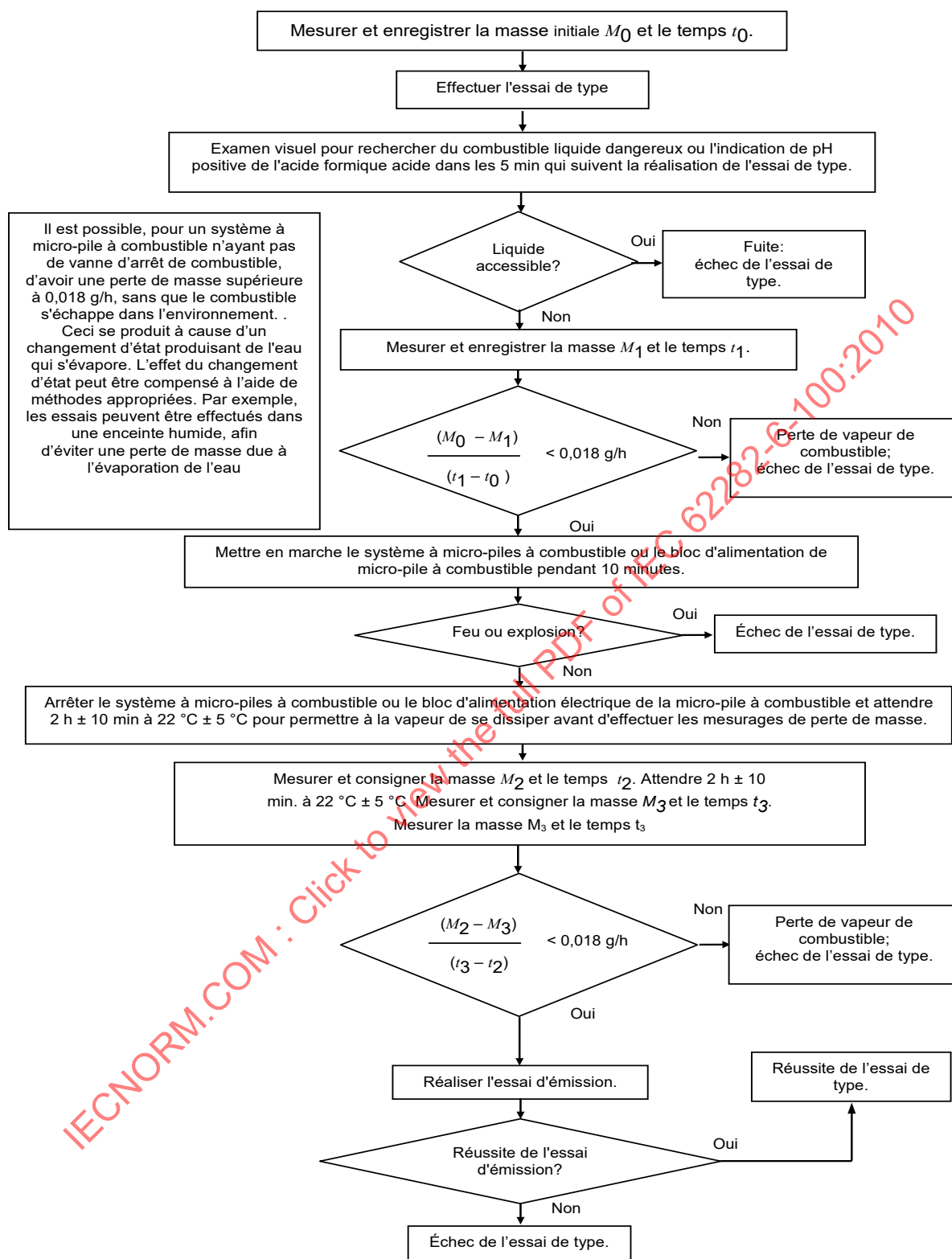


Figure A.4 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour les essais de pression différentielle, de vibrations, de cycles de température, de chute et de charge de compression – Remplace la Figure 4.

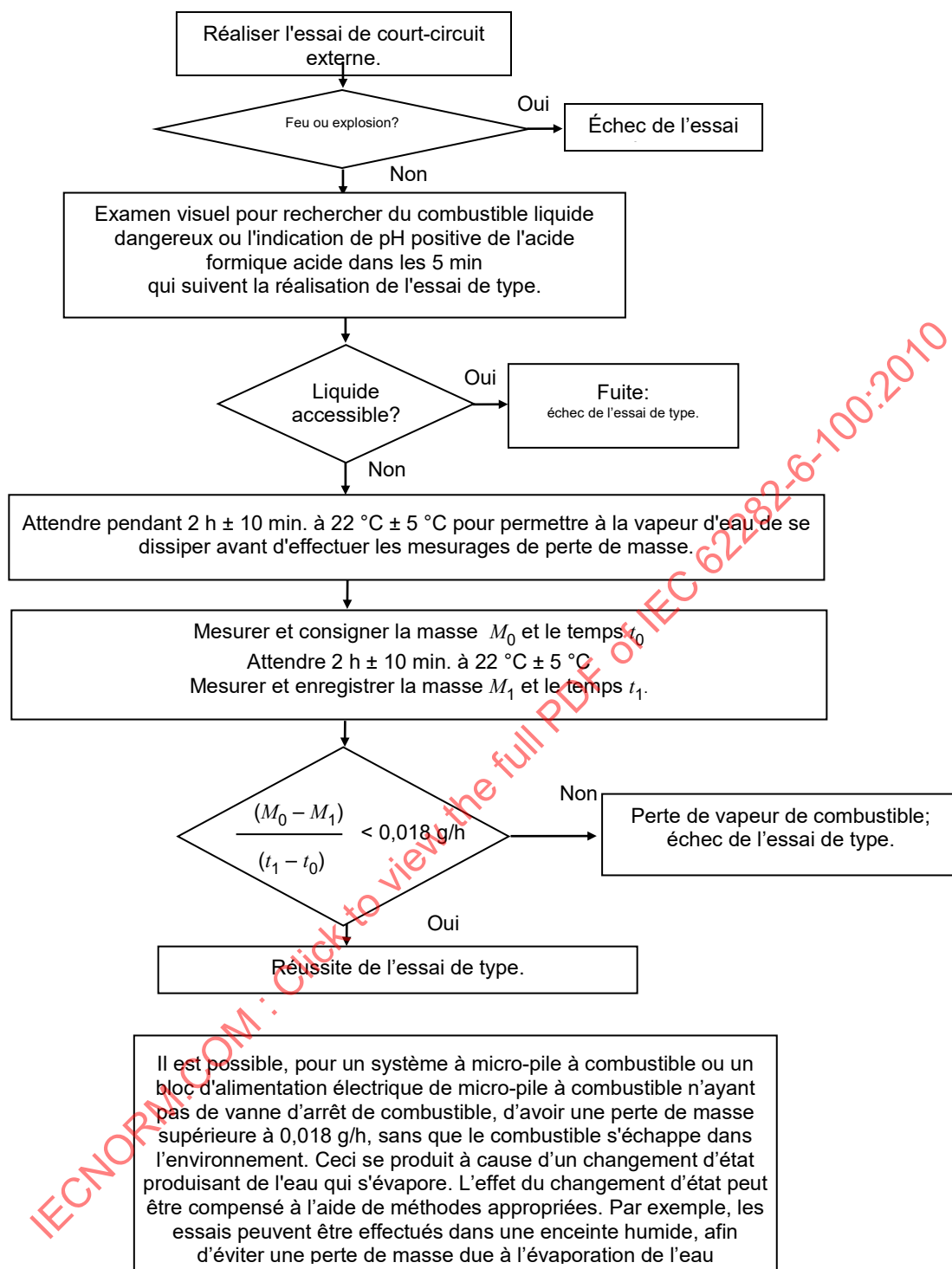


Figure A.5 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai de court-circuit externe – Remplace l'essai de court-circuit de la Figure 5.

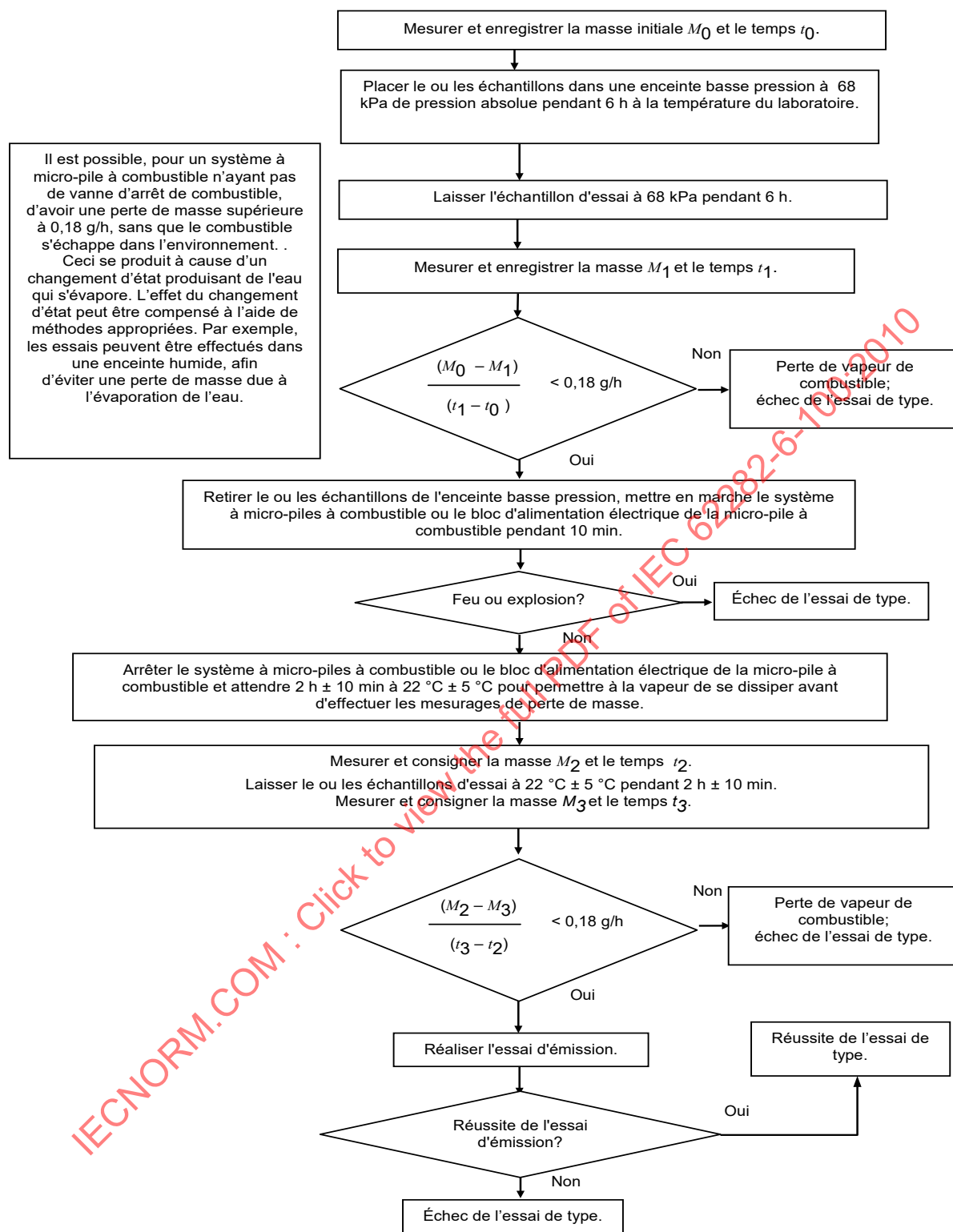


Figure A.6 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai à basse pression externe à 68 kPa – Remplace la Figure 6.

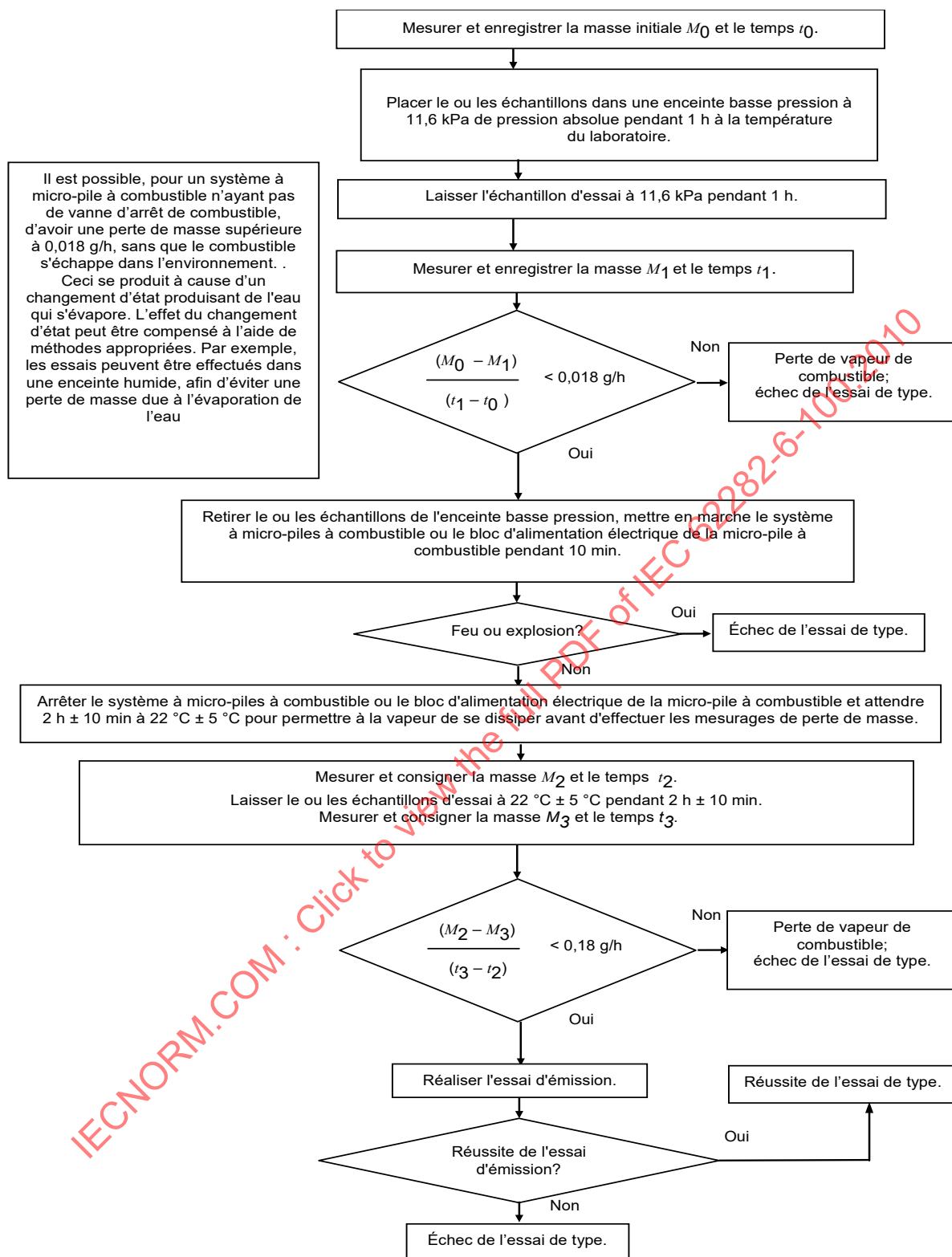


Figure A.7 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai à basse pression externe à 11,6 kPa – Remplace la Figure 7.

A.7.3 Essais de type

A.7.3.1 Essais de pression différentielle

A.7.3.1.1 Généralités

Le paragraphe A.7.3.1 remplace le 7.3.1.

Certaines parties de cet essai sont conformes à 4.12.1.2 utilisé pour confirmer qu'il ne doit pas y avoir de fuite au niveau de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. Deux options d'essai sont proposées, en fonction des conditions de pression de limite donnant la valeur la plus élevée:

- a) Si la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C donne une valeur supérieure à deux fois la pression manométrique de la cartouche de combustible à 55 °C, le A.7.3.1.2 ou le A.7.3.1.3 peut être utilisé pour vérifier la conformité à 4.12.1.2.
- b) Si deux fois la pression manométrique de la cartouche de combustible à 55 °C donne une valeur supérieure à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, le A.7.3.1.2 doit être utilisé pour vérifier la conformité à 4.12.1.2.

A.7.3.1.2 Essai de mise sous pression interne de la cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement et vanne de la cartouche de combustible.
- b) **Objet:** simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**

Pour l'essai de mise sous pression interne, le corps de la cartouche de combustible et la vanne de la cartouche de combustible doivent être soumis à l'essai séparément.

- 1) À l'aide d'un milieu liquide adapté comme l'eau, mettre sous pression le corps de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée.
 - 2) L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
 - 3) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
 - 4) À l'aide d'un milieu liquide adapté comme l'eau, mettre sous pression la vanne fermée de la cartouche de combustible à une pression égale soit à la pression manométrique de 95 kPa plus la pression normale de service à 22 °C de la cartouche, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée.
 - 5) L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
 - 6) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
- d) **Critères de réussite:** Aucune fuite du milieu d'essai liquide accessible et aucune chute soudaine de pression au cours de l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et la vanne de la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue.

A.7.3.1.3 Essai de la cartouche de combustible à basse pression externe

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** Simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer cet essai conformément à la Figure A.2.
 - 2) L'échantillon doit être placé dans une chambre à vide, et la pression dans la chambre à vide doit être réduite à 95 kPa en dessous de la pression atmosphérique normale.
 - 3) Maintenir le vide pendant 30 min.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible ni aucune perte de vapeur de combustible. Voir la Figure A.2. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. La présence de feu ou de flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

A.7.3.1.4 Essais de pression différentielle du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible**A.7.3.1.4.1 Essai à basse pression externe à 68 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible**

Cet essai est exigé pour tous les systèmes à piles à combustible à l'acide formique et tous les blocs d'alimentation électrique des micropiles à combustible à l'acide formique.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure A.6.
 - 2) Les échantillons d'essai doivent être stockés à basse pression externe à 68 kPa de pression absolue pendant 6 h à la température ambiante du laboratoire. La fuite doit être mesurée d'après la procédure décrite à la Figure A.6.
 - 3) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à A.7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible ni aucune perte de vapeur de combustible. Voir la Figure A.6. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. L'essai d'émission doit satisfaire aux critères de réussite de A.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais que les émissions ne dépassent pas les limites fixées en 7.3.12, le résultat de l'essai d'émission est acceptable. Pendant l'essai de 6 h à 68 kPa de pression externe absolue, la perte de vapeur de combustible doit être inférieure à 0,018 g/h.

A.7.3.1.4.2 Essai à basse pression externe à 11,6 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

Cet essai est exigé pour tous les systèmes à piles à combustible à l'acide formique et tous les blocs d'alimentation électrique des micropiles à combustible à l'acide formique.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure A.7.
 - 2) Les échantillons d'essai doivent alors être stockés à basse pression externe à 11,6 kPa de pression absolue pendant 1 h à la température ambiante du laboratoire. La fuite doit être mesurée en se basant sur la procédure décrite à la Figure 7, avec pour critère de réussite OUI/NON une perte de vapeur de combustible à 11,6 kPa inférieure à 0,018 g/h en ne dépassant pas 25 % de la limite inférieure d'inflammabilité (LII).
 - 3) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à A.7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible ni aucune perte de vapeur de combustible. Voir la Figure A.7. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. L'essai d'émission doit satisfaire aux critères de réussite de A.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de A.7.3.12, le résultat de l'essai d'émission est acceptable. Pendant l'essai de 1 h à 11,6 kPa de pression externe absolue, la perte de vapeur de combustible doit être inférieure à 0,018 g/h.

A.7.3.9 Essai de stockage de longue durée

A.7.3.9.1 Généralités

Le A.7.3.9 remplace le 7.3.9 pour les essais des cartouches de combustible à l'acide formique dans la présente Annexe A. La Figure A.9, incluse ici, remplace la Figure 9 pour la présente Annexe A.

- a) Il est permis d'utiliser soit A.7.3.9.2 Option 1 – Mesurage du poids en continu, A.7.3.9.3 Option 2 – Mesurages périodiques, soit A.7.3.9.4 Option 3 – Un seul mesurage du poids.
- b) Si les résultats de cet essai ne satisfont pas à la limite de 0,018 g/h pour la perte de vapeur combustible, un essai d'émission complet (A.7.3.12) doit alors être effectué en situation cartouche de combustible uniquement à 50 °C dans le volume 1 m³ ACH, toutes les composantes d'émission étant mesurées. Les limites en situation de «DISPOSITIF EN POSITION «OFF»» données dans le Tableau A.7 doivent être satisfaites.

A.7.3.9.2 Option 1 – Mesurage du poids en continu

L'option 1 n'est pas préférentielle pour les cartouches de combustible à l'acide formique en raison de la perte de vapeur de combustible anticipée très faible.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai** (Voir Figure A.9):

- 1) Utiliser un dynamomètre (dispositif de pesage électronique continu) conçu et étalonné pour une utilisation à 50 °C à l'intérieur de l'enceinte de température.
- 2) Placer le dynamomètre dans une enceinte de température à 50 °C ± 2 °C. Placer la cartouche de combustible sur la partie supérieure du dynamomètre, de sorte que toute la masse soit appliquée sur le dynamomètre. Un dispositif de fixation peut être utilisé pour contrôler la position de la cartouche de combustible, pour garantir que toute la masse est appliquée sur le dynamomètre.
- 3) Connecter un affichage numérique sur le dynamomètre et collecter les données manuellement ou automatiquement. Il convient de collecter les données avec un degré de confiance élevé, pour assurer que la perte de vapeur de combustible ne dépasse pas 0,018 g/h.
- 4) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
- 5) L'échantillon doit rester dans l'enceinte d'essai de température à 50 °C ± 2 °C pendant au moins 28 jours.
- 6) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,018 g/h, l'échantillon d'essai subit alors avec succès l'essai de perte de vapeur de combustible.

$$\text{i) Perte de vapeur de combustible} = \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initiale}} = \text{masse initiale de la cartouche de combustible.}$$

$$\text{iv) } M_{\text{finale}} = \text{masse finale de la cartouche de combustible.}$$

- 7) Si la cartouche de combustible est vide avant la fin de l'essai, le taux de perte de masse doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que la cartouche de combustible ne soit vide. L'essai est réussi si la perte de vapeur de combustible est inférieure 0,018 g/h.

$$\text{i) Perte de vapeur de combustible} = \frac{M_{\text{initiale}} - M_{\text{dernière}}}{\Delta t_{\text{dernier}}}$$

$$\text{ii) } \Delta t_{\text{dernier}} = \text{le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.}$$

$$\text{iii) } M_{\text{initiale}} = \text{masse initiale de la cartouche de combustible.}$$

$$\text{iv) } M_{\text{dernière}} = \text{le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.}$$

- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible et aucune fuite de liquide. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure A.9. Si la perte de vapeur de combustible de la cartouche de combustible n'est pas inférieure à 0,018 g/h, alors l'échantillon d'essai échoue à l'essai.

La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

Si les résultats de cet essai ne satisfont pas à la limite de 0,018 g/h pour la perte de vapeur de combustible, un essai d'émission complet (A.7.3.12) doit alors être effectué en situation cartouche de combustible uniquement à 50 °C dans le volume 1 m³ ACH, toutes les composantes d'émission étant mesurées. Les limites en situation de «DISPOSITIF EN POSITION «OFF»» données dans le Tableau A.7 doivent être satisfaites.

A.7.3.9.3 Option 2 – Mesurages périodiques du poids

L'option 2 est préférentielle pour les cartouches de pile à combustible à l'acide formique.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai** (Voir Figure A.9):
 - 1) Placer la cartouche de combustible dans une enceinte de température à 50 °C ± 2 °C. Il convient de recueillir les mesurages du poids avec un degré de confiance élevé, afin de déterminer si la perte de vapeur de combustible ne dépasse pas 0,018 g/h, avec une fréquence minimale d'une fois tous les trois jours.
 - 2) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
 - 3) L'échantillon doit rester dans l'enceinte d'essai de température à 50 °C ± 2 °C pendant au moins 28 jours.
 - 4) La durée pendant laquelle les échantillons d'essai sont retirés de l'enceinte pour le mesurage ne doit pas être incluse dans la durée pendant laquelle l'échantillon d'essai doit être soumis à l'essai (28 jours). Il convient d'ajouter une durée supplémentaire pour que l'échantillon d'essai soit à la température d'essai (50 °C ± 2 °C), à chaque fois que l'échantillon d'essai est retiré de l'enceinte. Il convient que les échantillons d'essai ne soient stabilisés à la température ambiante du laboratoire que si la perte de masse est affectée.
 - 5) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,018 g/h, l'échantillon d'essai subit alors avec succès l'essai de perte de vapeur de combustible.
 - i) Perte de vapeur de combustible
$$= \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$$
 - ii) $\Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h}$.
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) M_{finale} = masse finale de la cartouche de combustible.
 - 6) Si la cartouche de combustible est vide avant la fin de l'essai, le taux de perte de masse doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que la cartouche de combustible ne soit vide. L'essai est réussi si la perte de vapeur de combustible est inférieure 0,018 g/h.
 - i) Perte de vapeur de combustible
$$= \frac{M_{\text{initiale}} - M_{\text{dernière}}}{\Delta t_{\text{dernier}}}$$

- ii) $\Delta t_{\text{dernier}}$ = le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) $M_{\text{dernière}}$ = le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, aucune perte de vapeur de combustible et aucune fuite de liquide. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure A.9. Si le taux de perte de vapeur de combustible de la cartouche de combustible n'est pas inférieur aux critères de 0,018 g/h de perte de vapeur de combustible, alors l'échantillon d'essai échoue à l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

Si les résultats de cet essai ne satisfont pas à la limite de 0,018 g/h pour la perte de vapeur de combustible, un essai d'émission complet (A.7.3.12) doit alors être effectué en situation cartouche de combustible uniquement à 50 °C dans le volume 1 m³ ACH, toutes les composantes d'émission étant mesurées. Les limites en situation de «DISPOSITIF EN POSITION «OFF»» données dans le Tableau A.7 doivent être satisfaites.

A.7.3.9.4 Option 3 – Un seul mesurage du poids

Cette option est destinée aux cartouches de combustible avec des taux de fuite très faibles. L'option 3 peut aussi être utilisée pour les cartouches de combustible à l'acide formique avec des taux de fuite très faibles.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai** (Voir Figure A.9):
 - 1) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
 - 2) Placer les cartouches de combustible dans une enceinte de température à 50 °C ± 2 °C. Après 28 jours, les cartouches de combustible sont retirées de l'enceinte pour le mesurage. Il convient que les échantillons d'essai soient stabilisés à la température ambiante du laboratoire si la perte de masse est affectée. Le mesurage de la masse est ensuite effectué.
 - 3) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,018 g/h, l'échantillon d'essai subit alors avec succès l'essai de perte de vapeur de combustible.

i) Perte de vapeur de combustible $= \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$

ii) $\Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h}$.

iii) M_{initiale} = masse initiale de la cartouche de combustible.

iv) M_{finale} = masse finale de la cartouche de combustible.

- 4) Si la cartouche de combustible est vide après 28 jours, alors l'essai de type conformément à A.7.3.9.2 Option 1 ou A.7.3.9.3 Option 2 doit être effectué.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible et aucune fuite de liquide. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure A.9. Si la perte de vapeur de combustible de la cartouche de combustible est inférieure aux critères de 0,018 g/h de perte de vapeur de combustible, alors l'échantillon d'essai satisfait à l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

Si les résultats de cet essai ne satisfont pas à la limite de 0,018 g/h pour la perte de vapeur de combustible, un essai d'émission complet (A.7.3.12) doit alors être effectué en situation cartouche de combustible uniquement à 50 °C dans le volume 1 m³ ACH, toutes les composantes d'émission étant mesurées. Les limites en situation de «DISPOSITIF EN POSITION «OFF»» données dans le Tableau A.7 doivent être satisfaites.

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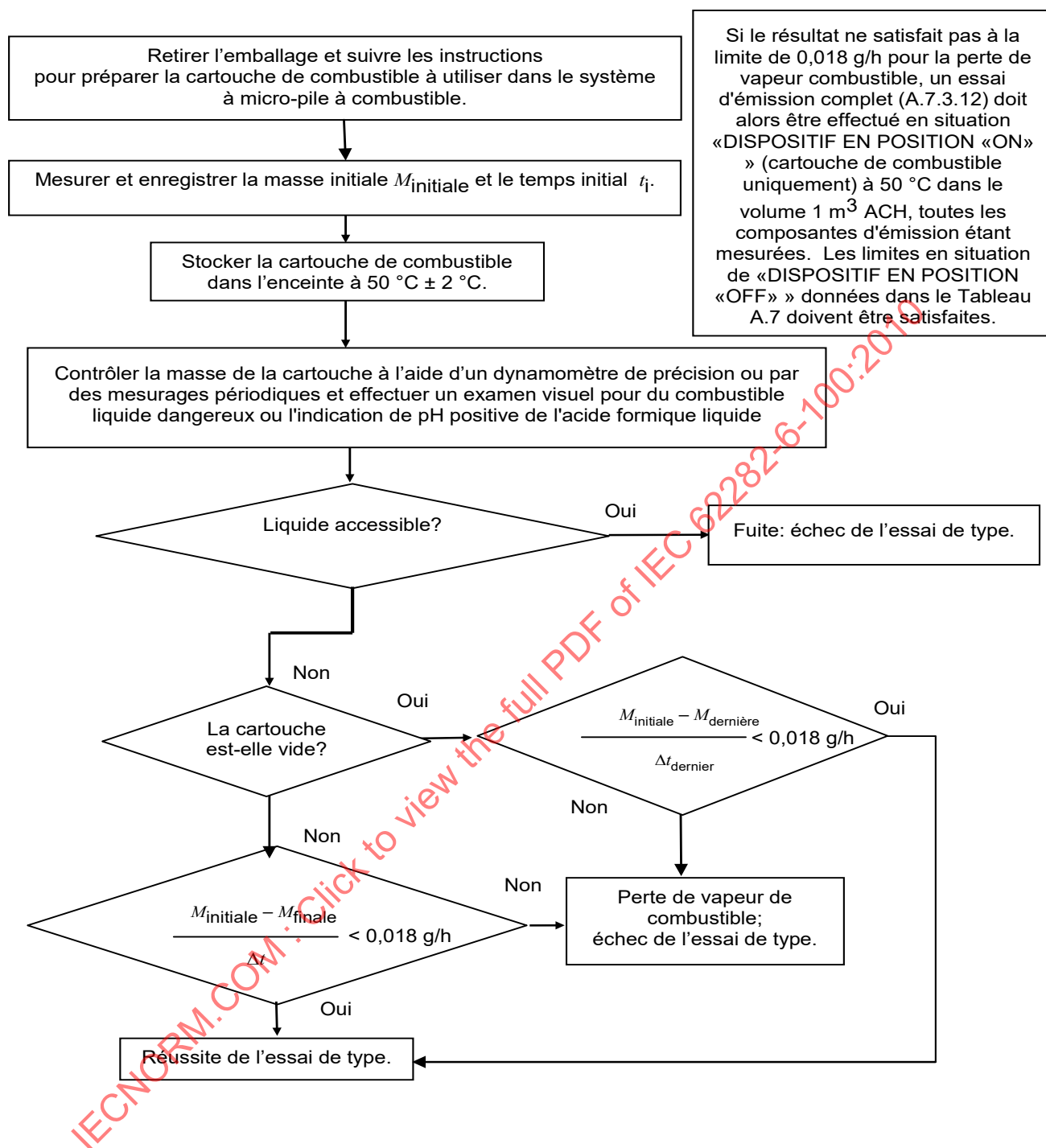


Figure A.9 – Diagramme de fuite de la cartouche de combustible et de perte de masse pour l'essai de stockage de longue durée – Remplace la Figure 9

NOTE La limite de concentration moyenne pondérée dans le temps (TWA – *time weighted average*) sur huit heures pour le monoxyde de carbone est de 25 ppmv². La limite d'exposition à court terme (STEL – *short term exposure limit*) sur quinze minutes pour le monoxyde de carbone est de 200 ppmv. En raison du taux de décomposition extrêmement faible de l'acide formique par rapport au monoxyde de carbone à 50 °C et de la limite d'exposition humaine au monoxyde de carbone qui est supérieure à la limite d'exposition à l'acide formique (TWA = 5 ppmv et STEL = 10 ppmv), l'hypothèse selon laquelle toute la perte de masse dans cet essai concerne l'acide formique rend cette évaluation plus satisfaisante. Si le résultat ne satisfait pas à la limite de 0,018 g/h pour la perte de vapeur de combustible, un essai d'émission complet (A.7.3.12) est autorisé.

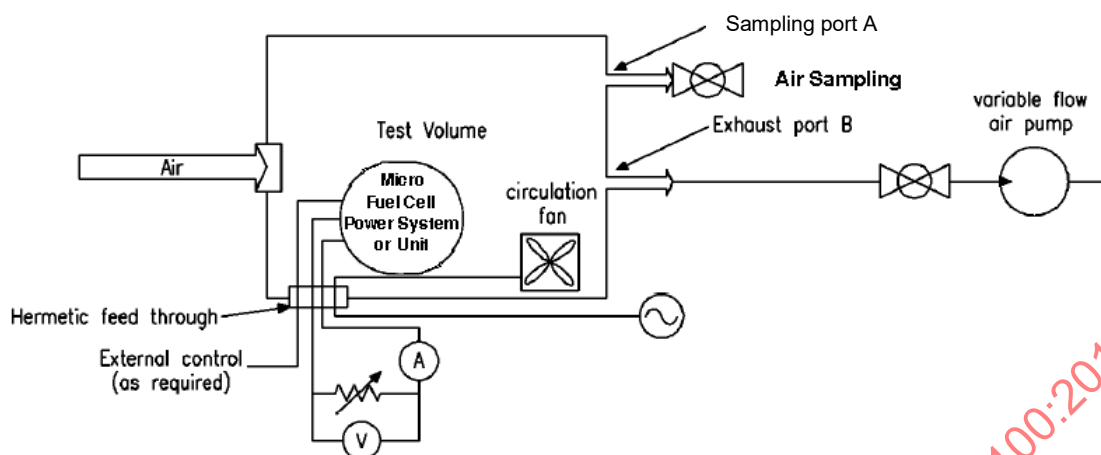
²) ppmv = parties par million en volume.

A.7.3.12 Essai d'émission

Ce paragraphe A.7.3.12 doit remplacer le 7.3.12 pour les systèmes à micropiles à combustible à l'acide formique ou les blocs d'alimentation électrique de pile à combustible à l'acide formique soumis à l'essai conformément à l'Annexe A. Le Tableau A.7, Limites d'émission, inclus remplace le Tableau 7 de 7.3.12. Le nouveau Tableau A.8 supplémentaire, Limites d'exposition en milieu professionnel, est fourni pour donner à l'utilisateur des informations relatives aux limites d'exposition. La Figure A.10 remplace la Figure 10 et lui est identique. Les émissions d'hydrogène sont évaluées séparément. La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure A.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe A.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) du système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible – qui est alimenté en méthanol – les émissions de vapeurs d'acide formique, de dioxyde de carbone (de monoxyde de carbone, de formaldéhyde, d'hydrogène et de vapeur d'eau doivent être maintenues à un niveau inférieur aux valeurs spécifiées. Le fait de maintenir ces limites empêche non seulement une exposition déconseillée, mais garantit aussi le maintien d'une alimentation adéquate en oxygène dans l'environnement de fonctionnement.

Étant donné que même avec le système à micropile à combustible à l'arrêt, des vapeurs de monoxyde de carbone et d'acide formique peuvent être produites à partir d'une cartouche de combustible à l'acide formique et d'un système à micropile à combustible, l'essai d'émission doit aussi être réalisé avec le système à micropile à combustible à l'arrêt (DISPOSITIF EN POSITION «OFF»), comme un essai supplémentaire. Le monoxyde de carbone et les vapeurs d'acide formique doivent être maintenus en dessous des limites en situation de «DISPOSITIF EN POSITION «OFF»» données pour éviter les expositions nocives.

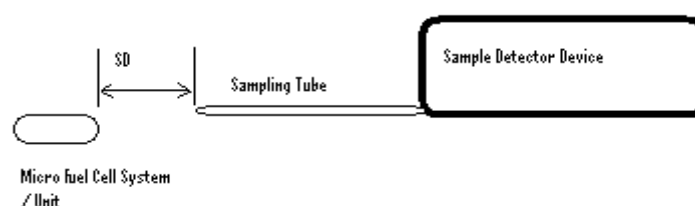


Anglais	Français
Sampling port	Orifice d'échantillonnage
Test volume	Volume d'essai
Micro fuel cell power system or unit	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Circulation fan	Ventilateur de brassage
Hermetic feed through	Passage hermétique
External control (as required)	Commande extérieure (si exigée)
Air sampling	Échantillonnage de l'air
Exhaust port B	Orifice d'évacuation B
Variable flow air pump	Pompe à air à débit variable

Figure A.10 – Appareillage d'essai du taux d'émission opérationnel – Remplace la Figure 10

- c) **Appareillage d'essai:** Un exemple d'appareillage d'essai d'émission opérationnel est représenté à la Figure A.10. La configuration représentée à la Figure A.10 sert aux essais de taux d'émission de tous les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe A. Les essais de taux d'émission conformes à A.7.3.12 d) 1) sont exigés pour tous les types de systèmes à micropiles à combustible et de blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe A.

Pour les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur (tels que les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible utilisés pour alimenter des téléphones cellulaires, des jeux tenus à la main, etc.), des essais complémentaires conformes à A.7.3.12 d) 3) et A.7.3.12 d) 4) sont exigés pour vérifier que les concentrations des émissions dans le voisinage de la bouche ou du nez d'un utilisateur sont maintenues dans des limites appropriées. Ces essais de concentrations d'émissions doivent être réalisés dans une grande salle ouverte en utilisant un appareillage d'essai de concentration d'émission différent. Un exemple d'appareillage d'essai de la concentration d'émission opérationnel est représenté à la Figure A.11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé) pour les essais de la limite de concentration des émissions.



Anglais	Français
Sampling tube	Tube d'échantillonnage
Sample detector device	Dispositif de détection d'échantillon
Micro fuel cell system/unit	Système à micropile à combustible / bloc d'alimentation de la micropile à combustible

Figure A.11 – Appareillage d'essai de concentration d'émission opérationnel – Remplace la Figure 11

Les gaz d'émission peuvent être composés de matières organiques toxiques, telles que les vapeurs d'acide formique, le dioxyde de carbone, le monoxyde de carbone et le formaldéhyde, qui peuvent être évacuées d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible.

Pour analyser ces matières organiques, un chromatographe en phase gazeuse avec un détecteur à ionisation de flamme (GC/FID, gas chromatograph/flame ionization detector) ou avec un spectromètre de masse (GC/MS, gas chromatograph/mass spectrometer) doivent être utilisés en absorbant les gaz d'émission sur le tube à adsorption fixé sur l'orifice d'échantillonnage A de l'enceinte d'essai, ou directement sur un analyseur à travers l'orifice d'échantillonnage A de la Figure 10. Toutefois, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus.

Un détecteur d'hydrogène étalonné pour la plage de concentration massique d'hydrogène de 0 % à 1 %, peut être utilisé pour mesurer la concentration d'hydrogène.

La concentration de CO et de CO₂ peut être mesurée par un analyseur à absorption infrarouge non dispersif. Ces appareils de mesure analytiques doivent être conformes à l'ISO 16000-3, à l'ISO 16000-6 et à l'ISO 16017-1. Cependant, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus, en utilisant les normes mentionnées ci-dessus.

d) Procédure d'essai:

Les émissions d'hydrogène sont évaluées séparément. *La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure A.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe A.*

Les essais d'échantillonnage de taux d'émission doivent être effectués tant avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») qu'avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») comme suit:

- 1) Pour tous les systèmes à micropiles à combustible et les blocs d'alimentation électrique de micropiles à combustible – aussi bien ceux destinés à être utilisés très près de la bouche ou du nez d'un consommateur que ceux qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur – l'essai suivant d'échantillonnage du taux d'émission doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit.

- i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure A.10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
- ii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- iii) Les émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure A.10.
- iv) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
- v) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure A.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
- vi) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau A.7.
- vii) Calculer le taux d'émission des composés chimiques concernés émis en multipliant la concentration stabilisée maximale de chaque constituant par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit en régime établi de la pompe à air à débit variable à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux d'émission.

Voir ci-dessous:

$$ER = (F_p + F_s) \times C$$

ou

$$ER = (F_i) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_p est le débit de la pompe à air à débit variable en litres normalisés par heure;

F_s est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre normalisé;

- viii) Comparer le taux d'émission (DISPOSITIF EN POSITION «ON») mesuré maximal par rapport au Tableau A.7. Si le taux d'émission n'est pas inférieur à la limite de taux d'émission dans le Tableau A.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite A.7.3.12 e) 1) i) et A.7.3.12 e) 2) i).

- ix) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 2) Pour tous les systèmes à micropiles à combustible et les blocs d'alimentation électrique de micropiles à combustible – aussi bien ceux destinés à être utilisés très près de la bouche ou du nez d'un consommateur que ceux qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur – l'essai suivant d'échantillonnage du taux d'émission doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») comme suit.
- i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure A.10 pendant une durée de 10 min ou pendant la durée jusqu'à l'instant où 10 % de la pleine capacité en combustible d'une cartouche de combustible pleine ont été consommés, en prenant la plus courte des deux durées.
 - ii) Mettre le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») et mesurer les taux d'émission avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») à l'intérieur de la petite enceinte d'essai représentée à la Figure A.10.
 - iii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
 - iv) Les émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure 10.
 - v) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
 - vi) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure A.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
 - vii) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau A.7.
 - viii) Calculer le taux d'émission des composés chimiques émis en multipliant la concentration stabilisée maximale de chaque constituant par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit en régime établi de la pompe à air à débit variable à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux d'émission.

Voir ci-dessous:

$$ER = (F_P + F_S) \times C$$

ou

$$ER = (F_i) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre normalisé;

- ix) Comparer le taux d'émission [DISPOSITIF EN POSITION «OFF»] mesuré maximal par rapport au Tableau A.7. Si le taux d'émission n'est pas inférieur à la limite de taux d'émission dans le Tableau A.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite A.7.3.12 e) 1) i) et A.7.3.12 e) 2) i).
 - x) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 3) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur, l'essai complémentaire suivant d'échantillonnage de concentration d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit:
- i) Les essais de taux d'émission des systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible doivent être réalisés dans une grande salle ouverte. L'intention de cet essai est d'approcher et de mesurer la concentration d'émission attendue près de la bouche ou du nez d'une personne en air calme. Un mannequin ou autre simulateur peut être utilisé pour améliorer la précision de l'essai. L'air à l'intérieur de la salle doit être échantillonné avant les essais afin d'assurer la précision et éviter les résultats erronés non conformes. Veiller à s'assurer que les matières dans la salle ou dans le système d'échantillonnage n'apportent pas d'émissions (c'est-à-dire, de contaminants) à l'essai. Avant les essais, il est recommandé de rechercher les traces de contamination dans le système sans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, pour éviter les résultats erronés non conformes. Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
 - ii) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à la puissance assignée dans la grande salle ouverte lors de l'échantillonnage de concentrations d'émissions à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure A.11. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai de concentration d'émission doit être effectué avec le

- système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible, et avec l'interrupteur d'alimentation électrique en position «ON».
- iii) Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
 - iv) Les concentrations des émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être échantillonnées à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure A.11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé).
 - v) La vitesse d'échantillonnage pour les mesurages de concentration d'émission très près doit être de 5 l par minute, ce qui représente la vitesse de respiration d'un être humain adulte.
 - vi) Laisser le débit d'échantillon se stabiliser.
 - vii) Échantillonner et enregistrer les émissions gazeuses du système à pile à combustible ou du bloc d'alimentation électrique de la pile à combustible qui se produisent à une distance représentative de la zone de respiration d'un consommateur.
 - viii) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau A.7.
 - ix) Comparer les concentrations stabilisées maximales avec le Tableau A.7. Si les concentrations d'émission ne sont pas inférieures aux limites de concentration d'émission dans le Tableau A.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite A.7.3.12 e) 2) ii).
 - x) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 4) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur, l'essai complémentaire suivant d'échantillonnage de concentration d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») comme suit:
- i) Les essais de taux d'émission des systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible doivent être réalisés dans une grande salle ouverte. L'intention de cet essai est d'approcher et de mesurer la concentration d'émission attendue près de la bouche ou du nez d'une personne en air calme. Un mannequin ou autre simulateur peut être utilisé pour améliorer la précision de l'essai. L'air à l'intérieur de la salle doit être échantillonné avant les essais afin d'assurer la précision et éviter les résultats erronés non conformes. Veiller à s'assurer que les matières dans la salle ou dans le système d'échantillonnage n'apportent pas d'émissions (c'est-à-dire, de contaminants) à l'essai. Avant les essais, il est recommandé de rechercher les traces de

contamination dans le système sans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, pour éviter les résultats erronés non conformes. Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.

- ii) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée pendant une durée de 10 min ou pendant la durée jusqu'à l'instant où 10 % de la pleine capacité en combustible d'une cartouche de combustible pleine ont été consommés, en prenant la plus courte des deux durées.
 - iii) Mettre le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») tout en échantillonnant les concentrations d'émission à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure A.11.
 - iv) Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
 - v) Les concentrations des émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être échantillonnées à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure A.11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé).
 - vi) La vitesse d'échantillonnage pour les mesurages de concentration d'émission très près doit être de 5 l par minute, ce qui représente la vitesse de respiration d'un être humain adulte
 - vii) Laisser le débit d'échantillon se stabiliser.
 - viii) Échantillonner et enregistrer les émissions gazeuses du système à pile à combustible ou du bloc d'alimentation électrique de la pile à combustible qui se produisent à une distance représentative de la zone de respiration d'un consommateur.
 - ix) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau A.7.
 - x) Comparer les concentrations stabilisées maximales avec le Tableau A.7 Si les concentrations d'émission ne sont pas inférieures aux limites de concentration d'émission dans le Tableau A.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite A.7.3.12 e) 2) ii).
 - xi) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 5) À l'issue des mesurages d'émissions avec («DISPOSITIF EN POSITION «ON»») et avec («DISPOSITIF EN POSITION «OFF» conformément au Tableau A.7, les émissions d'hydrogène en situation «DISPOSITIF EN POSITION «ON»») sont évaluées comme suit:

- i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure A.10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
- ii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- iii) Les émissions de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure A.10.
- iv) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
- v) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure A.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
- vi) Enregistrer la concentration d'hydrogène.
- vii) Calculer le taux d'émission de l'hydrogène émis en multipliant la concentration stabilisée maximale d'hydrogène par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit en régime établi de la pompe à air à débit variable à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux d'émission.

Voir ci-dessous.

$$ER = (F_P + F_S) \times C$$

ou

$$ER = (F_i) \times C$$

ou

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre normalisé.

- viii) Comparer le taux d'émission maximal mesuré d'hydrogène en situation [DISPOSITIF EN POSITION «ON»] par rapport au Tableau A.7.

NOTE Il s'agit d'un mesurage de concentration stabilisée.

- ix) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du

matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.

6) À l'issue des mesurages des émissions d'hydrogène avec «DISPOSITIF EN POSITION «ON»», les émissions d'hydrogène avec («DISPOSITIF EN POSITION «OFF»») sont évaluées comme suit:

- i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure A.10 pendant une durée de 10 min ou pendant la durée jusqu'à l'instant où 10 % de la pleine capacité en combustible d'une cartouche de combustible pleine ont été consommés, la plus courte des deux durées étant choisie.
- ii) Mettre le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») et mesurer les taux d'émission avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») à l'intérieur de la petite enceinte d'essai représentée à la Figure A.10.
- iii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- iv) Les émissions de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure A.10.
- v) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
- vi) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure A.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
- vii) Enregistrer la concentration d'hydrogène.
- viii) Calculer le taux d'émission de l'hydrogène émis en multipliant la concentration stabilisée maximale d'hydrogène par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit en régime établi de la pompe à air à débit variable à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux d'émission.

Voir ci-dessous:

$$ER = (F_p + F_s) \times C$$

ou

$$ER = (F_i) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_p est le débit de la pompe à air à débit variable en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre normalisé.

- ix) Comparer le taux d'émission maximal mesuré d'hydrogène en situation «DISPOSITIF EN POSITION «OFF»» par rapport au Tableau A.7.

NOTE Il s'agit d'un mesurage de concentration stabilisée.

- x) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.

7) Évaluer le taux d'émission d'hydrogène comme suit:

- i) Si le taux d'émission d'hydrogène mesuré est inférieur à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») et est inférieur à la valeur admissible 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible satisfait à l'essai et aucun essai supplémentaire n'est nécessaire.
- ii) Si le taux d'émission d'hydrogène mesuré n'est pas inférieur à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») et n'est pas inférieur à la valeur admissible totale 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système ou le bloc échoue à l'essai et aucun essai supplémentaire n'est nécessaire.
- iii) Si le taux d'émission d'hydrogène mesuré est inférieur à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») et est inférieur à la valeur admissible totale 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), mais n'est pas inférieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), passer en A.7.3.13 Essai de détection de pertes localisées de gaz hydrogène pour vérifier qu'aucune source de perte de gaz hydrogène ne dépasse 0,016 g/h.

e) **Critères de réussite:**

- 1) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau A.7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau 7 lorsqu'il est respectivement vérifié par essai conformément aux essais A.7.3.12 d) 1) pour le dispositif en marche («DISPOSITIF EN POSITION «ON»») et A.7.3.12 d) 2) pour le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
- 2) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible à utiliser très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau A.7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau 7 lorsqu'il est respectivement vérifié par essai conformément aux essais A.7.3.12 d) 1) pour le dispositif en marche («DISPOSITIF EN POSITION «ON»») et A.7.3.12 d) 2) pour le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la

micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.

- ii) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible destinés à être utilisés très près de la bouche ou du nez d'un consommateur: En plus de satisfaire à la limite du taux d'émission ci-dessus, la concentration maximale d'émission pour chacun des constituants concernés doit être inférieure à la limite de concentration d'émission indiquée dans le Tableau A.7 lorsqu'elle est respectivement vérifiée par essai conformément aux essais A.7.3.12 d) 3) pour le dispositif en marche («DISPOSITIF EN POSITION «ON»») et A.7.3.12 d) 4) pour le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
- 3) Les émissions d'hydrogène sont évaluées séparément. *La procédure pour les essais d'émission d'hydrogène est détaillée à la Figure A.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe A.* À l'issue des mesurages des émissions d'hydrogène avec le dispositif en marche («DISPOSITIF EN POSITION «ON»») et le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») conformément au Tableau A.7, les émissions d'hydrogène sont évaluées comme suit:
 - i) **Critères de réussite pour systèmes en non-fonctionnement:** Le taux d'émission d'hydrogène doit être inférieur à 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»).
 - ii) **Critères de réussite pour les systèmes opérationnels:** Si le taux total d'émission d'hydrogène est inférieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible satisfait à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux total d'émission d'hydrogène n'est pas inférieur à 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible échoue à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux d'émission d'hydrogène est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), l'essai décrit en A.7.3.13, Essai de détection de pertes localisées de gaz hydrogène, doit être effectué avec des résultats acceptables pour indiquer que les fuites d'hydrogène ne dépassent pas 0,016 g/h à partir d'une seule fuite localisée.

NOTE 1 Le niveau d'émission d'hydrogène inflammable admissible qui n'entretient pas de flamme est de 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain et M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). La limite d'émission d'hydrogène non inflammable est fondée sur les critères selon lesquels l'émission d'hydrogène n'augmente pas de plus de 25 % de la LII dans le volume de référence.

NOTE 2 L'hydrogène est défini comme un asphyxiant simple, mais, pour que ce risque existe, les niveaux d'oxygène doivent descendre à moins de 18 % à la pression atmosphérique normale. Le risque d'inflammabilité lié à l'hydrogène se produit à des concentrations d'hydrogène dans l'air supérieures à 4 %, tandis que le risque d'asphyxie survient à des concentrations d'hydrogène dans l'air supérieures à 12 %. Par conséquent, les limites d'inflammabilité sont utilisées en définissant les limites pour les émissions d'hydrogène.

NOTE 3 Les limites des niveaux d'émissions de vapeurs de dioxyde de carbone, de monoxyde de carbone et d'acide formique sont fondées sur les effets de la toxicité et de la corrosivité (acide formique uniquement) sur les humains, tandis que les limites des niveaux d'émissions d'hydrogène sont fondées sur le risque lié à la création d'une atmosphère inflammable dans des espaces confinés et sur le risque d'une flamme d'hydrogène qui peut être entretenue.

NOTE 4 Le risque d'inflammabilité de l'acide formique, basé sur les critères liés au maintien d'une concentration dans l'air en dessous de 25 % de la LII, est d'un ordre de grandeur inférieur au risque de toxicité (limite d'inflammabilité = 42 500 ppmv, et limite de toxicité = 5 ppmv). Ainsi, le niveau de toxicité de l'acide formique est utilisé pour établir les limites de ses émissions.

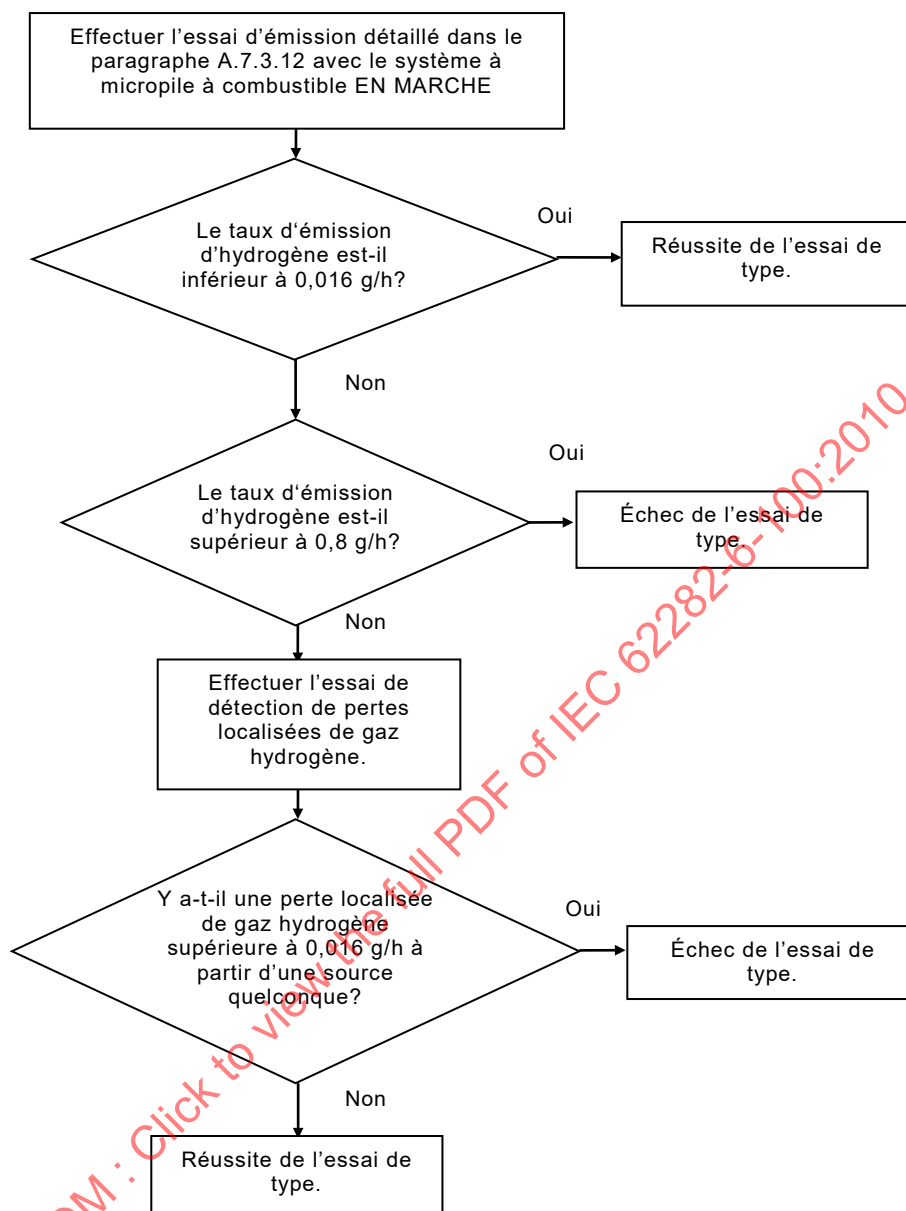


Figure A.12 – Procédure pour l'essai d'émission d'hydrogène pour le système à micropile à combustible en fonctionnement

Tableau A.7 – Limites d'émissions – Remplace le Tableau 7

Émissions	«DISPOSITIF EN POSITION «OFF»» Limite de concentration ^a d'après les valeurs de STEL pour la condition d'essai d'arrêt du dispositif («DISPOSITIF EN POSITION «OFF»»)	«DISPOSITIF EN POSITION «ON»» Limite de concentration ^a d'après les valeurs de TWA pour la condition d'essai de marche du dispositif («DISPOSITIF EN POSITION «ON»»)	«DISPOSITIF EN POSITION «OFF»» Taux d'émission admissible dans le volume 1 m ³ ACH ^c	«DISPOSITIF EN POSITION «ON»» Taux d'émission admissible dans le volume 10 m ³ ACH ^b
Eau	Illimitée	Illimitée		
CO	0,232 g/m ³	0,029 g/m ³	0,232 g/h	0,290 g/h
CO ₂	54 g/m ³	9 g/m ³	non applicable (voir A.1.3.C.5)	60 g/h ^d
Acide formique	0,018 g/m ³	0,009 g/m ³	0,018 g/h	0,09 g/h
Formaldéhyde ^e	0,000 1 g/m ³	0,000 1 g/m ³	0,000 06 g/h	0,000 6 g/h
Hydrogène ^f	Voir note de bas de tableau f	0,8 g/m ³	0,0032 g/h	0,8 g/h total 0,016 g/h à partir d'une seule fuite localisée

^a Les limites de concentration pour le CO, le CO₂ et l'acide formique de ce tableau sont l'équivalent en mg/m³ des limites d'exposition TWA et STEL, indiquées en ppmv, dans le Tableau A.8.

^b La limite du taux d'émission «DISPOSITIF EN POSITION «ON»» était basée sur la valeur 10 m³ ACH, choisie comme le produit du volume de référence par les renouvellements d'air par heure (ACH), parce qu'elle couvre les environnements raisonnablement prévisibles dans lesquels les systèmes à micropiles à combustible sont utilisés. L'espace intérieur dans une petite voiture et le volume minimal par personne à bord d'un avion commercial sont fixés à 1 m³. L'ACH minimal utilisé à bord d'un avion de passagers est de 10 et le réglage de ventilation le plus faible dans les voitures est de 10 ACH. Les maisons et les bureaux peuvent présenter des niveaux d'ACH aussi bas que 0,5, mais le volume par personne est supérieur à 20 m³, et donc un produit de 10 est satisfaisant.

^c Le taux d'émission du dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») est basé sur 1 m³ ACH, parce qu'il couvre les environnements raisonnablement prévisibles dans lesquels les systèmes à micropiles à combustible peuvent être stockés. Les limites sont basées sur les valeurs de STEL, parce qu'il est raisonnable de prévoir une exposition humaine à de telles conditions pour de courtes durées (équivalentes aux paramètres de STEL).

^d Un être humain adulte assis a un taux d'émission de CO₂ de 30 g/h. Les taux d'émission des piles à combustible, mais aussi des adultes sont limités, de telle sorte que la concentration de CO₂ n'atteigne pas la limite de concentration sur huit heures fixée par l'OMS de 9 g/m³. Dans un environnement avec 10 m³ ACH, ceci limite la contribution de la pile à combustible à 60 g/h.

^e La limite fixée par l'OMS est de 0,000 1 g/m³. Les niveaux de fond sont de 0,000 03 g/m³. La limite d'émission ne peut pas faire passer le niveau de fond au-dessus de la limite fixée.

^f Le taux d'émission d'hydrogène pour l'état d'arrêt du dispositif («DISPOSITIF EN POSITION «OFF»») est basé sur un volume de 0,283 m³, 0 ACH et une durée de 24 h pour l'environnement d'émission. Le taux d'émission pour l'état de marche du dispositif («DISPOSITIF EN POSITION «ON»») est conforme à la note b, mais avec un facteur de sécurité supplémentaire de 10.

Tableau A.8 – Limites d'exposition en milieu professionnel

Émissions	Limite d'exposition TWA (TWA – moyenne pondérée dans le temps sur 8 h de fonctionnement)	Valeur de STEL (expositions de 15 min à une fréquence maximale de 4 fois par jour)
CO ₂	< 5 000 ppmv	< 30 000 ppmv
Acide formique	< 5 ppmv	< 10 ppmv
CO	< 25 ppmv	< 200 ppmv

A.7.3.13 Essai de détection de pertes localisées de gaz hydrogène

La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure A.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe A. Ce paragraphe doit être utilisé si cela est exigé par le A.7.3.12 d) 7) ii) pour démontrer la conformité au Tableau A.7, pour les systèmes à micropiles à combustible à l'acide formique et les blocs d'alimentation électrique des micropiles à combustible à l'acide formique. Il est nécessaire d'exécuter ce paragraphe pour satisfaire aux critères de réussite de A.7.3.12 e) 3) ii) si le taux total d'émission d'hydrogène provenant d'un système à micropile à combustible à l'acide formique opérationnel ou d'un bloc d'alimentation électrique de la micropile à combustible à l'acide formique opérationnel est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»). Ce paragraphe s'ajoute aux exigences de l'Article 7.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible – qui est alimenté en acide formique – l'émission de l'hydrogène doit être maintenue à un niveau inférieur aux valeurs spécifiées dans le Tableau A.7. L'essai de détection de pertes localisées de gaz hydrogène doit être effectué pour déterminer qu'aucune source sur le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne peut entretenir une flamme dans tous les cas où une telle conformité ne peut être définitivement déterminée par l'essai d'émission d'hydrogène. Le fait de maintenir ces limites assure qu'il n'y aura ni accumulation de la concentration inflammable dans le volume de référence ni pertes de gaz hydrogène provenant de l'éprouvette qui pourraient entretenir une flamme. Ce maintien garantit également avec les autres essais d'émissions qu'une alimentation adéquate en oxygène sera maintenue dans l'environnement de fonctionnement
- c) **Appareillage d'essai:** La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25% de la LII. La réponse des détecteurs d'hydrogène susmentionnés est généralement lente, le temps de réponse étant de plusieurs secondes, et donc des vitesses de balayage élevées peuvent causer une sous-estimation de la concentration d'hydrogène. Un élément d'importance est que la vitesse de balayage doit être suffisamment lente pour mesurer précisément la concentration d'hydrogène.
- d) Procédure d'essai
 - 1) Le système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible doit rester en marche («DISPOSITIF EN POSITION «ON»») pendant toute la durée de l'essai de détection de pertes localisées de gaz hydrogène.
 - 2) L'essai doit être réalisé dans un espace sans circulation d'air importante. La vitesse mesurée du vent à 10 cm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ne doit pas dépasser 0,02 m/s. La concentration locale de la diffusion d'hydrogène mesurée dans cet essai est très sensible à l'effet du vent. Il est souhaitable que la vitesse du vent en n'importe quel endroit de l'espace d'essai soit aussi proche que possible de zéro. Les essais réalisés dans un espace clos, tel qu'une boîte à gants ou enceinte équivalente, constituent un moyen disponible de satisfaire à cette exigence.
 - 3) La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25 % de la LII.

- 4) Le capteur du détecteur d'hydrogène doit balayer le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à une distance inférieure ou égale à 3 mm, perpendiculairement à la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les balayages linéaires consécutifs ne doivent pas être éloignés de plus de 8 mm le long de la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. La surface totale du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être balayée de cette manière.
 - 5) Une méthode efficace pour réaliser ces balayages consisterait à fixer une cale sur le capteur, qui assure le maintien en toutes circonstances d'un espacement de 3 mm depuis le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Un stylo ou autre ustensile de marquage fixé sur la cale pourrait être utilisé pour identifier les zones balayées et pour garantir que la distance entre les balayages ne dépasse pas 8 mm.
 - 6) Il convient que le capteur soit toujours dirigé directement vers le bas, et que le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible soit déplacé sous ce dernier de telle sorte que la surface juste en dessous du capteur soit toujours horizontale.
 - 7) Si aucun point n'est détecté lorsque la concentration d'hydrogène est supérieure à 25 % de la LII, l'essai est terminé et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être considéré comme ayant satisfait à l'essai.
 - 8) Lorsqu'un certain nombre de balayages de source ponctuelle présentent une vaste région de 25 % ou plus de la LII dans les balayages linéaires initiaux, le fait d'enregistrer les valeurs mesurées de la concentration permet de déterminer le point de départ des balayages en spirale secondaires. Les sources ponctuelles sont censées se trouver aux endroits auxquels il existe des valeurs maximales locales dans la distribution des valeurs mesurées de la concentration.
 - 9) S'il est détecté que des points ont une concentration d'hydrogène de 25 % de la LII ou plus, un deuxième essai doit être réalisé pour garantir que l'émission ne dépasse pas 0,016 g/h d'hydrogène pur depuis une source quelconque.
 - 10) Le deuxième essai doit être réalisé avec la hauteur du capteur réglée à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.
 - 11) Un balayage en spirale doit alors être réalisé, depuis le point auquel a eu lieu la détection de 25% de la LII ou plus de l'hydrogène au cours du balayage linéaire initial. Le balayage en spirale doit présenter un espacement de 1 mm ou moins entre les balayages et doit former une spirale sur une distance radiale d'au moins 4 mm et suffisamment loin pour détecter le niveau maximal d'hydrogène à partir de la source d'hydrogène particulière.
 - 12) Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Si le balayage en spirale ne détecte pas de concentrations d'hydrogène supérieures ou égales à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible satisfait à l'essai.
- e) **Critères de réussite:** Aucune perte de gaz hydrogène provenant d'une source quelconque à plus de 0,016 g/h telle qu'indiquée par les essais de balayage. Aucune indication d'hydrogène qui soit à 25 % de la LII pendant les essais de balayage primaire ni aucune indication d'hydrogène à 25 % de la LII pendant les essais de balayage secondaire à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Voir Tableau A.7.

Annexe B (normative)

Hydrogène stocké dans un alliage métallique absorbant l'hydrogène et systèmes à micropiles à combustible

B.1 Domaine d'application

B.1.2 Combustibles et technologies traités dans la présente annexe

L'Annexe B traite des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible de l'hydrogène (contenu dans un récipient en alliage métallique absorbant l'hydrogène). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de proton.

NOTE Les cartouches de combustible pour cette technologie sont appelées par l'ISO 16111:2008 «assemblages métal-hydrure».

B.1.3 Niveau de sécurité équivalent

Ce paragraphe remplace le 1.3 pour la présente Annexe B

- a) Les exigences de la présente norme ne sont pas destinées à limiter l'innovation. Le fabricant peut prendre en considération des combustibles, des matériaux, des conceptions ou des constructions qui ne sont pas spécifiquement traités dans la présente norme. Il convient d'évaluer ces alternatives selon leur aptitude à fournir des niveaux de sécurité équivalents à ceux définis dans la présente norme.
- b) Il est évident que tous les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible doivent être conformes aux exigences locales et nationales, y compris, entre autres, à celles relatives au transport, la protection des enfants, et le stockage, le cas échéant.
- c) Les différences suivantes entre les systèmes à micropiles à combustible au méthanol et à l'hydrogène sont présentées pour aider à mieux comprendre pourquoi les exigences relatives à l'hydrogène contenues dans l'Annexe B diffèrent des exigences relatives au méthanol dans le corps principal:
 - i) L'hydrogène n'est pas toxique; par conséquent, plusieurs des paragraphes du corps principal contenant des exigences, des procédures et des essais dans le corps principal traitant de toxicité sont modifiés dans la présente Annexe B. En outre, les exigences relatives à l'étiquetage concernant la toxicité ne sont pas exigées (voir Article B.6).
 - ii) L'hydrogène est défini comme un asphyxiant simple, mais, pour que ce risque existe, les niveaux d'oxygène doivent descendre à moins de 18 % à la pression atmosphérique normale. Le risque d'inflammabilité lié à l'hydrogène se produit à des concentrations d'hydrogène dans l'air supérieures à 4 %, tandis que le risque d'asphyxie survient à des concentrations d'hydrogène dans l'air supérieures à 12 %. Par conséquent, les limites d'inflammabilité sont utilisées en définissant les limites pour les émissions d'hydrogène.
 - iii) Le danger principal du gaz hydrogène est son inflammabilité. La plage d'inflammabilité du gaz hydrogène se situe entre 4 % et 75 % de concentration en volume dans l'air à la pression atmosphérique. Par conséquent, les limites des pertes non admissibles d'hydrogène" (voir B.3.38) et des émissions d'hydrogène indiquées dans l'Annexe B sont fondées sur le non-dépassement de 25 % de la limite inférieure d'inflammabilité (LII) de l'hydrogène dans un volume de référence donné. En outre, les limites des émissions d'hydrogène pour les systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible en fonctionnement font l'objet d'une surveillance supplémentaire afin de garantir qu'aucune flamme ne peut être

entretenu par une quelconque émission d'hydrogène à partir d'aucune source ponctuelle

- iv) La présente Annexe B considère comme un combustible le gaz hydrogène stocké dans un alliage métallique (solide) absorbant l'hydrogène. Les systèmes ne contenant aucun combustible liquide, les définitions pour «combustible liquide dangereux» et «liquide non accessible» ne s'appliquent pas à la présente Annexe. La présente Annexe définit et utilise aussi «perte de gaz hydrogène non admissible» au lieu de «aucune perte de vapeur de combustible» comme critère pour les systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible en fonctionnement. De surcroît, les cartouches de combustible sont soumises à une recherche de fuite d'hydrogène en utilisant un détecteur de fuites liquide ou une méthode équivalente (voir B.7.2.1) et elles sont examinées visuellement pour garantir l'absence de «fuite d'alliage métallique absorbant l'hydrogène» au lieu d'être examinées pour déceler un liquide accessible à la suite d'essais de type.
- v) Les sous-produits possibles du fonctionnement d'une pile à combustible PEM fonctionnant à l'hydrogène sont la chaleur et l'eau. Comme le combustible ne contient pas d'hydrocarbure (et donc ne produira pas de dérivés d'hydrocarbures lors du fonctionnement), les émissions d'hydrocarbures recherchées dans les essais du corps principal ne font pas l'objet de recherche dans la présente Annexe B. À la place, seules les émissions d'hydrogène font l'objet de recherche par les essais.
- vi) Il est nécessaire de prendre en compte des considérations spéciales pour concevoir une cartouche de combustible ou un réservoir interne contenant un alliage métallique absorbant l'hydrogène. Pour assurer la sûreté de ces dispositifs, la présente Annexe B exige qu'ils soient également conçus, soumis à l'essai et certifiés conformément à l'ISO 16111:2008 (se reporter à B.2, B.7.3.14 et B.7.3.15).

B.2 Références normatives

En plus des références normatives spécifiées dans l'Article 2, les documents de référence suivants sont indispensables pour l'application du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

ISO 16111:2008, *Appareils de stockage de gaz transportables — Hydrogène absorbé dans un hydrure métallique réversible*

B.3 Termes et définitions

Les termes et définitions ci-dessous remplacent les termes et définitions correspondants de l'Article 3 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B. Tous les termes et conditions de l'Article 3 qui ne sont pas spécifiquement mentionnés ici s'appliquent également.

B.3.5

combustible

gaz hydrogène, stocké dans un alliage métallique absorbant l'hydrogène

B.3.8

combustible liquide dangereux

non applicable à la présente Annexe B

B.3.11

fuite

non applicable à la présente Annexe B

B.3.18**liquide non accessible**

non applicable à la présente Annexe B

B.3.19**absence de perte de vapeur de combustible**

non applicable à la présente Annexe B

Les termes supplémentaires et leurs définitions ci-dessous sont nécessaires pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B en plus de ceux donnés dans l'Article B.3 et dans l'Article 3.

B.3.37**fuite d'hydrogène**

gaz hydrogène à l'extérieur du système de confinement de combustible, y compris la cartouche de combustible et le réservoir interne (voir B.7.2.1)

B.3.38**perte non admissible de gaz hydrogène**

gaz hydrogène s'échappant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible en non-fonctionnement à un débit supérieur ou égal à 0,0032 g/h

B.3.39**absence de fuite d'alliage métallique absorbant l'hydrogène**

absence d'alliage métallique absorbant l'hydrogène à l'extérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ou de la cartouche de combustible

B.4 Matériaux et construction des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible

B.4.1 Généralités

Ces exigences s'appliquent aux systèmes à micropiles à combustible, aux blocs d'alimentation électrique de micropiles à combustible et aux cartouches de combustible traités par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.1.

- a) La conformité aux exigences de l'Article B.4 doit être vérifiée pendant la revue de l'AMDE de sécurité et/ou au cours des essais de type spécifiés à l'Article B.7.
- b) Le bloc d'alimentation électrique de la micropile à combustible lorsqu'il est couplé à la cartouche de combustible, doit être conçu et construit pour éviter tout risque crédible de fuite, feu ou d'explosion posé par le système à micropile à combustible lui-même ou par l'hydrogène ou les hydrures métalliques, ou d'autres substances produites ou utilisées par le système à micropile à combustible.
- c) Pour éviter un danger de feu ou d'explosion à l'intérieur du système à micropile à combustible, le fabricant doit éliminer la ou les sources d'inflammation potentielles dans les zones où le combustible est présent (ou peut être potentiellement dégagé).
- d) Les matériaux inflammables, toxiques ou corrosifs doivent être maintenus à l'intérieur d'un système de confinement fermé, par exemple dans une tuyauterie pour combustible, un réservoir, une cartouche de combustible ou une enveloppe similaire.

B.4.3 Matériaux généraux

Ces exigences s'appliquent aux systèmes à micropiles à combustible, aux blocs d'alimentation électrique de micropiles à combustible et aux cartouches de combustible traités par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.3.

- a) Les matériaux et le revêtement doivent résister à la dégradation au cours des conditions normales de transport et d'utilisation, pendant la durée de vie du produit définie par le fabricant.
- b) Les cartouches de combustible doivent être conformes aux exigences de matériaux et de construction de l'ISO 16111:2008.

B.4.4 Sélection des matériaux

- a) Ces exigences de B.4.4 ci-dessous s'appliquent aux systèmes à micropiles à combustible, aux blocs d'alimentation électrique de micropiles à combustible et aux cartouches de combustible traités par la présente Annexe B.
- b) *Ces exigences remplacent les exigences correspondantes de 4.4.*

B.4.4.1 Les systèmes à micropiles à combustible et les blocs d'alimentations électriques des micropiles à combustible sont susceptibles d'être exposés à un certain nombre de conditions environnementales pendant la durée de vie du produit définie par le fabricant, telles que les vibrations, les chocs, les niveaux d'humidité variables et les environnements corrosifs. Les matériaux utilisés dans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doivent résister à ces conditions environnementales. Si un système à micropile à combustible ou un bloc d'alimentation électrique d'une micropile à combustible doit être utilisé en service, où les conditions environnementales spécifiques sont au-delà de celles prises en compte dans les essais exigés de la présente norme, des essais supplémentaires doivent alors être effectués pour vérifier la sécurité dans ces conditions environnementales.

B.4.4.2 Les matériaux métalliques et non métalliques utilisés pour construire des pièces extérieures ou intérieures du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, en particulier ceux étant exposés directement ou indirectement à l'humidité, au combustible et/ou aux sous-produits sous forme gazeuse ou liquide, ainsi que toutes les pièces et tous les matériaux utilisés pour les souder ou les raccorder, par exemple les consommables pour le soudage, doivent être adaptés à toutes les conditions physiques, chimiques et thermiques raisonnablement prévisibles dans les conditions habituelles de transport et d'utilisation au cours de la durée de vie du produit définie par le fabricant, et à toutes les conditions d'essai, en particulier, ils doivent être conçus pour conserver leur stabilité mécanique dans les conditions d'utilisation normale; en particulier: ils doivent être conçus pour conserver leur stabilité mécanique dans les conditions d'utilisation normale:

- ils doivent être suffisamment résistant à l'action chimique et physique des fluides qu'ils contiennent et à la dégradation environnementale;
- les propriétés physiques et chimiques nécessaires à un fonctionnement sans risque ne doivent pas être considérablement affectées au cours de la durée de vie du produit définie par le fabricant. En particulier, lors du choix des matériaux et des méthodes de fabrication, la résistance à l'usure et à la corrosion, la conductivité électrique, la force d'impact, la résistance au vieillissement, les effets des variations de température, les effets de l'assemblage de certains matériaux (par exemple la corrosion galvanique), et les effets du rayonnement ultraviolet, doivent être pris en considération;
- lorsque des conditions d'érosion, d'abrasion, de corrosion ou d'autres attaques chimiques sont possibles, des mesures appropriées doivent être prises pour:
 - réduire le plus possible cet effet à l'aide d'une conception appropriée, par exemple une épaisseur supplémentaire, ou par une protection adaptée, par exemple l'utilisation de coussinets, de matériaux de parement ou de revêtements de surface, en prenant en compte l'utilisation normale;
 - permettre le remplacement des pièces les plus affectées;

- et attirer l'attention, dans le manuel dont il est fait référence à l'Article 6, sur le type et la fréquence des mesures d'inspection et de maintenance nécessaires pour une utilisation sûre et continue; les pièces sujettes à l'usure et les critères pour un remplacement doivent être spécifiés si nécessaire.
- Les parties contenant des combustibles, telles que les systèmes de tuyauterie, doivent utiliser des matériaux adaptés à une exposition à l'hydrogène, tel que défini dans les exigences relatives à la sélection des matériaux de l'ISO 16111:2008, 5.2. En outre, l'Annexe A de l'ISO 16111:2008 détaille la compatibilité des matériaux pour l'utilisation de l'hydrogène.

B.4.4.3 Les matériaux élastomères tels que les joints et les tuyaux flexibles en contact avec les combustibles doivent résister à la détérioration lorsqu'ils sont en contact avec ces combustibles et doivent être adaptés aux températures auxquelles ils sont exposés au cours d'une utilisation normale. La conformité doit être déterminée par la norme suivante: ISO 188.

B.4.4.4 *Le 4.4.4 ne s'applique pas aux systèmes à micropiles à combustible, aux blocs d'alimentation électrique de micropiles à combustible et aux cartouches de combustible traités par la présente Annexe B.*

B.4.6 Vannes de combustibles

Ces exigences de B.4.6 s'appliquent aux systèmes à micropiles à combustible, aux blocs d'alimentation électrique de micropiles à combustible et aux cartouches de combustible traités par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.6. Le présent paragraphe s'applique à toutes les vannes d'arrêt, les vannes de remplissage, les vannes de détente, les vannes de rechargement, y compris tous les types de cartouches de combustible.

B.4.6.1 Les parties en fonctionnement et à l'épreuve de la pression des ensembles vanne d'arrêt et vanne de détente doivent durer pendant la durée de vie du produit définie par le fabricant dans les conditions normales.

B.4.6.2 Les vannes doivent comporter des dispositifs pour empêcher la fuite de combustible au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible, et du stockage de la cartouche de combustible.

B.4.6.3 Les vannes ne doivent pas être sensibles à une manœuvre involontaire ou à une manœuvre manuelle par un utilisateur n'utilisant pas d'outils, qui entraîne une fuite de combustible. La conformité doit être vérifiée à l'aide du calibre d'essai 11 de l'IEC 61032, et d'une force de 9,8 N.

B.4.6.4 Il ne doit pas y avoir de fuite de combustible ni matériau d'hydrure métallique au cours du stockage, de la connexion, de la déconnexion ou du transfert du combustible de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible.

B.4.7 Matériaux et construction — système

Ces exigences de B.4.7 s'appliquent aux systèmes à micropiles à combustible et aux blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.7.

B.4.7.1 La quantité maximale d'hydrogène stocké dans le bloc d'alimentation électrique de la micropile à combustible ne doit pas être supérieure à 25 g. L'hydrogène stocké dans le réservoir interne du bloc d'alimentation électrique de la micropile à combustible peut être stocké dans un alliage métallique absorbant l'hydrogène.

B.4.7.2 Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être conçu de telle sorte qu'une explosion ne puisse pas se produire, même en cas de fuite de combustible en provenance du système à micropile à

combustible ou à l'intérieur de ce dernier. Les critères de conception de ces dispositifs (par exemple, débit de ventilation nécessaire) doivent être fournis par le fabricant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les dispositifs doivent être fournis soit par le fabricant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, soit par le fabricant du dispositif alimenté par le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.

B.4.7.3 Les composants et les matériaux à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être construits ou doivent utiliser des matériaux tels que la propagation du feu et l'inflammation soient atténuées. L'inflammabilité des matériaux doit être telle qu'un feu soutenu ne perdure pas après coupure du courant électrique et de l'alimentation en combustible et en oxydant. Ceci peut être démontré en choisissant des matériaux FV 0, FV 1 ou FV 2 conformes à l'IEC 60695-1-1 et à l'IEC 60695-11-10.

B.4.7.4 Exemptions

B.4.7.4.1 Il n'est pas exigé que les membranes des micropiles à combustible aient des caractéristiques assignées d'inflammabilité.

B.4.7.4.2 Les autres matériaux à l'intérieur de la micropile à combustible qui représentent moins de 30 % de la masse totale de la micropile à combustible sont considérés comme une quantité limitée et sont admissibles sans tenir compte de leurs caractéristiques assignées d'inflammabilité.

B.4.8 Sources d'inflammation

Ces exigences de B.4.8 s'appliquent aux systèmes à micropiles à combustible et aux blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.8.

Pour éviter un danger de feu ou d'explosion à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, le fabricant doit soit éliminer la ou les sources d'inflammation accidentelles potentielles dans les zones où le combustible est présent (ou peut être potentiellement dégagé) ou doit assurer qu'une oxydation immédiate et contrôlée se produit par l'utilisation d'un réacteur catalytique.

Les sources d'inflammation accidentelles potentielles doivent être éliminées par un ou plusieurs des éléments suivants:

- Les températures en surface ne doivent pas dépasser 80 % de la température d'auto-inflammation, exprimée en degrés Celsius du gaz inflammable.
- Les équipements contenant des matériaux ou des composants capables de catalyser la réaction des fluides inflammables avec l'air doivent être capables d'arrêter la propagation de la réaction entre l'équipement et l'atmosphère inflammable environnante.
- Les matériels et/ou les composants électriques, s'ils sont soumis à un contact avec un combustible, doivent être adaptés à la zone dans laquelle ils sont installés.
- Le potentiel de décharge statique suffisant pour provoquer une inflammation doit être éliminé par un choix de matériaux appropriés et par une liaison équipotentielle et une mise à la terre correctes.
- Les composants électriques tels que les fusibles, les autres dispositifs de protection contre les surintensités, les capteurs, les vannes et solénoïdes électriques lorsqu'ils fonctionnent dans les conditions pour lesquelles ils sont conçus, ne doivent pas être à l'origine d'effets thermiques, d'arcs ou étincelles susceptibles de produire un dégagement inflammable de gaz.

L'oxydation immédiate et contrôlée doit être assurée par les éléments suivants.

- Les réacteurs catalytiques conçus pour contrôler l'oxydation sans risque sont acceptables. La température à l'intérieur de réacteurs de ce type peut être supérieure à la température d'auto-inflammation du fluide. Si le réacteur catalytique s'écarte des conditions de fonctionnement correctes, telles que définies par le fabricant, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être mis automatiquement dans un état sûr.

B.4.10 Protection contre les dangers d'incendie, d'explosion, de corrosivité et de toxicité

Ces exigences s'appliquent aux systèmes à micropiles à combustible, aux blocs d'alimentation électrique de micropiles à combustible et aux cartouches de combustible traités par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.10.

B.4.10.1 Les fluides inflammables, le gaz hydrogène en particulier, doivent être maintenus à l'intérieur d'un système de confinement fermé, par exemple dans une tuyauterie pour combustible, un réservoir, une cartouche de combustible ou une enveloppe similaire. Les essais conformément à B.7.2 vérifient cette exigence.

B.4.10.2 Un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible peut être équipé d'un dispositif permettant de détecter les niveaux de concentration des fluides, voir Tableau B.7, et d'arrêter le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible avant que la limite de concentration ne soit dépassée.

B.4.10.3 Le câblage interne et l'isolation en général ne doivent pas être exposés au combustible, aux huiles, graisses ou substances similaires, à moins que l'isolation n'ait été évaluée pour un contact avec ces substances.

B.4.12 Construction de l'alimentation en combustible

B.4.12.1 Construction de la cartouche de combustible

Ces exigences s'appliquent à la cartouche de combustible traitée par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.12.1. Les cartouches de combustible doivent être conformes aux exigences suivantes:

B.4.12.1.1 Il ne doit y avoir ni fuite d'hydrogène ni fuite d'alliage métallique absorbant l'hydrogène provenant de la cartouche de combustible dans la plage de température de -40 °C à +70 °C. La conformité doit être déterminée par des essais de type conformes à B.7.3.3 et B.7.3.4.

B.4.12.1.2 Il ne doit y avoir ni fuite d'hydrogène ni fuite d'alliage métallique absorbant l'hydrogène provenant de la cartouche de combustible après avoir subi un vide de 95 kPa en dessous de la pression atmosphérique normale à 22 °C ± 5 °C. La conformité doit être déterminée par des essais de type conformes à B.7.3.1.2 Les cartouches doivent satisfaire aux exigences de conception des enveloppes selon 5.3 de l'ISO 16111:2008 et aux exigences relatives à l'absence de fuite d'hydrogène de l'essai de fuite selon 6.2.5 de l'ISO 16111:2008.

B.4.12.1.3 La quantité maximale de gaz hydrogène absorbé dans un alliage métallique absorbant l'hydrogène autorisée dans la cartouche de combustible est de 100 g.

B.4.12.1.4 Pour l'utilisation normale, le mauvais usage raisonnablement prévisible et le transport pour la vente d'une cartouche de combustible avec un bloc d'alimentation électrique de la micropile à combustible par un consommateur, des dispositifs doivent être prévus pour éviter une fuite de combustible ou de l'alliage métallique absorbant l'hydrogène avant, pendant et après la connexion ou le transfert de combustible vers le bloc d'alimentation électrique de la micropile à combustible. La conformité doit être déterminée par l'essai de cycles de connexion, B.7.3.11.

B.4.12.1.5 Une cartouche de combustible doit résister à la corrosion dans son environnement d'utilisation.

B.4.12.1.6 Une cartouche de combustible doit être équipée de dispositifs pour empêcher une mauvaise connexion qui entraînerait une fuite de combustible ou d'alliage métallique absorbant l'hydrogène lorsqu'elle est installée dans un système à micropile à combustible. La conformité doit être déterminée par l'essai de cycles de connexion, B.7.3.11.

B.4.12.1.7 Les connecteurs d'alimentation en combustible prévus sur la cartouche de combustible doivent être construits de telle sorte qu'ils empêchent la fuite de combustible ou d'alliage métallique absorbant l'hydrogène lorsqu'ils ne sont pas fixés sur une micropile à combustible au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible et du transport pour la vente. La conformité doit être déterminée par l'essai de chute, B.7.3.5, et l'essai de cycles de connexion, B.7.3.11.

B.4.12.1.8 Dans le cas où une vanne régulatrice de pression ou un dispositif similaire sont prévus, une vanne régulatrice de pression de ce type doit satisfaire aux exigences de performance pour chaque essai de type. Cette vanne doit réussir tous les essais de type sans fuite.

B.4.12.1.9 La structure à la connexion à la cartouche de combustible ne doit pas permettre de fuite de combustible ou d'alliage métallique absorbant l'hydrogène

B.4.12.1.10 Une cartouche de combustible, y compris l'interface entre la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible, y compris la vanne, doit présenter une construction suffisamment solide pour résister à une utilisation normale et à un mauvais usage raisonnablement prévisible généré par les vibrations, la chaleur, la pression, les chutes ou les chocs mécaniques, etc. La conformité doit être déterminée par:

- essais de pression différentielle, 7.3.1;
- essai de vibrations, B.7.3.2;
- essai de cycles de températures, B.7.3.3;
- essai d'exposition à température élevée, B.7.3.4;
- essai de chute, B.7.3.5;
- essai de charge de compression, B.7.3.6;
- essai de stockage de longue durée, B.7.3.9;
- essai de connexion à température élevée, B.7.3.10;
- essais de cycles de connexion, B.7.3.11.
- essai d'intégrité de la cartouche de combustible B.7.3.14;
- essai d'intégrité du réservoir interne B.7.3.15.

B.4.12.1.11 Les vannes de la cartouche de combustible doivent fonctionner comme prévu, sans l'utilisation d'outils et sans force excessive nécessaire pour la connexion ou la déconnexion.

B.4.12.1.12 Les cartouches de combustible doivent être conformes à l'ISO 16111:2008.

B.4.12.1.13 La capacité volumétrique maximale de la cartouche de combustible ne doit pas dépasser 1 l.

B.4.12.2 Exigences de remplissage de la cartouche de combustible

Ces exigences s'appliquent aux systèmes à micropiles à combustible et aux blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe B. Ces

exigences remplacent les exigences correspondantes de 4.12.2. Les cartouches de combustible doivent être conformes aux exigences suivantes.

- a) La cartouche de combustible ne doit pas être remplie au-delà de sa capacité assignée, comme défini dans l'ISO 16111:2008.
- b) La pression dans la cartouche de combustible ou dans le réservoir interne ne doit pas dépasser 5 MPa de pression manométrique interne à 55 °C lorsque la cartouche de combustible ou le réservoir interne est rempli(e) à sa capacité assignée.

B.4.13 Protection contre les dangers mécaniques

B.4.13.1 Tuyauterie et canalisation autres que les conduites de combustible

Ces exigences s'appliquent aux systèmes à micropiles à combustible et aux blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe B. Ces exigences remplacent les exigences correspondantes de 4.13.1. Des exigences sont données ci-dessous pour la construction de la tuyauterie, des canalisations et des fixations, autres que les conduites de combustible, à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

B.4.13.1.1 Lorsque les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible sont conçus pour des pressions manométriques internes supérieures à 100 kPa, ils doivent être conçus, construits et soumis à l'essai conformément à l'ISO 15649.

B.4.13.1.2 Les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible conçus pour un fonctionnement à une pression manométrique inférieure à 100 kPa ou, conformément aux codes et aux normes locaux ou nationaux applicables des équipements sous pression non qualifiés comme systèmes sous pression, tels que les flexibles à eau basse pression, les canalisations en plastique, ou autres raccords vers les réservoirs atmosphériques ou basse pression et les conteneurs similaires, doivent être construits avec des matériaux appropriés, et leurs joints et fixations associés doivent être conçus et construits avec une force et une résistance aux fuites appropriées pour éviter les dégagements involontaires.

B.4.13.1.3 Les raccords-unions doivent être conçus pour être étanches en utilisant des méthodes d'étanchéisation résistant au fluide transporté et aux conditions ambiantes d'utilisation.

B.4.13.1.4 La construction des tuyauteries et canalisations doit présenter une capacité suffisante pour résister à la pression et à d'autres charges, et il n'y aura pas de danger de contamination ou de fuite du contenu des conduites. La conformité est déterminée par B.7.3.1 et B.7.3.6.

B.4.13.1.5 La construction des tuyauteries et canalisations doit avoir été conçue avec des mesures appropriées pour empêcher le gel, les cassures, la corrosion, etc. La conformité pour le gel est déterminée par 7.3.3. La conformité pour les cassures est présentée en B.7.3.5.

B.6 Instructions et avertissements pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

B.6.2 Marquages minimaux exigés sur la cartouche de combustible

Ces marquages remplacent les marquages exigés par le 6.2.

Au minimum, la cartouche de combustible doit porter les marquages suivants:

- a) CONTENU INFLAMMABLE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) GARDER HORS DE PORTÉE DES ENFANTS.
- d) NE PAS EXPOSER À DES TEMPÉRATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES.
- e) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- f) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT.
- g) COMPOSITION ET QUANTITÉ DE COMBUSTIBLE.
- h) TEXTE OU MARQUAGE INDIQUANT QUE LA CARTOUCHE DE COMBUSTIBLE EST CONFORME À L'IEC 62282-6-100.
- i) MARQUAGES EXIGES PAR L'ISO 16111:2008.

B.6.3 Marquages minimaux exigés sur le système à micropile à combustible

Ces marquages remplacent les marquages exigés par le 6.3.

De plus, au minimum, le système à micropile à combustible doit également porter les marquages suivants:

- a) CONTENU INFLAMMABLE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) NE PAS EXPOSER À DES TEMPÉRATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES.
- d) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- e) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT.
- f) COMPOSITION ET QUANTITÉ DE COMBUSTIBLE.
- g) CAPACITÉ MAXIMALE DE COMBUSTIBLE DANS LE RÉSERVOIR INTERNE, SI APPLICABLE.
- h) TEXTE OU MARQUAGE INDIQUANT QUE LE SYSTÈME À MICROPILE À COMBUSTIBLE EST CONFORME À L'IEC 62282-6-100.
- i) SORTIE ÉLECTRIQUE (TENSION, COURANT, PUISSANCE ASSIGNÉE).
- j) SI UN ALLIAGE MÉTALLIQUE ABSORBANT L'HYDROGÈNE EST PRÉSENT DANS LE RÉSERVOIR INTERNE, LES MARQUAGES EXIGES PAR L'ISO 16111:2008 DOIVENT FIGURER SUR LE BLOC D'ALIMENTATION ÉLECTRIQUE DE LA MICROPILE À COMBUSTIBLE.

B.7 Essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

B.7.1 Généralités

Ce paragraphe B.7.1 remplace le 7.1 pour la présente annexe lors des essais sur les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible qui utilisent comme combustible le gaz hydrogène stocké dans un alliage métallique absorbant l'hydrogène.

- a) Les essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible doivent permettre de vérifier que ces systèmes à micropiles à combustible, blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible sont sûrs pour une utilisation normale.
- b) Le Tableau B.5 énumère les essais de type qui doivent être effectués. *Le Tableau B.5 remplace le Tableau 5.*
- c) Sauf exigence explicite contraire dans cet article, les conditions de laboratoire sont spécifiées dans le Tableau B.6. *Le Tableau B.6 remplace le Tableau 6.*
- d) Le système à micropile à combustible, le bloc d'alimentation électrique de la micropile à combustible et/ou la cartouche de combustible doivent être conditionnés à une température de laboratoire normalisée de $22\text{ °C} \pm 5\text{ °C}$ pendant au moins 3 h avant la réalisation de chaque essai.
- e) Avertissement: Ces essais de type utilisent des procédures qui peuvent entraîner des dommages si des précautions appropriées ne sont pas prises. Il convient que les essais ne soient effectués que par des techniciens qualifiés et expérimentés utilisant une protection appropriée.

Tableau B.5 – Liste des essais de type – Remplace le Tableau 5

Référence de l'essai	Entité d'essai	Échantillon d'essai
B.7.3.1	Essais de pression différentielle	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
B.7.3.2	Essai de vibrations	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible utilisé en B.7.3.1.3
B.7.3.3	Essai de cycles de températures	Cartouche de combustible utilisée en B.7.3.2 Cartouche de combustible remplie partiellement utilisée en B.7.3.2 Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible utilisé en B.7.3.2
B.7.3.4	Essai d'exposition à température élevée	Cartouche de combustible Cartouche de combustible remplie partiellement
B.7.3.5	Essai de chute	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
B.7.3.6	Essai de charge de compression	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
B.7.3.7	Essai de court-circuit externe	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.8	Essai de température de surface, de composant et de gaz d'échappement	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
B.7.3.9	Essai de stockage de longue durée	Cartouche de combustible Cartouche de combustible remplie partiellement
B.7.3.10	Essai de connexion à température élevée	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible remplie partiellement et bloc

Référence de l'essai	Entité d'essai	Échantillon d'essai
		d'alimentation électrique de la micropile à combustible
B.7.3.11	Essai de cycles de connexion	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible
B.7.3.12	Essai d'émission	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
B.7.3.14	Intégrité de la cartouche de combustible	Cartouche de combustible (ISO 16111)
B.7.3.15	Intégrité du réservoir interne	Réservoir interne du bloc d'alimentation électrique de la micropile à combustible (ISO 16111)
Le Tableau B.5 remplace le Tableau 5. Échantillon d'essai: Le nombre d'échantillons doit être au moins de six (6) cartouches de combustible, neuves ou partiellement remplies, comme spécifié pour les essais individuels ci-dessus, ou au moins de trois (3) systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible pour chaque essai de type. Le nombre des échantillons pour B.7.3.14 et B.7.3.15 doit être conforme à l'ISO 16111:2008. Séquence d'essai: Les essais B.7.3.2 et B.7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes cartouches de combustible. Les essais B.7.3.1, B.7.3.2, et B.7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes systèmes à micropile à combustible ou des mêmes blocs d'alimentation électrique de micropiles à combustible. Réutilisation des échantillons: Les cartouches de combustible et les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible peuvent être réutilisés à l'initiative du fabricant, si ceci ne compromet pas l'essai individuel.		

Tableau B.6 – Conditions normalisées de laboratoire – Remplace le Tableau 6

Élément	Condition
Température de laboratoire	La température de laboratoire est la «température ambiante» (condition de température normalisée, 22 °C ± 5 °C)
Atmosphère de laboratoire; pour les essais du système à micropile à combustible et du bloc d'alimentation électrique de la micropile à combustible uniquement	L'atmosphère de la pièce du laboratoire ne contient pas plus de 0,2 % de dioxyde de carbone et pas plus de 0,002 % de monoxyde de carbone. L'atmosphère de la pièce du laboratoire contient au moins 18 %, mais pas plus de 21 %, d'oxygène. L'atmosphère de laboratoire ne contient pas plus de 0,008 % d'hydrogène
Le Tableau B.6 remplace le Tableau 6.	

B.7.2 Mesurage des fuites d'hydrogène et procédure de mesure

Ce paragraphe B.7.2 remplace le 7.2 pour la présente Annexe lors des essais sur les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible qui utilisent comme combustible le gaz hydrogène stocké dans un alliage métallique absorbant l'hydrogène.

- Le mesurage des fuites d'hydrogène doit être effectué en principe conformément aux procédures présentées dans les Figures B.2 à B.5, B.9 et B.12, selon le cas. Ces figures et leurs procédures remplacent les figures correspondantes présentées en 7.2.
- La conformité aux exigences d'absence de «fuite d'hydrogène» et d'absence de «perte non admissible de gaz hydrogène» pour tous les essais de type spécifiés en B.7.3 doit être déterminée par la procédure de mesure des fuites d'hydrogène de B.7.2.1 et la procédure de mesure des pertes de gaz hydrogène de B.7.2.2, conjointement avec la définition de la «perte d'hydrogène» de B.3.37 et la définition de «perte non admissible de gaz hydrogène» de B.3.38, sauf spécification contraire.

B.7.2.1 Mesurage des fuites d'hydrogène à partir des cartouches de combustible et/ou des réservoirs internes, et procédures de mesure

- a) Pour les cartouches de combustible contenant de l'hydrogène stocké dans un alliage métallique absorbant l'hydrogène, le mesurage des fuites d'hydrogène doit être effectué à la suite de chaque essai de type à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) ou autre dispositif équivalent sur tous les emplacements de fuite éventuels de la cartouche de combustible. Voir Figure B.2 et Figure B.3.
- b) Si la cartouche de combustible est du type rechargeable par le fabricant (de façon automatisée ou par des techniciens formés), elle doit être chargée d'hydrogène jusqu'à sa capacité assignée, à la pression de charge assignée avant les essais. Si la cartouche de combustible n'est pas rechargeable, elle doit être soumise à l'essai dans l'état dans lequel elle a terminé l'essai de type en question. La cartouche de combustible doit être soumise à l'essai pour détecter des fuites éventuelles à la température de laboratoire. Il ne doit se produire de fuite en aucun point de la cartouche de combustible.
- c) Pour les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible comportant un réservoir interne qui contient du gaz hydrogène à une pression supérieure à la pression ambiante, le mesurage des fuites d'hydrogène doit être effectué à la suite de chaque essai de type à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) ou autre dispositif équivalent sur tous les emplacements de fuite éventuels du réservoir interne. Le réservoir interne doit être soumis à l'essai pour détecter des fuites éventuelles à la température de laboratoire. Il ne doit se produire de fuite en aucun point du réservoir interne.
- d) Aucune fuite d'hydrogène n'est permise aussi bien pour les cartouches de combustible contenant de l'hydrogène stocké dans un alliage métallique absorbant l'hydrogène que pour les réservoirs internes contenant de l'hydrogène. Les essais pour détecter une fuite d'hydrogène avec une solution de détecteur de fuite liquide (formation de bulles) sont acceptables si aucune bulle n'a été détectée.

NOTE Les critères d'absence de fuite pour les cartouches de combustible contenant de l'hydrogène stocké dans un hydrure métallique ont été choisis pour être cohérents avec la 15^e édition des Recommandations des Nations Unies relatives au transport des marchandises dangereuses, Règlement type; Disposition spéciale 339 pour l'UN 3479, Fuel Cell Cartridges containing hydrogen in metal hydride.

B.7.2.2 Mesurages des pertes de gaz hydrogène à partir des systèmes à micropiles à combustible et des blocs d'alimentation électrique des micropiles à combustible, et procédures de mesure

- a) Pour les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible, à la fin de chaque essai de type, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être soumis à l'essai pour détecter d'éventuelles pertes de gaz hydrogène, conformément à la Figure B.4 ou B.5, selon le cas, comme suit:
 - 1) Effectuer les essais d'émissions d'hydrogène conformément à B.7.3.12.2 avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») La perte de gaz hydrogène doit être inférieure à 0,0032 g/h.
 - 2) Effectuer les essais d'émissions d'hydrogène conformément à B.7.3.12.1 avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») pour rechercher les émissions d'hydrogène, que le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible soit opérationnel ou non. Les émissions d'hydrogène doivent être inférieures à 0,8 g/h.
 - 3) Comme l'exigent les dispositions de B.7.3.12.1, si les émissions d'hydrogène conformément à B.7.3.12 avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») dans l'étape B.7.2.2 a) 2) ont été supérieures à 0,016 g/h, effectuer l'essai de détection de pertes localisées de gaz hydrogène conformément à B.7.3.13. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la

micropile à combustible échoue à l'essai de détection de pertes localisées de gaz hydrogène conformément à B.7.3.13, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai de type et aucun essai supplémentaire n'est nécessaire.

- 4) Les émissions totales d'hydrogène à partir d'un système opérationnel doivent être inférieures à 0,8 g/h et la perte de gaz hydrogène à partir d'une seule fuite localisée doit être inférieure à 0,016 g/h. Voir Tableau B.7.
- 5) La perte totale de gaz hydrogène à partir d'un système en non-fonctionnement doit être inférieure à 0,0032 g/h. Voir Tableau B.7.

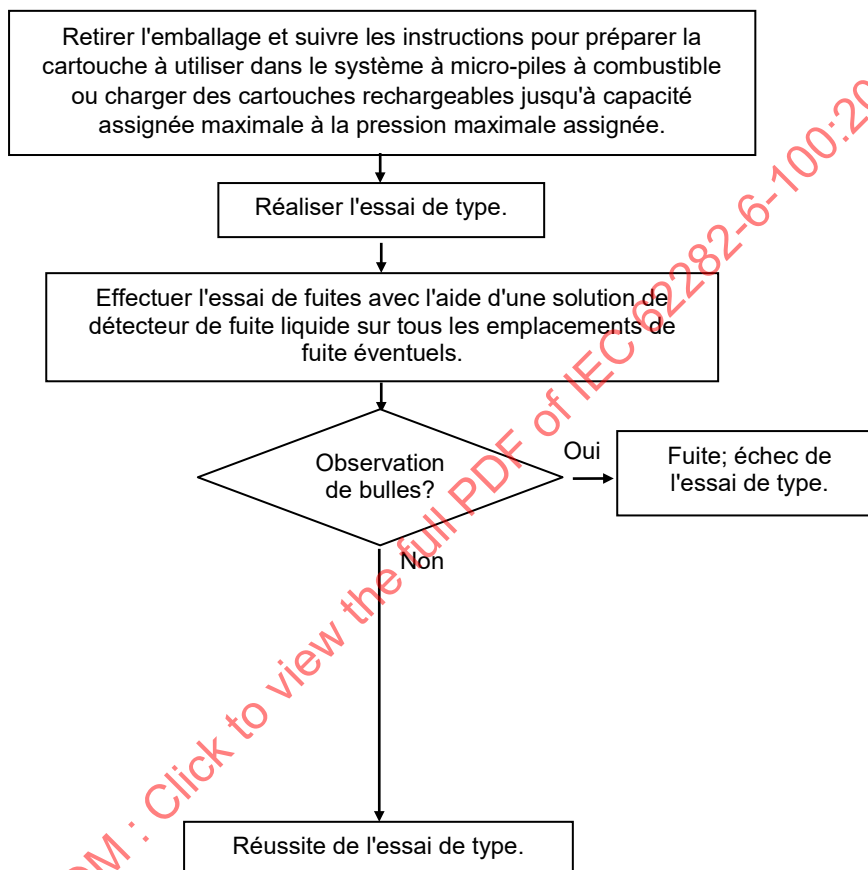


Figure B.2 – Diagramme d'essai de fuite de la cartouche de combustible pour les essais de pression différentielle, de vibrations, de chute et de charge de compression – Remplace la Figure 2

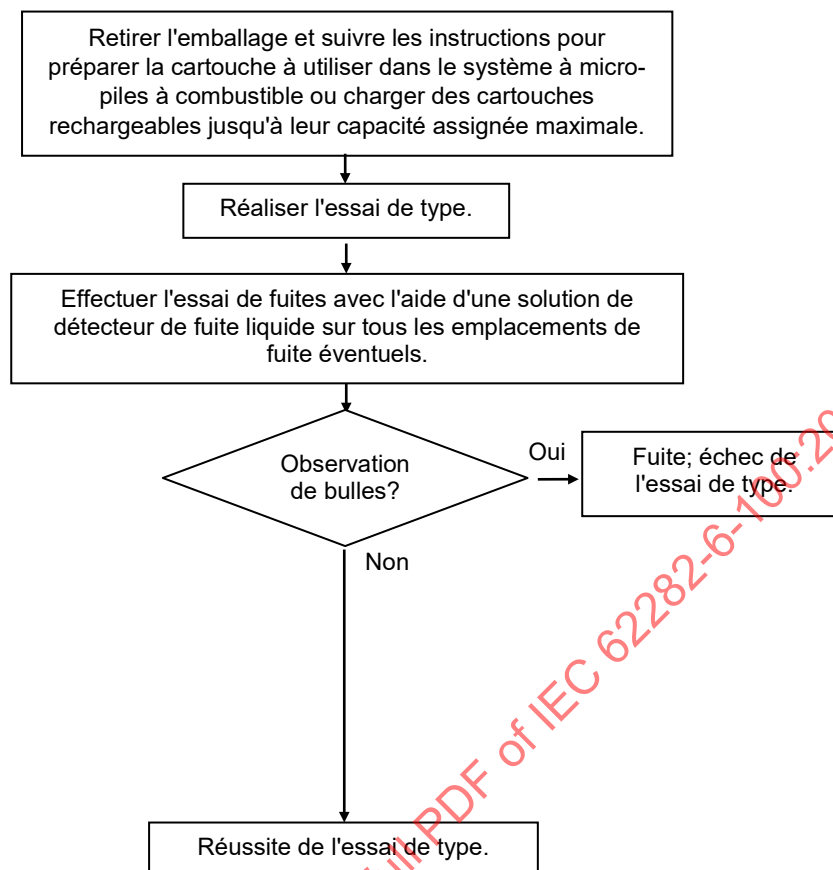


Figure B.3 – Diagramme d'essai de fuite de la cartouche de combustible pour l'essai de cycles de températures et l'essai d'exposition à température élevée – Remplace la Figure 3.

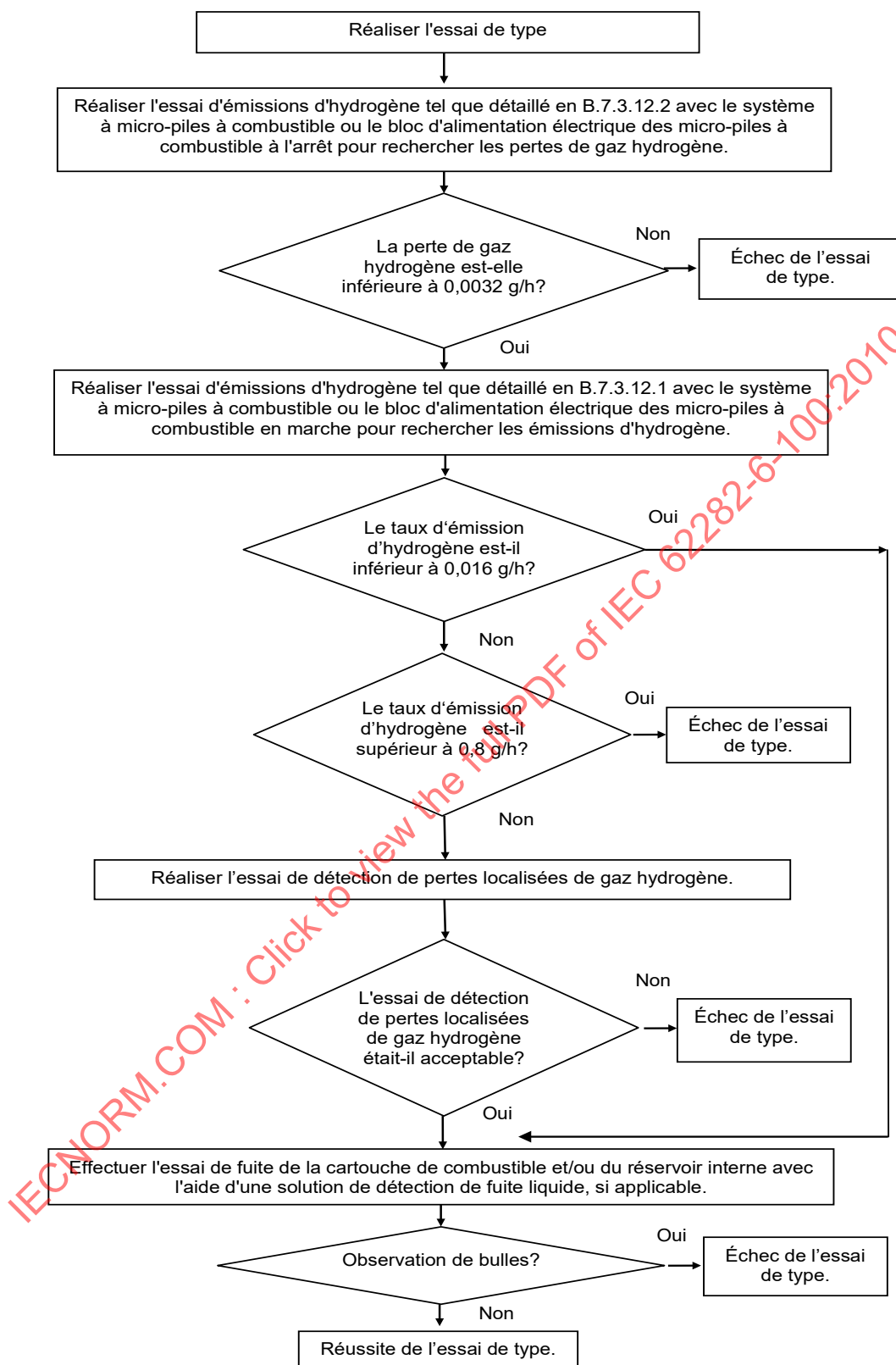
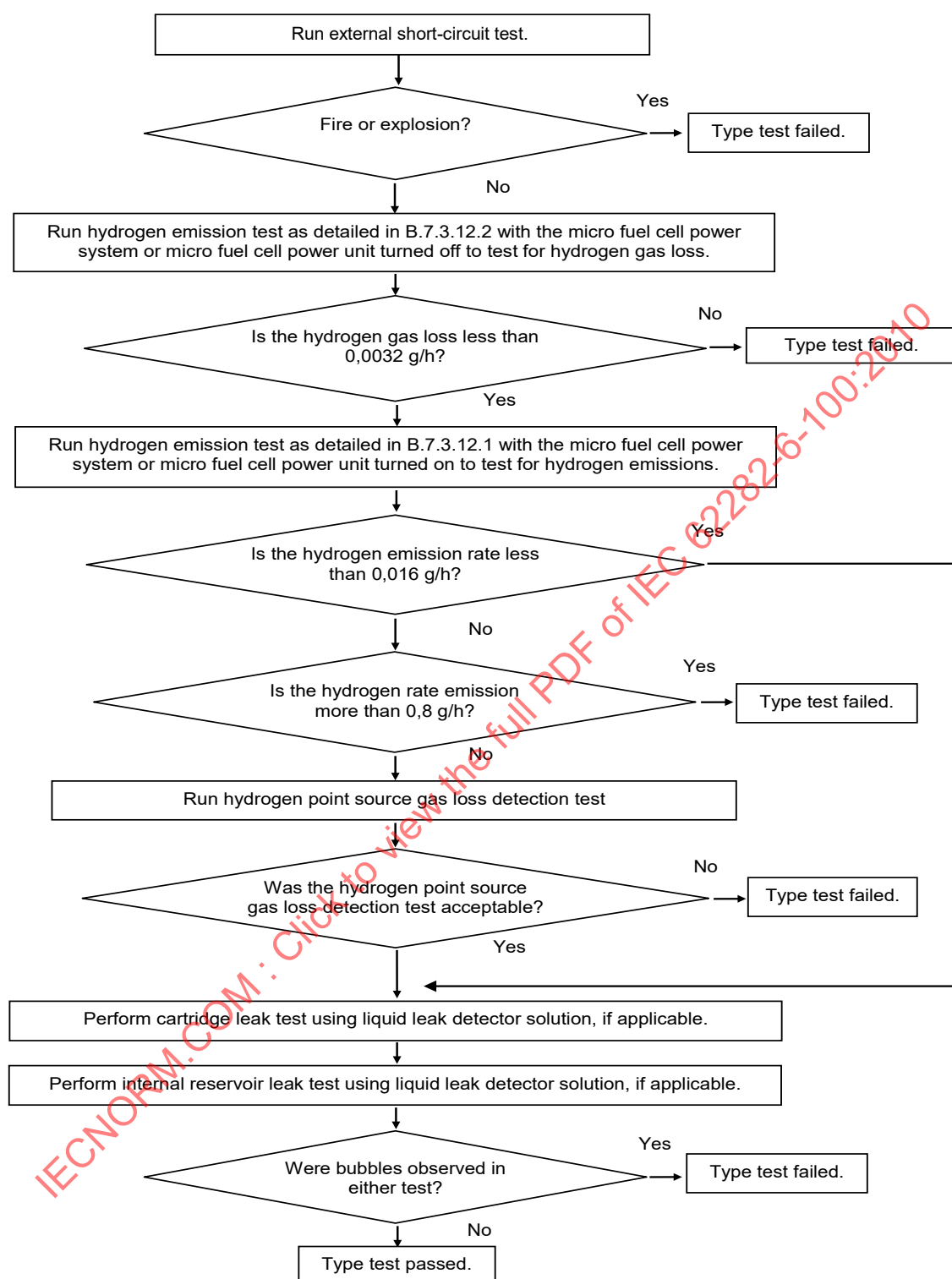


Figure B.4 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour les essais de pression différentielle, de vibrations, de cycle de températures, de chute et de charge de compression – Remplace la Figure 4.



Anglais	Français
Run external short-circuit test	Réaliser l'essai de court-circuit externe
Fire or explosion ?	Feu ou explosion ?
Yes	Oui
No	Non
Type test failed	Echec de l'essai de type
Run hydrogen emission test as detailed in B.7.3.12.2	Réaliser l'essai d'émission d'hydrogène tel que détaillé

Anglais	Français
with the micro fuel cell power system or micro fuel cell power unit turned off to test for hydrogen gas loss	en B.7.3.1.2.2 avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible arrêté pour éprouver les pertes de gaz hydrogène
Is the hydrogen gas loss less than 0,0032 g/h ?	Perte de gaz hydrogène inférieure à 0,003 2 g/h?
Run hydrogen emission test as detailed in B.7.3.12.1 with the micro fuel cell power system or micro fuel cell power unit turned on to test for hydrogen emissions	Réaliser l'essai d'émission d'hydrogène tel que détaillé en B.7.3.1.2.1.avec le système à micropile à combustible ou le bloc d'alimentation de micropile à combustible en marche pour éprouver les émissions d'hydrogène
Is the hydrogen emission rate less than 0,016 g/h ?	Taux d'émission d'hydrogène inférieur à 0,016 g/h?
Is the hydrogen rate emission more than 0,8 g/h ?	Taux d'émission d'hydrogène supérieur à 0,8 g/h?
Run hydrogen point source gas loss detection test	Effectuer l'essai de détection de pertes localisées de gaz hydrogène
Was the hydrogen point source gas loss detection test acceptable ?	Essai de détection de pertes localisées de gaz hydrogène acceptable ?
Perform cartridge leak test using liquid leak detector solution, if applicable	Effectuer l'essai de fuite de cartouche à l'aide d'une solution de détecteur de fuite liquide, si applicable
Perform internal reservoir leak test using liquid leak detector solution, if applicable	Effectuer l'essai de fuite de réservoir interne à l'aide d'une solution de détecteur de fuite liquide, si applicable
Were bubbles observed in either test ?	Observation de bulles dans l'un ou l'autre essai?
Type test passed	Réussite de l'essai de type

Figure B.5 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai de court-circuit externe – Remplace la Figure 5.

B.7.3 Essais de type

B.7.3.1 Essais de pression différentielle

B.7.3.1.1 Généralités

Le B.7.3.1 remplace le 7.3.1.

Des parties de cet essai vérifient la conformité avec le B.4.12.1.2 pour s'assurer qu'il ne doit y avoir ni fuite d'hydrogène ni fuite d'alliage métallique absorbant l'hydrogène provenant de la cartouche de combustible après avoir subi un vide de 95 kPa en dessous de la pression atmosphérique normale à 22 °C ± 5 °C.

B.7.3.1.2 Essai de la cartouche de combustible à basse pression externe

- Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- Objet:** simuler les effets de la basse pression interne sur une cartouche de combustible et garantir l'absence de fuite.
- Procédure d'essai:**

Effectuer cet essai conformément à la Figure B.2.

- 1) L'échantillon doit être placé dans une chambre à vide, et la pression dans la chambre à vide doit être réduite à 95 kPa en dessous de la pression atmosphérique normale.
- 2) Maintenir le vide pendant 30 min.
- 3) Retirer l'échantillon de la chambre à vide et rechercher les fuites à l'aide de la procédure donnée en B.7.2.1 en utilisant une solution de détecteur de fuite liquide (formation de bulle) et examiner visuellement l'échantillon pour rechercher les fuites d'alliage métallique absorbant l'hydrogène.

- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène et aucune fuite d'alliage métallique absorbant l'hydrogène. Voir Figure B.2. La fuite d'hydrogène doit être vérifiée à l'aide de la procédure de mesure des fuites d'hydrogène de B.7.2.1. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.1.3 Essai de pression différentielle de 33,3 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

B.7.3.1.3.1 Généralités

Cet essai est exigé pour tous les systèmes à micropiles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe B. Cet essai peut être réalisé en utilisant l'une ou l'autre de deux méthodes d'essai. Les deux méthodes d'essai éprouvent les échantillons avec un différentiel de pression de 33,3 kPa au moins en utilisant soit une basse pression externe, soit une mise sous pression interne pour obtenir le différentiel de pression de 33,3 kPa.

Soit B.7.3.1.3.2, Essai à basse pression externe à 68 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

soit, en variante;

B.7.3.1.3.3, Essai de mise sous pression interne de 33,3 kPa du système à micropile à combustible ou du bloc d'alimentation électrique des micropiles à combustible, peut être utilisé.

B.7.3.1.3.2 Essai à basse pression externe à 68 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Appareillage d'essai:** Les échantillons d'essai doivent être stockés dans une chambre à vide hermétique à basse pression externe à 68 kPa de pression absolue pendant 6 h. Il est recommandé que la taille de la chambre à vide fournisse plus de 0,022 m³ d'espace d'air libre et moins de 0,28 m³ d'espace d'air libre. La taille de l'enceinte affecte les mesurages de la concentration d'hydrogène et il convient de la sélectionner de façon à assurer la sécurité pendant tout l'essai. Il convient de prendre soin de s'assurer qu'une concentration inflammable d'hydrogène ne s'accumule pas dans l'enceinte hermétique. Un matériel d'échantillonnage approprié doit être utilisé pour le prélèvement effectué pour la concentration d'hydrogène à la fin de la période d'essai.
- d) **Procédure d'essai:**
 - 1) Calculer la concentration d'hydrogène dans l'enceinte d'essai qui résulterait du taux de perte non admissible de gaz hydrogène de 0,0032 g/h d'hydrogène au cours de l'essai de six heures comme suit

$$C_{pv} = \frac{\frac{HLR \times t}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{\frac{0,0032 \frac{g}{h} \times 6h}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{0,213l}{V} \times 100$$

où:

C_{pv} est la concentration d'hydrogène en % en volume qui résulterait d'un taux de perte de gaz hydrogène de 0,0032 g/h d'hydrogène dans la chambre à vide en 6 h;

V est le volume de l'espace libre dans la chambre à vide, en litres normalisés;

HLR est le taux de perte non admissible de gaz hydrogène de 0,0032 g/h;

t est la durée de l'essai, en l'occurrence, 6 h;

ou par simplification:

$$C_{pv} = \frac{0,213I}{V} \times 100$$

où

C_{pv} est la concentration d'hydrogène en % en volume qui résulterait d'un taux de perte de gaz hydrogène de 0,0032 g/h d'hydrogène dans la chambre à vide en 6 h;

V est le volume de l'espace libre dans la chambre à vide, en litres normalisés.

Par exemple, dans une chambre à vide comportant 0,28 m³ d'espace d'air libre, la concentration d'hydrogène de 0,08 % indique une perte de gaz hydrogène de 0,003 2 g/h et échoue à l'essai.

- 2) Les échantillons d'essai doivent être stockés dans la chambre à vide hermétique à basse pression externe à 68 kPa de pression absolue pendant au moins 6 h à la température ambiante du laboratoire.
- 3) À la fin de la période d'essai de six heures, mettre sous pression de nouveau la chambre à vide à 101,3 kPa avec de l'air de pureté connue ou en bouteille qui satisfait aux exigences relatives à l'atmosphère de laboratoire données au Tableau B.6. Laisser l'atmosphère dans la chambre à vide se stabiliser ou assurer un mélange approprié. L'atmosphère dans la chambre à vide doit ensuite être vérifiée pour détecter sa concentration en hydrogène.
- 4) Comparer la valeur mesurée de la concentration d'hydrogène dans la chambre à vide à la concentration d'hydrogène qui résulterait d'un taux de perte de gaz hydrogène de 0,0032 g/h calculée en 1) ci-dessus.
- 5) Le taux de perte de gaz hydrogène doit être inférieur à la limite de perte non admissible de gaz hydrogène de 0,0032 g/h conformément à B.3.38 et il doit être calculé en s'assurant que la concentration d'hydrogène dans la chambre à vide est inférieure à la concentration d'hydrogène calculée qui résulterait d'un taux de perte de gaz hydrogène de 0,0032 g/h. Si la concentration d'hydrogène dans la chambre à vide est inférieure à la concentration d'hydrogène C_{pv} calculée en 1) ci-dessus, alors l'échantillon d'essai satisfait à l'essai pour la perte de gaz hydrogène.
- 6) À la suite de l'essai de pression différentielle, retirer l'échantillon d'essai de la chambre à vide et effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2.
- 7) Si l'échantillon d'essai contient une cartouche de combustible, effectuer le mesurage de fuite d'hydrogène conformément à B.7.2.1 sur la cartouche de combustible. Aucune fuite d'hydrogène n'est permise.
- 8) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient un réservoir interne avec du gaz hydrogène à une pression supérieure à la pression ambiante; les fuites d'hydrogène doivent être vérifiées en B.7.3.3. Voir B.7.3.3 c) 7) iii).

e) **Critères de réussite:**

- 1) Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. La perte de gaz hydrogène au cours de l'essai doit être inférieure à la limite de perte non admissible de gaz hydrogène de 0,0032 g/h conformément à B.3.38. La concentration d'hydrogène dans

la chambre à vide doit être inférieure à la concentration d'hydrogène calculée [C_{pv}] qui résulterait d'un taux de perte de gaz hydrogène de 0,0032 g/h. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

- 2) Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la suite de l'essai de type. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est pas opérationnel à la suite de l'essai de type, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable

B.7.3.1.3.3 Essai de mise sous pression interne de 33,3 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Appareillage d'essai:** Une enceinte d'essai d'échantillonnage doit être équipée d'une ventilation et d'appareils d'échantillonnage et de mesure capables de mesurer précisément le débit d'air à travers l'enceinte d'essai ainsi que la concentration d'hydrogène dans l'enceinte d'essai. L'enceinte d'essai peut être similaire à l'appareillage d'essai d'émissions représenté à la Figure B.10. L'enceinte d'essai doit être alimentée en air propre provenant d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- d) **Procédure d'essai**
 - 1) Introduire les échantillons dans l'enceinte d'essai d'échantillonnage à la température du laboratoire.
 - 2) A l'aide d'adaptateurs appropriés, brancher le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à une source à régulation de pression d'hydrogène pur située à l'extérieur de l'enceinte d'échantillonnage.
 - 3) Mettre sous pression le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à une pression manométrique de 33,3 kPa avec la source à régulation de pression d'hydrogène pur suffisante pour maintenir la pression manométrique de 33,3 kPa à l'intérieur du bloc d'alimentation électrique des micropiles à combustible pendant toute la durée de l'essai de six heures.
 - 4) Les échantillons doivent rester sous pression à la pression manométrique de 33,3 kPa dans l'enceinte d'essai d'échantillonnage pendant au moins 6 h à la température du laboratoire.
 - 5) Les pertes de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées en continu à la sortie de l'enceinte d'essai, à un orifice d'échantillonnage semblable à l'orifice A représenté à la Figure B.10.
 - 6) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers un orifice d'échantillonnage d'air semblable à l'orifice A représenté à la Figure 10, tout en mesurant et enregistrant simultanément le débit d'air total à travers l'enceinte d'essai. Le débit d'air total à travers l'enceinte d'essai peut être calculé à partir de la somme du débit d'air à la sortie et du débit d'échantillon à travers l'orifice d'échantillonnage de l'air A ou en mesurant le débit d'air d'admission à l'enceinte d'essai. Le débit à travers

l'enceinte d'essai et la concentration d'hydrogène dans l'enceinte d'essai doivent être surveillés de façon continue.

- 7) Calculer le taux de perte de gaz hydrogène en multipliant la concentration d'hydrogène dans l'enceinte d'essai par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air à la sortie en régime établi à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux de fuite de gaz hydrogène.

Voir ci-dessous:

$$HLR = (F_O + F_S) \times C$$

ou

$$HLR = (F_i) \times C$$

où

HLR est le taux de perte de gaz hydrogène en grammes par heure;

F_O est le débit d'air de sortie en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration d'hydrogène en grammes par litre normalisé.

- 8) Comparer la valeur maximale calculée du taux de perte de gaz hydrogène à la limite de perte non admissible de gaz hydrogène de 0,0032 g/h. Si la valeur maximale calculée du taux de perte de gaz hydrogène est inférieure à la limite de perte non admissible de gaz hydrogène de 0,0032 g/h, le système satisfait à l'essai pour les pertes de gaz hydrogène.
- 9) À la suite de l'essai de pression différentielle, retirer l'échantillon d'essai de l'enceinte, ramener l'échantillon à la pression normale de fonctionnement et effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2.
- 10) Si l'échantillon d'essai contient une cartouche de combustible, effectuer le mesurage de fuite d'hydrogène conformément à B.7.2.1 sur la cartouche de combustible. Aucune fuite d'hydrogène n'est permise.
- 11) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient un réservoir interne avec du gaz hydrogène à une pression supérieure à la pression ambiante; les fuites d'hydrogène doivent être vérifiées en B.7.3.3. Voir B.7.3.3 c) 7) iii).

e) Critères de réussite:

- 1) Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. La perte de gaz hydrogène au cours de l'essai doit être inférieure à la limite de perte non admissible de gaz hydrogène de 0,0032 g/h conformément à B.3.38. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.
- 2) Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la suite de l'essai de type. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est pas

opérationnel à la suite de l'essai de type, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable

B.7.3.1.4 Essai de pression différentielle de 89,7 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

B.7.3.1.4.1 Généralités

Cet essai est exigé pour tous les systèmes à micropiles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe B. Cet essai peut être réalisé en utilisant l'une ou l'autre de deux méthodes d'essai. Les deux méthodes d'essai éprouvent les échantillons avec un différentiel de pression de 89,7 kPa au moins en utilisant soit une basse pression externe, soit une mise sous pression interne pour obtenir le différentiel de pression de 89,7 kPa.

Soit B.7.3.1.4.2, Essai à basse pression externe à 11,6 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

soit, en variante;

B.7.3.1.4.3, Essai de mise sous pression interne de 89,7 kPa du système à micropile à combustible ou du bloc d'alimentation électrique des micropiles à combustible, peut être utilisé.

B.7.3.1.4.2 Essai à basse pression externe à 11,6 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

- Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite. Les pertes de gaz hydrogène doivent être inférieures à 0,08 g/h, ne devant pas dépasser 25 % de la limite inférieure d'inflammabilité dans une période de 1 h.
- Appareillage d'essai:** Les échantillons d'essai doivent être stockés dans une chambre à vide hermétique à basse pression externe à 11,6 kPa de pression absolue pendant 1 h. Il est recommandé que la taille de la chambre à vide fournisse plus de 0,09 m³ d'espace d'air libre et moins de 0,28 m³ d'espace d'air libre. La taille de l'enceinte affecte les mesurages de la concentration d'hydrogène et il convient de la sélectionner de façon à assurer la sécurité pendant tout l'essai. Il convient de prendre soin de s'assurer qu'une concentration inflammable d'hydrogène ne s'accumule pas dans l'enceinte hermétique. Un matériel d'échantillonnage approprié doit être utilisé pour le prélèvement effectué pour la concentration d'hydrogène à la fin de la période d'essai.
- Procédure d'essai:**

- Calculer la concentration d'hydrogène dans l'enceinte d'essai qui résulterait du taux de perte maximal admissible de gaz hydrogène de 0,08 g/h d'hydrogène au cours de l'essai de 1 h comme suit

$$C_{pv} = \frac{\frac{HLR \times t}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{\frac{0,08 \frac{g}{h} \times 1h}{2 \times 1,00794 \frac{g}{mol}} \times 22,4 \frac{l}{mol}}{V} \times 100 = \frac{0,9l}{V} \times 100$$

où

C_{pv} est la concentration d'hydrogène en % en volume qui résulterait d'un taux de perte de gaz hydrogène de 0,08 g/h d'hydrogène dans la chambre à vide en 1 h;

V est le volume de l'espace libre dans la chambre à vide, en litres normalisés;

HLR est le taux de perte maximal admissible de gaz hydrogène de 0,08 g/h;

t est la durée de l'essai, en l'occurrence, 1 h;

ou par simplification:

$$C_{pv} = \frac{0,9I}{V} \times 100$$

où

C_{pv} est la concentration d'hydrogène en % en volume qui résulterait d'un taux de perte de gaz hydrogène de 0,08 g/h d'hydrogène dans la chambre à vide en 1 h;

V est le volume de l'espace libre dans la chambre à vide, en litres normalisés.

Par exemple, dans une chambre à vide comportant 0,28 m³ d'espace d'air libre, la concentration d'hydrogène de 0,32 % indique une perte de gaz hydrogène de 0,08 g/h et échoue à l'essai.

- 2) Les échantillons d'essai doivent être stockés dans la chambre à vide hermétique à basse pression externe à 11,6 kPa de pression absolue pendant au moins 1 h à la température ambiante du laboratoire.
- 3) À la fin de la période d'essai de 1 h, mettre sous pression de nouveau la chambre à vide à 101,3 kPa avec de l'air de pureté connue ou en bouteille qui satisfait aux exigences relatives à l'atmosphère de laboratoire données au Tableau B.6. Laisser l'atmosphère dans la chambre à vide se stabiliser ou assurer un mélange approprié. L'atmosphère dans la chambre à vide doit ensuite être vérifiée pour détecter sa concentration en hydrogène.
- 4) Comparer la valeur mesurée de la concentration d'hydrogène dans la chambre à vide à la concentration d'hydrogène qui résulterait d'un taux de perte de gaz hydrogène de 0,08 g/h calculée en 1) ci-dessus.
- 5) Les pertes de gaz hydrogène doivent être inférieures à 0,08 g/h, ne devant pas dépasser 25 % de la limite inférieure d'inflammabilité dans une période de 1 h. Elles doivent être déterminées en garantissant que la concentration d'hydrogène dans la chambre à vide est inférieure à la concentration d'hydrogène calculée qui résulterait d'un taux de perte de gaz hydrogène inférieur à la concentration d'hydrogène calculée qui résulterait d'un taux de perte de gaz hydrogène de 0,08 g/h. Si la concentration d'hydrogène dans la chambre à vide est inférieure à la concentration d'hydrogène C_{pv} calculée en 1) ci-dessus, alors l'échantillon d'essai satisfait à l'essai pour la perte de gaz hydrogène.
- 6) À la suite de l'essai de pression différentielle, retirer l'échantillon d'essai de la chambre à vide et effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2.
- 7) Si l'échantillon d'essai contient une cartouche de combustible, effectuer le mesurage de fuite d'hydrogène conformément à B.7.2.1 sur la cartouche de combustible. Aucune fuite d'hydrogène n'est permise.
- 8) Si l'échantillon d'essai contient un réservoir interne avec du gaz hydrogène à une pression supérieure à la pression ambiante, effectuer le mesurage de fuite d'hydrogène conformément à B.7.2.1 sur le réservoir interne. Aucune fuite d'hydrogène n'est permise.

e) Critères de réussite:

- 1) Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène pendant l'essai doivent être inférieures à 0,08 g/h, ne devant pas dépasser 25 % de la limite inférieure d'inflammabilité dans une période de 1 h. La concentration d'hydrogène dans la chambre à vide doit être inférieure à la concentration d'hydrogène calculée [C_{pv}] qui résulterait d'un taux de perte de gaz hydrogène de 0,08 g/h. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc

d'alimentation électrique de la micropile à combustible. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

- 2) Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la suite de l'essai de type. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est pas opérationnel à la suite de l'essai de type, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable.

B.7.3.1.4.3 Essai de mise sous pression interne de 89,7 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à micropile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Appareillage d'essai:** Une enceinte d'essai d'échantillonnage doit être équipée d'une ventilation et d'appareils d'échantillonnage et de mesure capables de mesurer précisément le débit d'air à travers l'enceinte d'essai ainsi que la concentration d'hydrogène dans l'enceinte d'essai. L'enceinte d'essai peut être similaire à l'appareillage d'essai d'émissions représenté à la Figure B.10. L'enceinte d'essai doit être alimentée en air propre provenant d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- d) **Procédure d'essai:**
 - 1) Introduire les échantillons dans l'enceinte d'essai d'échantillonnage à la température du laboratoire
 - 2) À l'aide d'adaptateurs appropriés, brancher le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à une source à régulation de pression d'hydrogène pur située à l'extérieur de l'enceinte d'échantillonnage
 - 3) Mettre sous pression le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à une pression manométrique de 89,7 kPa avec la source à régulation de pression d'hydrogène pur suffisante pour maintenir la pression manométrique de 89,7 kPa à l'intérieur du bloc d'alimentation électrique des micropiles à combustible pendant toute la durée de l'essai de 1 h.
 - 4) Les échantillons doivent rester sous pression à la pression manométrique de 89,7 kPa dans l'enceinte d'essai d'échantillonnage pendant au moins 1 h à la température du laboratoire.
 - 5) Les pertes de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropiles à combustible doivent être échantillonnées en continu à la sortie de l'enceinte d'essai, à un orifice d'échantillonnage semblable à l'orifice A représenté à la Figure B.10.
 - 6) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers un orifice d'échantillonnage d'air semblable à l'orifice A représenté à la Figure 10, tout en mesurant et enregistrant simultanément le débit d'air total à travers l'enceinte d'essai. Le débit d'air total à travers l'enceinte d'essai peut être calculé à partir de la somme du débit d'air à la sortie et du débit d'échantillon à travers l'orifice d'échantillonnage de l'air A ou en mesurant le débit d'air d'admission à l'enceinte d'essai. Le débit à travers l'enceinte d'essai et la concentration d'hydrogène dans l'enceinte d'essai doivent être surveillés de façon continue.
 - 7) Calculer le taux de perte de gaz hydrogène en multipliant la concentration d'hydrogène dans l'enceinte d'essai par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air à la sortie en régime établi à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux de fuite de gaz hydrogène.

Voir ci-dessous:

$$HLR = (F_o + F_S) \times C$$

ou

$$HLR = (F_i) \times C$$

où

HLR est le taux de perte de gaz hydrogène en grammes par heure;

F_o est le débit d'air de sortie en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration d'hydrogène en grammes par litre normalisé;

- 8) Comparer le taux de perte maximal calculé de gaz hydrogène à 0,08 g/h, ne devant pas dépasser 25 % de la limite inférieure d'inflammabilité dans une période de 1 h. Si le taux de perte maximal calculé de gaz hydrogène est inférieur à 0,08 g/h, le système réussit les pertes de gaz hydrogène.
- 9) À la suite de l'essai de pression différentielle, retirer l'échantillon d'essai de l'enceinte, ramener l'échantillon à la pression normale de fonctionnement et effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2.
- 10) Si l'échantillon d'essai contient une cartouche de combustible, effectuer le mesurage de fuite d'hydrogène conformément à B.7.2.1 sur la cartouche de combustible. Aucune fuite d'hydrogène n'est permise.
- 11) Si l'échantillon d'essai contient un réservoir interne avec du gaz hydrogène à une pression supérieure à la pression ambiante, effectuer le mesurage de fuite d'hydrogène conformément à B.7.2.1 sur le réservoir interne. Aucune fuite d'hydrogène n'est permise.

e) Critères de réussite:

- 1) Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène pendant l'essai doivent être inférieures à 0,08 g/h, ne devant pas dépasser 25 % de la limite inférieure d'inflammabilité dans une période de 1 h. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.
- 2) Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la suite de l'essai de type. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est pas opérationnel à la suite de l'essai de type, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable

B.7.3.2 Essai de vibrations

Le B.7.3.2 remplace le 7.3.2 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible remplie partiellement, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible utilisé en B.7.3.1.3.
- b) **Objet:** simuler les effets des vibrations au cours de conditions normales de transport, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
- 1) Effectuer ces essais conformément à la Figure B.2 pour la cartouche de combustible et conformément à la Figure B.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) L'échantillon d'essai doit être fixé solidement à la plate-forme du générateur de vibrations, sans déformer l'échantillon, et de manière à émettre correctement les vibrations.
 - 3) Les vibrations doivent être de forme d'onde sinusoïdale avec un balayage logarithmique entre 7 Hz et 200 Hz et de nouveau à 7 Hz, traversé en 15 min.
 - 4) Ce cycle doit être répété 12 fois pendant 3 h au total pour chacune des trois positions de montage perpendiculaires des échantillons d'essai.
 - 5) Le balayage en fréquence logarithmique se déroule comme suit: à partir de 7 Hz, une accélération de crête de 1 g_n est maintenue jusqu'à ce que la valeur de 18 Hz soit atteinte. L'amplitude est ensuite maintenue à 0,8 mm (excursion totale de 1,6 mm) et la fréquence est augmentée jusqu'à ce qu'une accélération de crête de 8 g_n se produise (environ 50 Hz). Une accélération de crête de 8 g_n est ensuite maintenue jusqu'à ce que la fréquence soit portée à 200 Hz.
 - 6) Pour la cartouche de combustible, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1. Voir Figure B.2.
 - 7) Pour le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible, effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2. Voir Figure B.4.
 - 8) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient une cartouche de combustible, effectuer le mesurage de fuite d'hydrogène conformément à B.7.2.1.
 - 9) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient un réservoir interne avec du gaz hydrogène à une pression supérieure à la pression ambiante; les fuites d'hydrogène doivent être vérifiées en B.7.3.3. Voir B.7.3.3 c) 7) iii).
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. Le feu ou la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement. Si le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible n'est pas opérationnel, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable.

B.7.3.3 Essai de cycles de températures

Le B.7.3.3 remplace le 7.3.3 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

- a) **Échantillon d'essai:** cartouche de combustible utilisée en B.7.3.2, cartouche de combustible remplie partiellement utilisée en B.7.3.2, bloc d'alimentation électrique de la

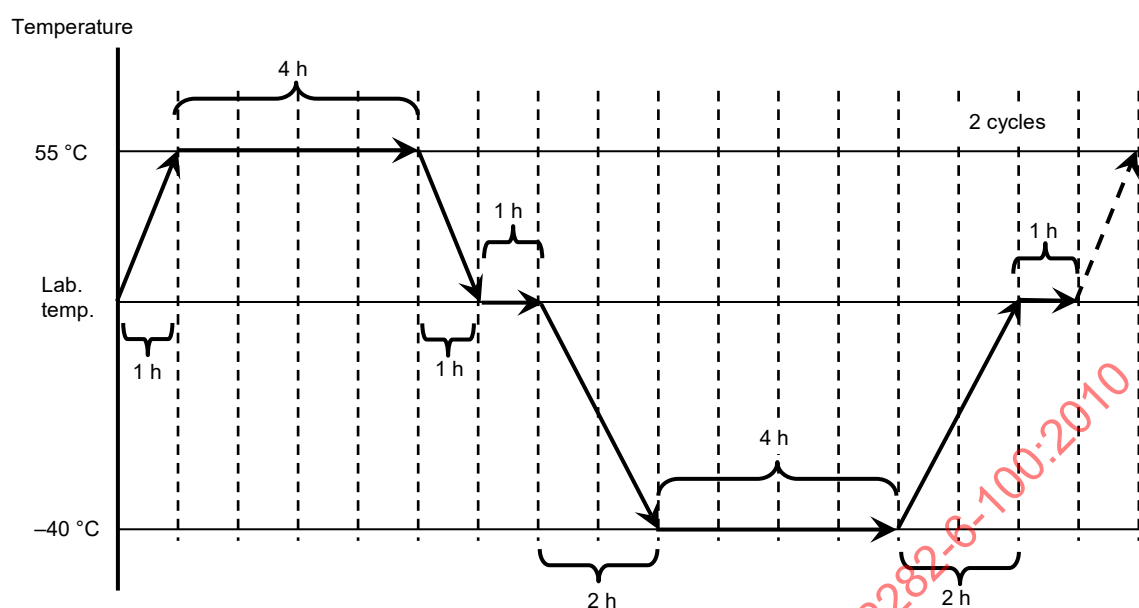
micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant utilisé en B.7.3.2, ou système à micropile à combustible utilisé en B.7.3.2.

b) **Objet:** simuler les effets d'une exposition à basse température et à température élevée et les effets de variations extrêmes de températures.

c) **Procédure d'essai:**

- 1) Pour une cartouche de combustible, deux orientations de cartouches de combustible doivent être soumises à l'essai – vanne vers le haut et vanne vers le bas. Pour un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible, il n'est pas nécessaire de vérifier par essai plus d'une orientation.
- 2) Voir Figure B.8 pour le profil de température à utiliser.
- 3) Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, et augmenter la température de l'enceinte de la température de laboratoire à $55\text{ °C} \pm 2\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$, et la maintenir à $55\text{ °C} \pm 2\text{ °C}$ pendant au moins 4 h.
- 4) Diminuer la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$, puis diminuer la température de l'enceinte à $-40\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$, et la maintenir à $-40\text{ °C} \pm 5\text{ °C}$ pendant au moins 4 h.
- 5) Augmenter la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$.
- 6) Le processus ci-dessus doit être réalisé deux fois.
- 7) Après 1 h à $22\text{ °C} \pm 5\text{ °C}$, effectuer les essais de fuite d'hydrogène suivants.
 - i) Pour la cartouche de combustible, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1. Voir Figure B.2.
 - ii) Pour le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible, effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2. (Ceci inclut les essais d'émissions d'hydrogène conformément à B.7.3.12). Voir Figure B.4.
 - iii) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient une cartouche de combustible ou un réservoir interne qui contient du gaz hydrogène à une pression supérieure à la pression ambiante, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1.

d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les émissions d'hydrogène doivent satisfaire aux critères de réussite en B.7.3.12. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement. Si le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible n'est pas opérationnel, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable.



Anglais	Français
Temperature	Température
Lab. temp.	Température du laboratoire
2 cycles	Deux cycles

Figure B.8 – Cycles de température – Remplace la Figure 8

B.7.3.4 Essai d'exposition à température élevée

Le B.7.3.4 remplace le 7.3.4 pour les cartouches de combustible traitées par la présente Annexe B.

- Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- Objet:** simuler les effets d'une cartouche de combustible laissée dans des environnements à température élevée.
- Procédure d'essai:**
 - Deux orientations doivent être soumises à l'essai – vanne vers le haut et vanne vers le bas.
 - Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, à une température de $70\text{ °C} \pm 2\text{ °C}$, et laisser la température de l'enceinte revenir à $70\text{ °C} \pm 2\text{ °C}$, et maintenir cette température pendant au moins 4 h avec l'échantillon dans l'enceinte.
 - Retirer l'échantillon d'essai à la température de laboratoire.
 - Effectuer les mesurages de fuites d'hydrogène conformément à B.7.2.1. Voir Figure B.2.
- Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.5 Essai de chute

Le B.7.3.5 remplace le 7.3.5 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

Si l'essai de chute décrit en 6.2.4 de l'ISO 16111:2008 est effectué à l'aide de la même cartouche de combustible pour chacune des quatre orientations de chute, l'essai de chute de la cartouche de combustible de B.7.3.5 n'est pas exigé. L'essai de chute de l'ISO 16111:2008 est considéré comme plus rigoureux, et par conséquent plus que suffisant pour assurer une sécurité adéquate de la cartouche de combustible. Si l'essai de chute de l'ISO 16111:2008 est effectué à l'aide d'une cartouche de combustible différente pour chaque orientation de chute, l'essai de chute de la cartouche de combustible de B.7.3.5 doit être effectué en plus de l'essai de chute de l'ISO 16111:2008.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible remplie partiellement, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets d'une chute involontaire, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) L'échantillon d'essai doit chuter sur une surface horizontale se composant de bois dur d'au moins 13 mm d'épaisseur monté sur deux couches de contreplaqué, chacune d'une épaisseur de 18 mm à 20 mm, le tout sur un sol en béton ou en matériau équivalent non élastique, à partir d'une hauteur prédéterminée.
 - 2) La hauteur de chute doit être de:
 - i) 1 200 mm $\pm$ 10 mm: dans le cas d'un bloc d'alimentation électrique de la micropile à combustible et/ou d'un système à micropile à combustible;
 - ii) 1 500 mm $\pm$ 10 mm: dans le cas d'une cartouche de combustible avec une capacité en eau de plus de 200 ml;
 - 3) 1 800 mm $\pm$ 10 mm: dans le cas d'une cartouche de combustible avec une capacité en eau jusqu'à 200 ml maximum.
 - 4) Pour les essais de la cartouche de combustible, l'essai de chute doit être effectué dans quatre orientations de chute avec le même échantillon.
 - 5) Pour le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible, un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible peut être utilisé pour chacune des quatre orientations de chute, ou plusieurs systèmes à micropiles à combustible ou blocs d'alimentation électrique de micropiles à combustible peuvent être utilisés pour les chutes suivantes, à l'initiative du fabricant.
 - 6) Pour tous les essais, les orientations de chute doivent être les suivantes:
 - i) vanne vers le haut;
 - ii) vanne vers le bas;
 - iii) Deux autres orientations perpendiculaires.
 - 7) Après chaque essai de chute, effectuer les essais de fuite d'hydrogène suivants.
 - i) Pour la cartouche de combustible, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1. Voir Figure B.2.
 - ii) Pour le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible, effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2. (Ceci inclut les essais d'émissions d'hydrogène conformément à B.7.3.12.) Voir Figure B.4.
 - iii) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient une cartouche de combustible ou un réservoir

interne qui contient du gaz hydrogène à une pression supérieure à la pression ambiante, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1.

- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les émissions d'hydrogène doivent satisfaire aux critères de réussite en B.7.3.12. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement. Si le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible n'est pas opérationnel, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable.

Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible est toujours en état de fonctionnement, les circuits de protection spécifiés par l'AMDE en tant que parties des systèmes de sécurité doivent toujours être pleinement fonctionnels. Il ne doit pas y avoir d'exposition des parties dangereuses.

B.7.3.6 Essai de charge de compression

Le B.7.3.6 remplace le 7.3.6 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

B.7.3.6.1 Système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur le bloc d'alimentation électrique de la micropile à combustible, ou le système à micropile à combustible.
- c) **Procédure d'essai:**
- 1) L'échantillon d'essai du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer à l'échantillon une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$.
 - 2) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).
 - 3) Une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 4) L'essai doit en général être effectué dans trois orientations perpendiculaires. Si l'échantillon n'est pas stable de lui-même, il n'est pas nécessaire qu'il soit soumis à l'essai dans cette orientation.
 - 5) Après l'essai de charge de compression, effectuer les essais de fuites d'hydrogène suivants.
 - i) Pour le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible, effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2. (Ceci inclut les essais d'émissions d'hydrogène conformément à B.7.3.12.) Voir Figure B.4.
 - ii) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient une cartouche de combustible ou un réservoir interne qui contient du gaz hydrogène à une pression supérieure à la pression ambiante, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1.

- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les émissions d'hydrogène doivent satisfaire aux critères de réussite en B.7.3.12. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement. Si le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible n'est pas opérationnel, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable.

B.7.3.6.2 Cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur la cartouche de combustible.
- c) **Procédure d'essai:**
- 1) L'échantillon d'essai de la cartouche de combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer à l'échantillon une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$.
 - 2) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).
 - 3) Une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 4) Les orientations de la cartouche de combustible doivent être choisies d'après les positions de repos en principe stables lors de chutes accidentelles (par exemple, les orientations ayant les centres de gravité les plus bas par rapport à la surface de repos). Il est acceptable de soumettre aux essais une seule surface d'une cartouche de combustible prismatique qui soit suffisamment cubique et la surface incurvée d'une cartouche de combustible cylindrique avec une longueur d'axe longitudinal supérieure à deux fois le diamètre.
 - 5) Pour l'échantillon: effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1. Voir Figure B.2.
- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.7 Essai de court-circuit externe

Le B.7.3.7 remplace le 7.3.7 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets d'un court-circuit externe.
- c) **Procédure d'essai:**
- 1) L'essai de court-circuit externe doit être effectué séparément et respectivement à la fois sur les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible en fonctionnement [DISPOSITIF EN POSITION «ON»] et

sur les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible en état de non-fonctionnement [DISPOSITIF EN POSITION «OFF»].

- 2) Chaque échantillon d'essai doit être court-circuité en reliant les bornes positive et négative du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible avec des conducteurs ayant une charge de résistance maximale de 0,1 Ω pendant au moins 5 min.
- 3) A la suite de l'essai de court-circuit, effectuer les essais de fuites d'hydrogène suivants conformément à Figure B.5.
 - i) Pour le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible, effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2. (Ceci inclut les essais d'émissions d'hydrogène conformément à B.7.3.12.) Voir Figure B.4.
 - ii) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient une cartouche de combustible ou un réservoir interne qui contient du gaz hydrogène à une pression supérieure à la pression ambiante, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1.
- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les émissions d'hydrogène doivent satisfaire aux critères de réussite en B.7.3.12. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement. Si le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible n'est pas opérationnel, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable.

Les surfaces externes ne doivent pas dépasser les températures du Tableau 2, pendant ou après les essais de court-circuit.

NOTE L'essai de court-circuit externe peut être réalisé de manière séquentielle avec l'essai de température de surface, de composant et de gaz d'échappement, en utilisant le même échantillon.

B.7.3.9 Essai de stockage de longue durée

B.7.3.9.1 Généralités

Le B.7.3.9 remplace le 7.3.9 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

Cinq options sont disponibles. N'importe quelle option peut être utilisée.

- 1) B.7.3.9.2 Option 1 – Mesurage en continu de la concentration d'hydrogène;
- 2) B.7.3.9.3 Option 2 – Mesurage de la concentration d'hydrogène à débit régulé;
- 3) B.7.3.9.4 Option 3 – Mesurage en continu du poids;
- 4) B.7.3.9.5 Option 4 – Mesurages périodiques du poids; ou,
- 5) B.7.3.9.6 Option 5 – Un seul mesurage du poids.

B.7.3.9.2 Option 1 – Mesurage en continu de la concentration d'hydrogène

- e) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- f) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.

g) **Appareillage d'essai:** Une enceinte d'essai de température doit être équipée d'appareils d'échantillonnage et de surveillance capables de mesurer précisément le débit d'air à travers l'enceinte d'essai ainsi que la concentration d'hydrogène dans l'enceinte d'essai. Cette enceinte d'essai de température peut être similaire à l'appareillage d'essai d'émissions représenté à la Figure B.10. L'enceinte d'essai de température doit être équipée de réchauffeurs capables de maintenir une température interne de $50\text{ °C} \pm 2\text{ °C}$ avec circulation d'air à travers le système. Il est recommandé d'équiper l'enceinte d'essai d'un capteur d'hydrogène ou autres caractéristiques de sécurité équivalentes pour assurer qu'aucune concentration inflammable d'hydrogène ne peut s'accumuler dans un volume clos.

h) **Procédure d'essai:**

- 1) L'enceinte d'essai doit être équipée d'un ventilateur de brassage, d'une ventilation et d'appareils de mesure capables de mesurer précisément le débit d'air à travers l'enceinte et de mesurer précisément la concentration d'hydrogène dans l'enceinte, selon la même configuration que celle de la Figure B.10.
- 2) L'enceinte d'essai doit être alimentée en air propre provenant d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- 3) Placer l'échantillon dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$.
- 4) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours.
- 5) Les pertes de gaz hydrogène de la cartouche de combustible doivent être échantillonnées en continu à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage de l'air semblable à celui représenté à la Figure B.10.
- 6) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers un orifice d'échantillonnage d'air semblable à l'orifice A représenté à la Figure 10, tout en mesurant et enregistrant simultanément le débit d'air total à travers l'enceinte d'essai. Le débit d'air total à travers l'enceinte d'essai peut être calculé à partir de la somme du débit d'air à la sortie et du débit d'échantillon à travers l'orifice d'échantillonnage de l'air A ou en mesurant le débit d'air d'admission à l'enceinte d'essai. Le débit à travers l'enceinte d'essai et la concentration d'hydrogène dans l'enceinte d'essai doivent être surveillés de façon continue.
- 7) Calculer le taux de perte de gaz hydrogène en multipliant la concentration d'hydrogène dans l'enceinte d'essai par le débit d'air simultanément total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air à la sortie en régime établi à travers le système au débit d'échantillon simultanément ou en mesurant le débit d'air d'admission.

NOTE – Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux de fuite de gaz hydrogène.

Voir ci-dessous:

$$HLR = (F_o + F_s) \times C$$

ou

$$HLR = (F_i) \times C$$

où

HLR est le taux de perte de gaz hydrogène en grammes par heure;

F_o est le débit d'air de sortie en litres normalisés par heure;

F_s est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration d'hydrogène en grammes par litre normalisé.

- 8) À la fin des 28 jours, effectuer les essais de fuite d'hydrogène, conformément à l'essai de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. Si la cartouche de combustible est vide d'hydrogène à la fin des 28 jours, remplir la cartouche (ou la mettre sous pression à l'aide d'un gaz inerte approprié) à la pression de charge assignée conformément aux instructions du fabricant avant d'effectuer le mesurage des fuites d'hydrogène.
- i) **Critères de réussite:** Aucune fuite d'alliage métallique absorbant l'hydrogène, aucun feu et aucune explosion. Aucune fuite d'hydrogène à la fin de la période de 28 jours comme spécifié par la procédure de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. La concentration d'hydrogène dans l'enceinte d'essai de température ne doit pas dépasser 25 % de la LII à aucun moment au cours de l'essai. Le taux de perte de gaz hydrogène en provenance de la cartouche doit être inférieur à 0,0032 g/h à tout moment au cours de l'essai. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.9.3 Option 2 – Mesurage de la concentration d'hydrogène à débit régulé

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Appareillage d'essai:** Une enceinte d'essai de température doit être équipée d'appareils d'échantillonnage et de surveillance capables de mesurer précisément le débit d'air à travers l'enceinte d'essai ainsi que la concentration d'hydrogène dans l'enceinte d'essai. Cette enceinte d'essai de température peut être similaire à l'appareillage d'essai d'émissions représenté à la Figure B.10. L'enceinte d'essai de température doit être équipée de réchauffeurs capables de maintenir une température interne de $50\text{ °C} \pm 2\text{ °C}$ avec circulation d'air à travers le système. Il est recommandé d'équiper l'enceinte d'essai d'un capteur d'hydrogène ou autres caractéristiques de sécurité équivalentes pour assurer qu'aucune concentration inflammable d'hydrogène ne peut s'accumuler dans un volume clos.
- d) **Procédure d'essai:**
- 1) L'enceinte d'essai doit être équipée d'un ventilateur de brassage, d'une ventilation et d'appareils de mesure capables de mesurer précisément le débit d'air à travers l'enceinte ainsi que d'un détecteur d'hydrogène étalonné pour détecter une concentration d'hydrogène de 25% de la LII (1 % en volume). Le détecteur d'hydrogène doit fournir une alarme ou autre indication de la présence d'une concentration d'hydrogène de 25 % de la LII (1% en volume) dans l'enceinte d'essai. L'enceinte d'essai doit avoir un volume d'air libre (volume total moins volume de la cartouche de combustible et des instruments à l'intérieur de l'enceinte) de moins de 3,56 l pour assurer un mélange adéquat et une distribution uniforme dans l'enceinte. L'enceinte d'essai peut utiliser une configuration semblable à celle représentée à la Figure B.10, avec les modifications appropriées apportées en fonction des limitations de l'espace d'air libre.
 - 2) L'enceinte d'essai doit être alimentée en air propre provenant d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
 - 3) Le débit d'air à travers l'enceinte doit être régulé de telle sorte qu'un taux de perte de gaz hydrogène à partir de la cartouche égal à 0,0032 g/h se traduise par une concentration d'hydrogène égale à 25 % de la LII (1 % en volume) et conduise à une alarme ou autre indication du détecteur d'hydrogène, conformément à la formule suivante:

$$F_t = \frac{HLR \times SV}{C} = \frac{0,0032 \frac{\text{g}}{\text{h}} \times \left(\frac{22,4 \text{ l/mol}}{2 \times 1,00794 \text{ g/mol}} \right)}{0,25 \times 4\%} = 3,56 \text{ l/h}$$

où

HLR est le taux de perte de gaz hydrogène en grammes par heure;

F_t est le débit d'air à travers l'enceinte d'essai de température en litres normalisés par heure;

C est la concentration d'hydrogène en grammes par litre normalisé;

SV est le volume spécifique d'un gramme d'hydrogène.

- 4) Placer l'échantillon dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$.
 - 5) Laisser la concentration dans la chambre s'équilibrer avant de commencer l'essai. Le temps nécessaire dépend de la taille de l'enceinte et de la capacité du ventilateur de brassage.
 - 6) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours. La concentration d'hydrogène dans l'enceinte d'essai et le débit d'air à travers l'enceinte d'essai doivent être surveillés de façon continue pendant toute la durée de l'essai.
 - 7) Si la concentration d'hydrogène atteint 25 % de la LII (1% en volume), cela indique 0,0032 g/h de perte de gaz hydrogène de l'échantillon et l'échantillon doit être considéré comme ayant échoué à l'essai.
 - 8) À la fin des 28 jours, effectuer les essais de fuite d'hydrogène, conformément à l'essai de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. Si la cartouche de combustible est vide d'hydrogène à la fin des 28 jours, remplir la cartouche (ou la mettre sous pression à l'aide d'un gaz inerte approprié) à la pression de charge assignée conformément aux instructions du fabricant avant d'effectuer le mesurage des fuites d'hydrogène.
- e) **Critères de réussite:** Pas de fuite d'alliage métallique absorbant l'hydrogène, pas de feu ni d'explosion. Aucune fuite d'hydrogène à la fin de la période de 28 jours comme spécifié par la procédure de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. La concentration d'hydrogène dans l'enceinte d'essai de température ne doit pas dépasser 25 % de la LII à aucun moment au cours de l'essai. Le taux de perte de gaz hydrogène en provenance de l'échantillon doit être inférieur à 0,0032 g/h à tout moment au cours de l'essai. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.9.4 Option 3 – Mesurage du poids en continu

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Appareillage d'essai:** Enceinte d'essai de température capable de maintenir une température interne de $50\text{ °C} \pm 2\text{ °C}$. Il est recommandé d'équiper l'enceinte d'essai d'un capteur d'hydrogène, d'une ventilation ou autres caractéristiques de sécurité équivalentes pour assurer qu'aucune concentration inflammable d'hydrogène ne peut s'accumuler dans un volume clos.
- d) **Procédure d'essai** (Voir Figure B.9, qui remplace la Figure 9):
 - 1) Utiliser un dynamomètre (dispositif de pesage électronique continu) conçu et étalonné pour une utilisation à 50 °C à l'intérieur de l'enceinte de température.
 - 2) Placer le dynamomètre dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$. Placer la cartouche de combustible sur la partie supérieure du dynamomètre, de sorte que toute la masse soit appliquée sur le dynamomètre. Un dispositif de fixation peut être utilisé pour contrôler la position de la cartouche de combustible, pour garantir que toute la masse est appliquée sur le dynamomètre.
 - 3) Connecter un affichage numérique sur le dynamomètre et collecter les données manuellement ou automatiquement. Il convient de collecter les données d'une manière

suffisant à assurer un degré de confiance élevé que la perte de gaz hydrogène ne dépasse pas 0,0032 g/h.

- 4) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
- 5) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours.
- 6) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer le taux de perte de masse d'hydrogène en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Calculer le taux de perte de masse d'hydrogène en utilisant la différence de masse ($M_{\text{initiale}} - M_{\text{finale}}$) divisée par le temps écoulé ($t_f - t_i$) conformément à la formule suivante:

$$\text{i) } \frac{(M_{\text{initiale}} - M_{\text{finale}})}{\Delta t} = \text{taux de perte de masse d'hydrogène;}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h;}$$

$$\text{iii) } M_{\text{initiale}} = \text{masse initiale de la cartouche de combustible;}$$

$$\text{iv) } M_{\text{finale}} = \text{masse finale de la cartouche de combustible.}$$

- 7) Si le taux de perte de masse d'hydrogène est inférieur à 0,0032 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de gaz hydrogène.
- 8) Si la cartouche de combustible ne contient plus d'hydrogène avant la fin de l'essai, le taux de perte de masse d'hydrogène doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que la cartouche de combustible ne soit vide. Si le taux de perte de masse d'hydrogène est inférieur à 0,0032 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de gaz hydrogène.

$$\text{i) } \frac{(M_{\text{initiale}} - M_{\text{finale}})}{\Delta t} = \text{taux de perte de masse d'hydrogène}$$

$$\text{ii) } \Delta t_{\text{dernier}} = \text{le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.}$$

$$\text{iii) } M_{\text{dernière}} = \text{le dernier mesurage du poids alors qu'il restait encore du combustible dans la cartouche de combustible.}$$

- 9) À la fin des 28 jours, effectuer les essais de fuite d'hydrogène, conformément à l'essai de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. Si la cartouche de combustible est vide d'hydrogène à la fin des 28 jours, remplir la cartouche (ou la mettre sous pression à l'aide d'un gaz inerte approprié) à la pression de charge assignée conformément aux instructions du fabricant avant d'effectuer le mesurage des fuites d'hydrogène.

- e) **Critères de réussite:** Pas de fuite d'alliage métallique absorbant l'hydrogène, pas de feu ni d'explosion. Aucune fuite d'hydrogène à la fin de la période de 28 jours comme spécifié par la procédure de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. Le taux de perte de masse d'hydrogène doit être déterminé conformément à la procédure d'essai et à la Figure B.9. Le taux de perte de masse d'hydrogène doit être inférieur au critère de 0,0032 g/h de perte non admissible de gaz hydrogène. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.9.5 Option 4 – Mesurages périodiques du poids

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.

c) **Appareillage d'essai:** Enceinte d'essai de température capable de maintenir une température interne de $50\text{ °C} \pm 2\text{ °C}$. Il est recommandé d'équiper l'enceinte d'essai d'un capteur d'hydrogène, d'une ventilation ou autres caractéristiques de sécurité équivalentes pour assurer qu'aucune concentration inflammable d'hydrogène ne peut s'accumuler dans un volume clos.

d) **Procédure d'essai** (Voir Figure B.9, qui remplace Figure 9):

- 1) Placer la cartouche de combustible dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$. Les mesurages de poids doivent être recueillis d'une manière suffisante pour assurer un degré de confiance élevé afin de déterminer si la perte de gaz hydrogène ne dépasse pas 0,0032 g/h, avec une fréquence minimale d'une fois tous les trois jours.
- 2) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
- 3) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours.
- 4) La durée pendant laquelle les échantillons d'essai sont retirés de l'enceinte pour le mesurage ne doit pas être incluse dans la durée pendant laquelle l'échantillon d'essai doit être soumis à l'essai (28 jours). Il convient d'ajouter une durée supplémentaire pour que l'échantillon d'essai soit à la température d'essai ($50\text{ °C} \pm 2\text{ °C}$), à chaque fois que l'échantillon d'essai est retiré de l'enceinte. Il convient que les échantillons d'essai ne soient stabilisés à la température ambiante du laboratoire que si la perte de masse est affectée.
- 5) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer le taux de perte de masse d'hydrogène en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Calculer le taux de perte de masse d'hydrogène en utilisant la différence de masse ($M_{\text{initiale}} - M_{\text{finale}}$) divisée par le temps écoulé ($t_f - t_i$) conformément à la formule suivante:

$$\text{i) } \frac{(M_{\text{initiale}} - M_{\text{finale}})}{\Delta t} = \text{taux de perte de masse d'hydrogène;}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h;}$$

$$\text{iii) } M_{\text{initiale}} = \text{masse initiale de la cartouche de combustible;}$$

$$\text{iv) } M_{\text{finale}} = \text{masse finale de la cartouche de combustible.}$$

- 6) Si le taux de perte de masse d'hydrogène est inférieur à 0,0032 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de gaz hydrogène.
- 7) Si la cartouche de combustible ne contient plus d'hydrogène avant la fin de l'essai, le taux de perte de masse d'hydrogène doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que la cartouche de combustible ne soit vide. Si le taux de perte de masse d'hydrogène est inférieur à 0,0032 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de gaz hydrogène.

$$\text{i) } \frac{(M_{\text{initiale}} - M_{\text{finale}})}{\Delta t} = \text{taux de perte de masse d'hydrogène;}$$

$$\text{ii) } \Delta t_{\text{dernier}} = \text{le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible;}$$

$$\text{iii) } M_{\text{dernière}} = \text{le dernier mesurage du poids alors qu'il restait encore du combustible dans la cartouche de combustible.}$$

- 8) A la fin des 28 jours, effectuer les essais de fuite d'hydrogène, conformément à l'essai de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. Si la cartouche de combustible est vide d'hydrogène à la fin des 28 jours, remplir la cartouche (ou la mettre sous pression à l'aide d'un gaz inerte approprié) à la pression de charge assignée conformément aux instructions du fabricant avant d'effectuer le mesurage des fuites d'hydrogène.

- e) **Critères de réussite:** Pas de fuite d'alliage métallique absorbant l'hydrogène, pas de feu ni d'explosion. Aucune fuite d'hydrogène à la fin de la période de 28 jours comme spécifié par la procédure de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. Le taux de perte de masse d'hydrogène doit être déterminé conformément à la procédure d'essai et à la Figure B.9. Le taux de perte de masse d'hydrogène doit être inférieur au critère de 0,0032 g/h de perte non admissible de gaz hydrogène. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.9.6 Option 5 – Un seul mesurage du poids

Cette option est destinée aux cartouches de combustible contenant plus de 2 g de gaz hydrogène.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible remplie partiellement.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Appareillage d'essai:** Enceinte d'essai de température capable de maintenir une température interne de $50\text{ °C} \pm 2\text{ °C}$. Il est recommandé d'équiper l'enceinte d'essai d'un capteur d'hydrogène, d'une ventilation ou autres caractéristiques de sécurité équivalentes pour assurer qu'aucune concentration inflammable d'hydrogène ne peut s'accumuler dans un volume clos.
- d) Procédure d'essai:
- 1) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
 - 2) Placer les cartouches de combustible dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$.
 - 3) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours.
 - 4) Après 28 jours, retirer les cartouches de combustible de l'enceinte pour le mesurage. Il convient que les échantillons d'essai soient stabilisés à la température ambiante du laboratoire si la perte de masse est affectée.
 - 5) Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si la cartouche de combustible contient encore du combustible dans l'échantillon d'essai à la fin de l'essai, calculer alors le taux de perte de masse d'hydrogène en utilisant la différence de masse ($M_{\text{initiale}} - M_{\text{finale}}$) divisée par le temps écoulé ($t_f - t_i$) conformément à la formule suivante:
 - i)
$$\frac{(M_{\text{initiale}} - M_{\text{finale}})}{\Delta t} = \text{taux de perte de masse d'hydrogène};$$
 - ii) $\Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h};$
 - iii) M_{initiale} = masse initiale de la cartouche de combustible;
 - iv) M_{finale} = masse finale de la cartouche de combustible.
 - 6) Si le taux de perte de masse d'hydrogène est inférieur à 0,0032 g/h, alors l'échantillon d'essai satisfait à l'essai de perte de gaz hydrogène.
 - 7) A la fin des 28 jours, effectuer les essais de fuite d'hydrogène, conformément à l'essai de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible.
 - 8) Si la cartouche de combustible ne contient plus d'hydrogène après 28 jours, l'essai de type conforme à l'une des procédures suivantes doit être effectué:
 - i) B.7.3.9.2 Option 1 – Mesurage en continu de la concentration d'hydrogène;
 - ii) B.7.3.9.3 Option 2 – Mesurage de la concentration d'hydrogène à débit régulé;
 - iii) B.7.3.9.4 Option 3 – Mesurage en continu du poids; ou
 - iv) B.7.3.9.5 Option 4 – Mesurages périodiques du poids;

- e) **Critères de réussite:** Pas de fuite d'alliage métallique absorbant l'hydrogène, pas de feu ni d'explosion. Aucune fuite d'hydrogène à la fin de la période de 28 jours comme spécifié par la procédure de mesure des fuites d'hydrogène de B.7.2.1 pour la cartouche de combustible. Le taux de perte de masse d'hydrogène doit être inférieur aux critères de 0,0032 g/h de perte non admissible de gaz hydrogène. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

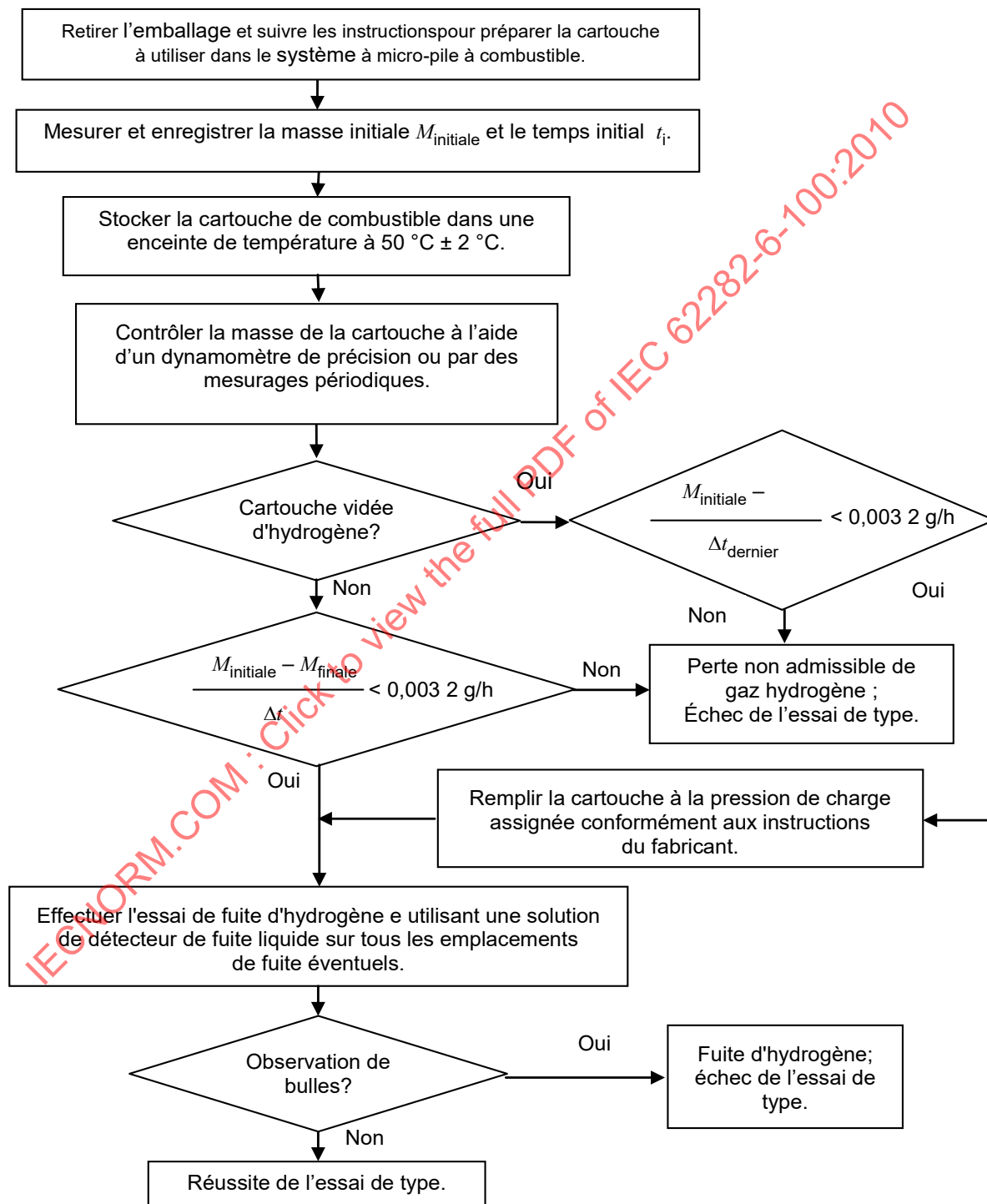


Figure B.9 – Diagramme d'essai de fuite d'hydrogène de la cartouche de combustible et de perte de masse pour l'essai de stockage de longue durée – Remplace la Figure 9.

B.7.3.10 Essai de connexion à température élevée

Le B.7.3.10 remplace le 7.3.10 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, ou cartouche de combustible remplie partiellement et bloc d'alimentation électrique de la micropile à combustible, ou une installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible, la cartouche de combustible étant à une température élevée, et garantir l'absence de fuite, de feu et d'explosion.
- c) **Procédure d'essai:**
 - 1) Placer l'échantillon d'essai de la cartouche de combustible dans une enceinte d'essai à température contrôlée, c'est-à-dire à une température de $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 4 h.
 - 2) Le bloc d'alimentation électrique de la micropile à combustible ou l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible sont maintenus à la température ambiante du laboratoire.
 - 3) Retirer l'échantillon d'essai de l'enceinte et connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible, dans les 5 min qui suivent le retrait de l'enceinte.
 - 4) Vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à B.7.2.1 à la connexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 5) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène.
 - i) pour la cartouche de combustible, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1. Voir Figure B.3;
 - ii) pour le bloc d'alimentation électrique des micropiles à combustible ou installation d'essai fixe avec une vanne de bloc d'alimentation électrique des micropiles à combustible, utiliser une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 sur l'interface ou vanne d'alimentation en combustible pour assurer l'absence de fuite d'hydrogène provenant la vanne.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment, aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Si, en utilisant une force normale, la cartouche de combustible ne peut pas être connectée, et qu'aucune fuite, aucun feu et aucune explosion ne se produisent, l'essai est acceptable. La fuite d'hydrogène doit satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible et le réservoir interne, si applicable. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.11 Essais de cycles de connexion

Le B.7.3.11 remplace le 7.3.11 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe B.

B.7.3.11.1 Cartouche de combustible

B.7.3.11.1.1 Cartouche insérable, cartouche externe ou cartouche fixée

- a) **Échantillon d'essai:** cartouche insérable, cartouche externe ou cartouche fixée inutilisée, et bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux instructions du fabricant ou installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible et alimentée en combustible conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à B.7.2.1 lors de la connexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 4) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à B.7.2.1 lors de la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 5) Répéter les étapes 1 à 4, incluses, deux fois de plus pour un total de trois connexions et déconnexions.
 - 6) Connecter et déconnecter la cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
 - 7) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 8) Connecter et déconnecter la cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
 - 9) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 10) Connecter la cartouche de combustible et faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 11) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 12) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à B.7.2.1 lors de la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.11.1.2 Cartouche satellite

- a) **Échantillon d'essai:** cartouche de combustible satellite inutilisée, et bloc d'alimentation électrique de la micropile à combustible ou installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible alimentée en combustible, conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible satellite au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
- 1) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible et amorcer ou simuler le débit de combustible. Vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à B.7.2.1 à la connexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 2) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à B.7.2.1 lors de la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 3) Répéter les étapes 1 et 2 deux autres fois pour un total de trois connexions et déconnexions.
 - 4) Connecter et déconnecter la première cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
 - 5) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 6) Connecter et déconnecter la cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
 - 7) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 8) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible et amorcer ou simuler le débit de combustible.
 - 9) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à B.7.2.1 lors de la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
 - 10) Répéter les étapes 1 à 9 quatre autres fois pour un total de 55 cycles, en attendant 1 h entre chaque série de 11 cycles.
- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 pour la cartouche de combustible. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement.

B.7.3.11.2 Bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** au moins deux cartouches de combustible inutilisées et 98 autres cartouches de combustible ou installations d'essai fixes comportant des vannes de cartouches de combustible supplémentaires et un bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la

géométrie et du matériau de la vanne de la cartouche de combustible et doit être apte à simuler le débit du combustible.

- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite, à la fois lors de l'utilisation initiale et après un vieillissement adapté de la connexion du bloc d'alimentation électrique de la micropile à combustible.

La première cartouche de combustible (#1) et la dernière cartouche de combustible (#100) sont examinées; les 980 cycles restants sont uniquement destinés à faire vieillir le bloc d'alimentation électrique de la micropile à combustible.

Dans le cas d'un bloc d'alimentation électrique de la micropile à combustible qui utilise une cartouche satellite, il doit être soumis à l'essai conformément à la procédure ci-dessous en simulant le débit de combustible entre la cartouche satellite et le bloc d'alimentation électrique de la micropile à combustible.

c) **Procédure d'essai:**

- 1) Connecter la première cartouche de combustible au bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 au point de connexion et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la connexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 4) Déconnecter la première cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 en particulier aux vannes de connexion de la cartouche de combustible et du bloc d'alimentation électrique des micropiles à combustible et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 5) Répéter les étapes 1 à 4, incluses, deux fois de plus pour un total de trois connexions et déconnexions.
- 6) Connecter et déconnecter la première cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 7) Vérifier s'il y a des fuites d'hydrogène à la déconnexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 en particulier aux vannes de connexion de la cartouche de combustible et du bloc d'alimentation électrique des micropiles à combustible et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 8) Connecter et déconnecter la première cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
- 9) Vérifier s'il y a des fuites d'hydrogène à la déconnexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 en particulier aux vannes de connexion de la cartouche de combustible et du bloc d'alimentation électrique des micropiles à combustible et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 10) Connecter la cartouche de combustible au bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 au point de connexion et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la connexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.

- 11) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 12) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 13) Déconnecter la première cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 en particulier aux vannes de connexion de la cartouche de combustible et du bloc d'alimentation électrique des micropiles à combustible et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 14) Pour un vieillissement de la connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible, suivre les étapes suivantes:
 - i) En utilisant soit des cartouches de combustible soit une installation d'essai fixe comportant des vannes de cartouche de combustible, lancer des cycles de connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible pour un total de 980 cycles de connexions et déconnexions.
 - ii) Simuler le débit de combustible après chaque série de 50 cycles de connexion/déconnexion.
 - iii) Après ce vieillissement, une dernière cartouche de combustible inutilisée est soumise à l'essai.
- 15) Connecter la dernière cartouche de combustible inutilisée au bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 au point de connexion et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la connexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 16) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 17) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 18) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1, en particulier aux vannes de connexion de la cartouche de combustible et du bloc d'alimentation électrique des micropiles à combustible et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 19) Répéter les étapes 15 à 18, incluses, deux fois de plus pour un total de trois connexions et déconnexions.
- 20) Connecter et déconnecter la dernière cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 21) Vérifier s'il y a des fuites d'hydrogène à la déconnexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 en particulier aux vannes de connexion de la cartouche de combustible et du bloc d'alimentation électrique des micropiles à combustible et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1. Connecter et déconnecter la dernière cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
- 22) Vérifier s'il y a des fuites d'hydrogène à la déconnexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 en particulier aux vannes de connexion de la cartouche de combustible et du bloc d'alimentation électrique des micropiles à combustible et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la déconnexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.

- 23) Connecter la cartouche de combustible au bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion en utilisant une solution de détecteur de fuite liquide (formation de bulles) conformément à B.7.2.1 au point de connexion et en tous les autres points auxquels une fuite d'hydrogène peut se produire à la connexion. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 24) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 25) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 26) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite de liquide (formation de bulles) conformément à B.7.2.1, pour la cartouche de combustible et le réservoir interne, si applicable. La fuite d'hydrogène doit satisfaire aux critères d'absence de fuite d'hydrogène indiqués en B.7.2.1.
- 27) Effectuer les essais de fuites d'hydrogène suivants.
 - i) Pour le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible, effectuer le mesurage des pertes de gaz hydrogène conformément à B.7.2.2 (ceci inclut des essais d'émissions d'hydrogène conformément à B.7.3.12). Voir Figure B.4.
 - ii) Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible contient une cartouche de combustible ou un réservoir interne qui contient du gaz hydrogène à une pression supérieure à la pression ambiante, effectuer le mesurage des fuites d'hydrogène conformément à B.7.2.1.
- d) **Critères de réussite:** Aucun feu ni aucune explosion à aucun moment, et aucune fuite d'alliage métallique absorbant l'hydrogène. Les pertes de gaz hydrogène doivent satisfaire aux exigences applicables de B.7.2.2 pour le bloc d'alimentation électrique de la micropile à combustible. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène de B.7.2.1 aux points de connexion lorsque la cartouche de combustible est connectée au bloc d'alimentation électrique de la micropile à combustible, et aux vannes de connexion lorsqu'elle est déconnectée, et pour la cartouche de combustible et le réservoir interne, si applicable. La flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement. La fuite d'alliage métallique absorbant l'hydrogène doit être vérifiée visuellement. Si le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible n'est pas opérationnel à la suite de l'essai, mais les exigences applicables de B.7.2.1 et B.7.2.2 sont satisfaites, l'essai est acceptable.

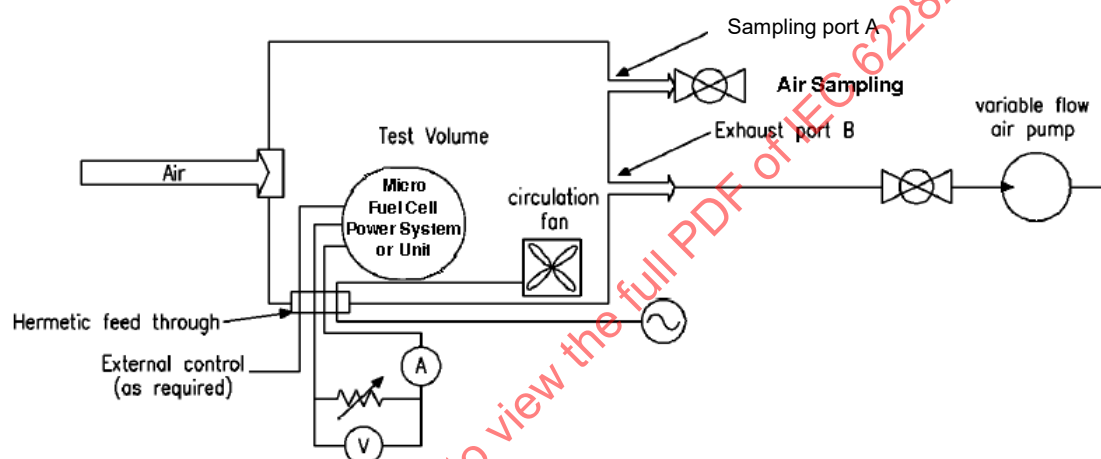
B.7.3.12 Essai d'émission

Ce paragraphe B.7.3.12 doit remplacer le 7.3.12 pour les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe B. Le Tableau B.7, Limites d'émissions, inclus remplace le Tableau 7 de 7.3.12. La Figure B.10 remplace la Figure 10 et lui est identique. Les émissions d'hydrogène sont les seules émissions possibles provenant de ces systèmes à micropiles à combustible et blocs d'alimentation électrique des micropiles à combustible utilisant de l'hydrogène stocké dans des systèmes de stockage d'hydrures métalliques. La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure B.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à la présente Annexe B.

Les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible doivent être soumis à l'essai conformément à B.7.3.12.1, Essai d'émissions d'hydrogène, dispositif en marche («DISPOSITIF EN POSITION «ON»»). Une seconde procédure d'essai, B.7.3.12.2, Essai d'émissions d'hydrogène, dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») est fournie pour être utilisée conjointement à B.7.2.2, Mesurages des pertes de gaz hydrogène provenant de systèmes à micropiles à combustible et de blocs d'alimentation électrique des micropiles à combustible et procédures de mesure.

B.7.3.12.1 Essai d'émissions d'hydrogène, dispositif en marche («DISPOSITIF EN POSITION «ON»»)

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible – qui est alimenté en hydrogène – les émissions d'hydrogène sont les seules émissions possibles. L'objet de cet essai est de s'assurer que les émissions d'hydrogène sont maintenues à un niveau suffisant bas pour garantir qu'il n'y aura ni formation de concentration inflammable dans le volume de référence ni fuites de gaz hydrogène en provenance du spécimen qui pourraient entretenir une flamme ($< 0,016$ g/h, ou 3 centimètres cubes normalisés par minute). Le fait de maintenir ces limites non seulement empêche l'apparition de mélanges inflammables en raison des émissions d'hydrogène, mais aussi garantit qu'une alimentation adéquate d'oxygène sera maintenue dans l'environnement de fonctionnement



Anglais	Français
Air	Air
Sampling port	Orifice d'échantillonnage
Test volume	Volume d'essai
Micro fuel cell power system or unit	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Circulation fan	Ventilateur de brassage
Hermetic feed through	Passage hermétique
External control (as required)	Commande extérieure (si exigée)
Exhaust port	Orifice d'évacuation
Air sampling	Échantillonnage de l'air
Variable flow air pump	Pompe à air à débit variable

Figure B.10 – Appareillage d'essai: de taux d'émission opérationnel – Remplace la Figure 10

- c) **Appareillage d'essai:** Un exemple d'appareillage d'essai du taux d'émission opérationnel est représenté à la Figure B.10. La configuration représentée à la Figure B.10 sert aux essais de taux d'émission de tous les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe B. Les essais de taux d'émission d'hydrogène conformément à

B.7.3.12.1 d) sont exigés pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe B.

Pour l'analyse des émissions d'hydrogène, un spectromètre de masse, un chromatographe en phase gazeuse ou un autre instrument approprié étalonné pour mesurer la concentration d'hydrogène doit être utilisé et connecté à l'orifice d'échantillonnage A de la Figure B.10. Toutefois, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus.

Un détecteur d'hydrogène étalonné pour la plage de concentration massique d'hydrogène de 0 % à 1 %, peut être utilisé pour mesurer la concentration d'hydrogène

d) **Procédure d'essai:**

- 1) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure B.10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
- 2) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- 3) Les émissions de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure B.10.
- 4) Laisser se stabiliser le débit d'air d'admission de l'enceinte d'essai, son débit d'air de sortie, le débit du ventilateur de brassage et le débit d'échantillon
- 5) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage d'air A représenté à la Figure 10, tout en mesurant et enregistrant simultanément le débit d'air total à travers l'enceinte d'essai. Le débit d'air total à travers l'enceinte d'essai peut être calculé à partir de la somme du débit d'air à la sortie et du débit d'échantillon à travers l'orifice d'échantillonnage de l'air A ou en mesurant le débit d'air d'admission à l'enceinte d'essai. Le débit à travers l'enceinte d'essai et la concentration d'hydrogène dans l'enceinte d'essai doivent être surveillés de façon continue.
- 6) Enregistrer la concentration d'hydrogène.
- 7) Calculer le taux d'émission de l'hydrogène émis en multipliant la concentration stabilisée maximale d'hydrogène par le débit d'air simultanément total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air à la sortie en régime établi à travers le système au débit d'échantillon simultanément ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux de fuite de gaz hydrogène.

Voir ci-dessous:

$$ER = (F_o + F_s) \times C$$

ou

$$ER = (F_i) \times C$$

où

ER est le taux d'émission d'hydrogène en grammes par heure;

F_o est le débit d'air de sortie en litres par heure;

F_S est le débit d'échantillon en litres par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre;

- 8) Comparer le taux d'émission d'hydrogène [DISPOSITIF EN POSITION «ON»] mesuré maximal par rapport au Tableau B.7.

NOTE Il s'agit d'un mesurage de concentration stabilisée.

- 9) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 10) Si le taux d'émission d'hydrogène est inférieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), l'essai est terminé.
- 11) Si le taux d'émission d'hydrogène mesuré est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), effectuer l'essai de détection de pertes localisées de gaz hydrogène conformément à B.7.3.13.
- 12) Si le taux d'émission d'hydrogène est supérieur à 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), l'essai a échoué. Aucun essai supplémentaire n'est nécessaire.

e) **Critères de réussite:**

La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure B.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe B. Les émissions d'hydrogène sont évaluées comme suit: Si le taux total d'émission d'hydrogène est inférieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible satisfait à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux total d'émission d'hydrogène n'est pas inférieur à 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible échoue à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux d'émission d'hydrogène est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), B.7.3.13, Essai de détection de pertes localisées de gaz hydrogène doit être effectué avec des résultats acceptables pour démontrer que les fuites d'hydrogènes ne dépassent pas 0,016 g/h à partir d'une seule fuite localisée. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser la limite pour les systèmes en non-fonctionnement du Tableau B.7, l'essai est acceptable.

NOTE 1 Le niveau d'émission d'hydrogène inflammable admissible qui n'entretient pas de flamme est de 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain et M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). La limite d'émission d'hydrogène non inflammable est fondée sur les critères selon lesquels l'émission d'hydrogène n'augmente pas de plus de 25 % de la LII dans le volume de référence.

NOTE 2 L'hydrogène est défini comme un asphyxiant simple, mais, pour que ce risque existe, les niveaux d'oxygène doivent descendre à moins de 18 % à la pression atmosphérique normale. Le risque d'inflammabilité lié à l'hydrogène se produit à des concentrations d'hydrogène dans l'air supérieures à 4 %, tandis que le risque d'asphyxie survient à des concentrations d'hydrogène dans l'air supérieures à 12 %. Par conséquent, les limites d'inflammabilité sont utilisées en définissant les limites pour les émissions d'hydrogène.

B.7.3.12.2 Essai d'émissions d'hydrogène, dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»)

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** Dans des conditions de stockage, ou de non-fonctionnement, d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible – qui est alimenté en hydrogène – les émissions d'hydrogène sont les seules émissions possibles. Cette procédure d'essai est destinée à être utilisée conjointement à l'essai de pertes de gaz hydrogène de B.7.2.2, afin de garantir qu'un système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible en non-fonctionnement ne dépasse pas la limite de perte non admissible de gaz hydrogène de 0,0032 g/h.
- c) **Appareillage d'essai:** Un exemple d'appareillage d'essai du taux d'émission opérationnel est représenté à la Figure B.10. La configuration représentée à la Figure B.10 sert aux essais de taux d'émission de tous les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe B.

Pour l'analyse des émissions d'hydrogène, un spectromètre de masse, un chromatographe en phase gazeuse ou un autre instrument approprié étalonné pour mesurer la concentration d'hydrogène doit être utilisé et connecté à l'orifice d'échantillonnage A de la Figure B.10. Toutefois, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus.

Un détecteur d'hydrogène étalonné pour la plage de concentration massique d'hydrogène de 0 % à 1 %, peut être utilisé pour mesurer la concentration d'hydrogène

d) Procédure d'essai:

- 1) Mettre le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») et mesurer les taux d'émissions d'hydrogène, ou de pertes de gaz hydrogène, avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») à l'intérieur de la petite enceinte d'essai représentée à la Figure B.10.
- 2) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- 3) Les émissions de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure B.10.
- 4) Laisser se stabiliser le débit d'air d'admission de l'enceinte d'essai, son débit d'air de sortie, le débit du ventilateur de brassage et le débit d'échantillon
- 5) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage d'air A représenté à la Figure 10, tout en mesurant et enregistrant simultanément le débit d'air total à travers l'enceinte d'essai. Le débit d'air total à travers l'enceinte d'essai peut être calculé à partir de la somme du débit d'air à la sortie et du débit d'échantillon à travers l'orifice d'échantillonnage de l'air A ou en mesurant le débit d'air d'admission à l'enceinte d'essai. Le débit à travers l'enceinte d'essai et la concentration d'hydrogène dans l'enceinte d'essai doivent être surveillés de façon continue.
- 6) Enregistrer la concentration d'hydrogène.

- 7) Calculer le taux de pertes de gaz hydrogène émis en multipliant la concentration stabilisée maximale d'hydrogène par le débit d'air simultanée total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air à la sortie en régime établi à travers le système au débit d'échantillon simultanée ou en mesurant le débit d'air d'admission.

NOTE Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux de fuite de gaz hydrogène.

$$HLR = (F_o + F_S) \times C$$

ou

$$HLR = (F_i) \times C$$

où

HLR est le taux d'émission en grammes par heure;

F_o est le débit d'air de sortie en litres par heure;

F_S est le débit d'échantillon en litres par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre;

- 8) Comparer le taux de perte de gaz hydrogène [DISPOSITIF EN POSITION «OFF»] mesuré maximal par rapport au Tableau B.7.

NOTE Il s'agit d'un mesurage de concentration stabilisée.

- 9) Les mesurages de taux de pertes de gaz hydrogène doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.

- 10) Évaluer le taux de pertes de gaz hydrogène comme suit:

- i) Si la valeur mesurée du taux d'émission d'hydrogène est inférieure à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible satisfait à l'essai et aucun essai supplémentaire n'est nécessaire.
- ii) Si la valeur mesurée du taux d'émission d'hydrogène n'est pas inférieure à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible échoue à l'essai et aucun essai supplémentaire n'est nécessaire.

e) **Critères de réussite:**

Critères de réussite pour systèmes en non-fonctionnement: Le taux de pertes de gaz hydrogène doit être inférieur à 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»).

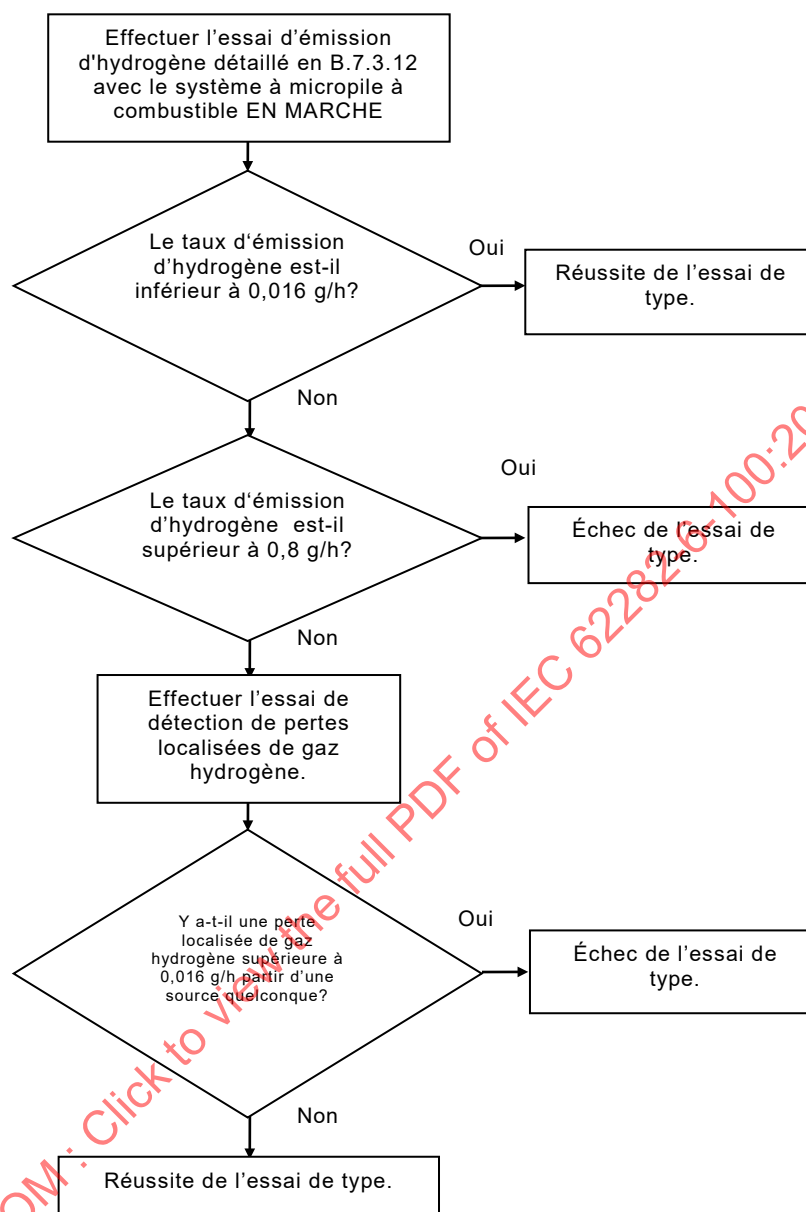


Figure B.12 – Procédure pour l'essai d'émission d'hydrogène pour le système à micropile à combustible en fonctionnement

Tableau B.7 – Limites d'émissions – Remplace le Tableau 7

Émissions	Système en fonctionnement Limite de taux d'émissions admissible ^a («DISPOSITIF EN POSITION «ON»»)	Système en non-fonctionnement perte non admissible de gaz ^b (y compris «DISPOSITIF EN POSITION «OFF»»)
Eau	Illimitée	Illimitée
Hydrogène	0,8 g/h total 0,016 g/h à partir d'une seule fuite localisée	0,0032 g/h
Le Tableau B.7 remplace le Tableau 7.		
^a La limite du taux d'émission en fonctionnement est basée sur le produit d'un volume de référence par les renouvellements d'air par heure (ACH), parce qu'elle couvre les environnements raisonnablement prévisibles dans lesquels les systèmes à micropiles à combustible sont utilisés. L'espace intérieur dans une petite voiture et le volume attribué minimal par personne à bord d'un avion commercial sont fixés à 1 m³. L'ACH minimal utilisé à bord d'un avion de passagers est de 10 et le réglage de ventilation le plus faible dans les voitures est de 10 ACH. Les maisons et les bureaux peuvent présenter des niveaux d'ACH aussi bas que 0,5, mais le volume par personne est habituellement supérieur à 20 m³, et donc un produit de 10 est satisfaisant. Un autre facteur de sécurité de 10 a été ajouté dans ce cas spécifique. ^b Les critères de «perte non admissible de gaz hydrogène» pour les systèmes à micropiles à combustible non opérationnels ont été choisis d'après un scénario de systèmes à micropiles à combustible dans un espace fermé avec aucune ventilation. L'espace choisi a un volume de 0,28 m³, ou environ 10 pieds cubes. Le critère a été prescrit, de telle sorte qu'une concentration d'hydrogène supérieure à 25 % de la LII n'est pas autorisée à se développer sur une période de vingt-quatre heures (24 h), si trois systèmes à micropiles à combustible sont dans l'espace fermé.		

B.7.3.13 Essai de détection de pertes localisées de gaz hydrogène

Ce paragraphe doit être seulement utilisé si cela est exigé par le B.7.3.12.1 d) 11) pour démontrer la conformité au Tableau B.7, pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible utilisant comme combustible l'hydrogène stocké dans un hydrure métallique. *La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure B.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe B.* Il est nécessaire d'exécuter ce paragraphe pour satisfaire aux critères de réussite de A.7.3.12.1 e) si le taux total d'émission d'hydrogène provenant d'un système à micropile à combustible opérationnel ou d'un bloc d'alimentation électrique de la micropile à combustible opérationnel est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»). Ce paragraphe s'ajoute aux exigences de l'Article 7.

- f) **Échantillon d'essai:** Bloc d'alimentation électrique de la micropile à combustible ou système à micropile à combustible utilisé en B.7.3.12.1.
- g) **Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible relevant du domaine d'application de la présente Annexe B, l'émission de l'hydrogène doit être maintenue à un niveau inférieur aux valeurs spécifiées dans le Tableau B.7. L'essai de détection de pertes localisées de gaz hydrogène doit être effectué pour déterminer qu'aucune source sur le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne peut entretenir une flamme dans tous les cas où une telle conformité ne peut être définitivement déterminée par l'essai d'émission d'hydrogène. Le fait de maintenir ces limites assure qu'il n'y aura ni accumulation de la concentration inflammable dans le volume de référence ni pertes de gaz hydrogène provenant de l'éprouvette qui pourraient entretenir une flamme.
- h) **Appareillage d'essai:** La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au

moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25 % de la LII.

NOTE La réponse des détecteurs d'hydrogène susmentionnés est généralement lente, le temps de réponse étant de plusieurs secondes, et donc des vitesses de balayage élevées peuvent causer une sous-estimation de la concentration d'hydrogène. Il est important que la vitesse de balayage soit suffisamment lente pour mesurer précisément la concentration d'hydrogène.

i) **Procédure d'essai:**

- 1) Le système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible doit rester en marche («DISPOSITIF EN POSITION «ON»») pendant toute la durée de l'essai de détection de pertes localisées de gaz hydrogène.
- 2) L'essai doit être réalisé dans un espace sans circulation d'air importante. La vitesse mesurée du vent à 10 cm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ne doit pas dépasser 0,02 m/s.

NOTE 1 La concentration locale de la diffusion d'hydrogène mesurée dans cet essai est très sensible à l'effet du vent. Il est souhaitable que la vitesse du vent en n'importe quel endroit de l'espace d'essai soit aussi proche que possible de zéro. Les essais réalisés dans un espace clos, tel qu'une boîte à gants ou enceinte équivalente, constituent un moyen disponible de satisfaire à cette exigence.

- 3) La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25 % de la LII.

NOTE 2 La réponse des détecteurs d'hydrogène susmentionnés est généralement lente – de l'ordre de secondes – et donc des vitesses de balayage aussi élevées peuvent causer la sous-estimation de la concentration d'hydrogène. Il est remarqué que la vitesse de balayage est suffisamment lente pour mesurer précisément la concentration d'hydrogène.

- 4) Le capteur du détecteur d'hydrogène doit balayer le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à une distance inférieure ou égale à 3 mm, perpendiculairement à la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les balayages linéaires consécutifs ne doivent pas être éloignés de plus de 8 mm le long de la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. La surface totale du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être balayée de cette manière.
- 5) Une méthode efficace pour réaliser ces balayages consisterait à fixer une cale sur le capteur, qui assure le maintien en toutes circonstances d'un espacement de 3 mm depuis le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Un stylo ou autre ustensile de marquage fixé sur la cale pourrait être utilisé pour identifier les zones balayées et pour garantir que la distance entre les balayages ne dépasse pas 8 mm.
- 6) Il convient que le capteur soit toujours dirigé directement vers le bas, et que le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible soit déplacé sous ce dernier de telle sorte que la surface juste en dessous du capteur soit toujours horizontale.
- 7) Si aucun point n'est détecté lorsque la concentration d'hydrogène est supérieure à 25 % de la LII, l'essai est terminé et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être considéré comme ayant satisfait à l'essai.

NOTE 3 Lorsqu'un certain nombre de balayages de source ponctuelle présentent une vaste région de 25 % ou plus de la LII dans les balayages linéaires initiaux, le fait d'enregistrer les valeurs mesurées de la concentration permet de déterminer le point de départ des balayages en spirale secondaires. Les sources ponctuelles sont censées se trouver aux endroits auxquels il existe des valeurs maximales locales dans la distribution des valeurs mesurées de la concentration.

- 8) S'il est détecté que des points ont une concentration d'hydrogène de 25 % de la LII ou plus, un deuxième essai doit être réalisé pour garantir que l'émission ne dépasse pas 0,016 g/h d'hydrogène pur depuis une source quelconque.
 - 9) Le deuxième essai doit être réalisé avec la hauteur du capteur réglée à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.
 - 10) Un balayage en spirale doit alors être réalisé, depuis le point auquel a eu lieu la détection de 25 % de la LII ou plus de l'hydrogène au cours du balayage linéaire initial. Le balayage en spirale doit présenter un espacement de 1 mm ou moins entre les balayages et doit former une spirale sur une distance radiale d'au moins 4 mm et suffisamment loin pour détecter le niveau maximal d'hydrogène à partir de la source d'hydrogène particulière.
 - 11) Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Si le balayage en spirale ne détecte pas de concentrations d'hydrogène supérieures ou égales à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible satisfait à l'essai.
- j) **Critères de réussite:** Aucune perte de gaz hydrogène provenant d'une source quelconque à plus de 0,016 g/h telle qu'indiquée par les essais de balayage. Aucune indication d'hydrogène qui soit à 25 % de la LII pendant les essais de balayage primaire ni aucune indication d'hydrogène à 25 % de la LII pendant les essais de balayage secondaire à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Voir Tableau B.7.

B.7.3.14 Essai d'intégrité de la cartouche de combustible

Le B.7.3.14 doit être réalisé en plus des essais exigés dans l'Article 7 pour les cartouches de combustible traitées par la présente Annexe B.

- a) **Échantillon d'essai:** cartouches de combustible telles qu'exigées par l'ISO 16111:2008.
- b) **Objet:** assurer l'intégrité des cartouches de combustible.
- c) **Procédure d'essai:**
Les cartouches de combustible doivent être soumises à l'essai comme un assemblage métal-hydrure conformément à l'ISO 16111:2008 et doivent satisfaire à toutes les exigences de ladite norme.
- d) **Critères de réussite:** Les critères de réussite sont donnés dans l'ISO 16111:2008.

B.7.3.15 Essai d'intégrité des réservoirs internes

Le B.7.3.15 doit être réalisé en plus des essais exigés dans l'Article 7 pour les blocs d'alimentation électrique des micropiles à combustible traités par la présente Annexe B qui comportent un régulateur de pression ou une vanne entre le bloc d'alimentation électrique des micropiles à combustible et le réservoir de combustible interne et le réservoir contient un alliage métallique absorbant l'hydrogène dans le réservoir interne.

- a) **Échantillon d'essai:** un réservoir interne du bloc d'alimentation électrique de la micropile à combustible.
- b) **Objet:** Assurer l'intégrité du réservoir interne.
- c) **Procédure d'essai:**
Les réservoirs internes qui comportent un régulateur de pression ou une vanne entre le bloc d'alimentation électrique des micropiles à combustible et le réservoir de combustible interne et qui contiennent de l'hydruure métallique pour le stockage de l'hydrogène doivent être soumis à l'essai conformément à l'ISO 16111:2008 comme un assemblage métal-hydruure et doivent satisfaire à toutes les exigences de ladite norme.
- d) **Critères de réussite:** Les critères de réussite sont donnés dans l'ISO 16111:2008.

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Annexe C (normative)

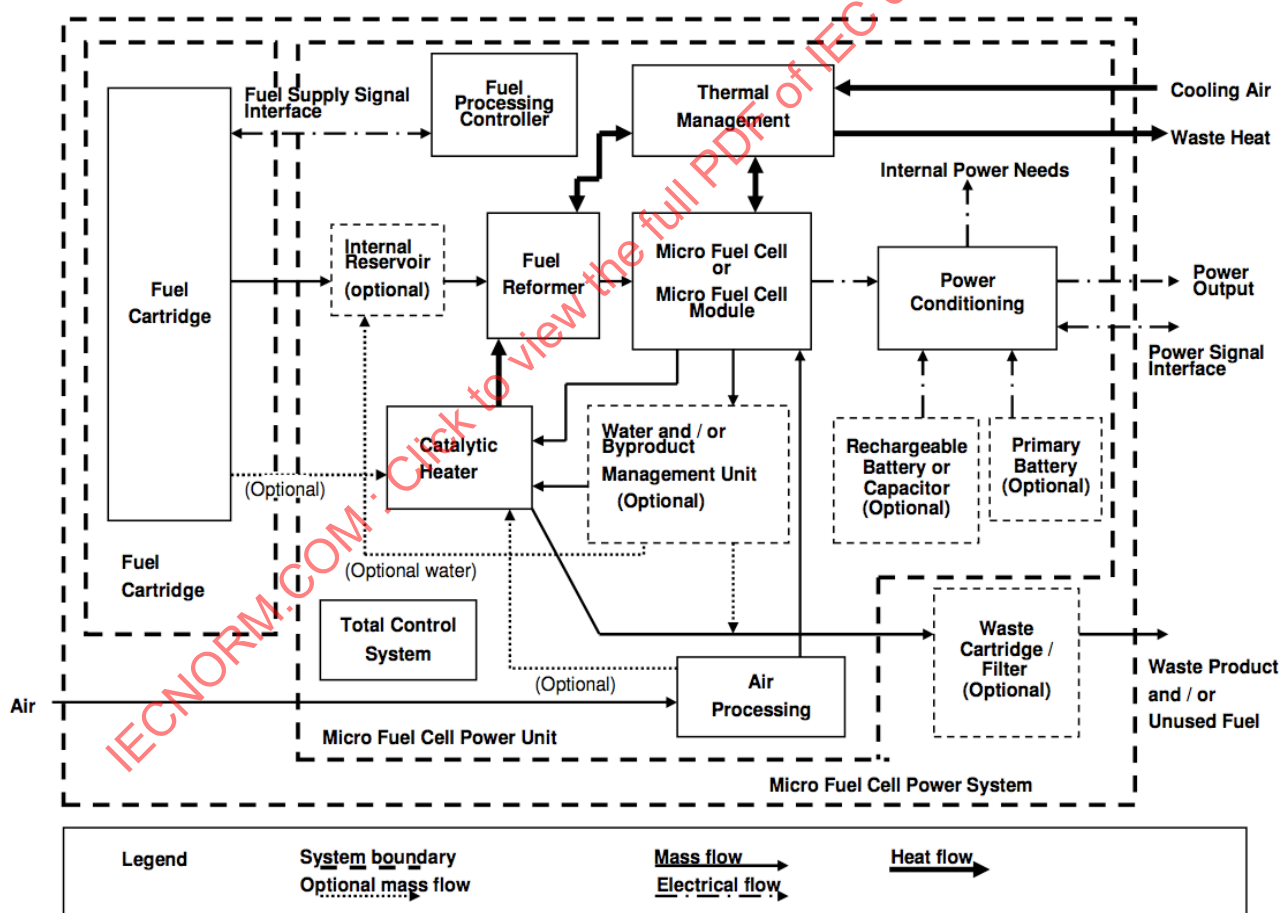
Systèmes à micropile à combustible à méthanol reformé

C.1 Domaine d'application

C.1.2 Combustibles et technologies traités dans la présente annexe

L'Annexe C traite des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible qui utilisent un reformeur pour convertir le méthanol ou des solutions de méthanol et d'eau en reformat de méthanol riche en hydrogène, lequel est immédiatement injecté comme combustible dans la pile à combustible ou le bloc de piles à combustible. Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de protons.

La Figure C.1 remplace la Figure 1 présentant un schéma de principe du système à micropile à combustible au méthanol reformé à utiliser avec la présente Annexe C.



Anglais	Français
Air	Air
Air processing	Traitement de l'air
Catalytic heater	Réchauffeur catalytique
Cooling air	Air de refroidissement
Electrical flow	Flux électrique

Anglais	Français
Fuel cartridge	Cartouche de combustible
Fuel processing controller	Contrôleur de traitement du combustible
Fuel reformer	Reformeur de combustible
Fuel supply signal interface	Interface de signal de l'alimentation en combustible
Heat flow	Flux thermique
Internal power needs	Besoins internes en énergie
Internal reservoir	Réservoir interne
Legend	Légende
Mass flow	Débit massique
Micro fuel cell or micro fuel cell module	Micropile à combustible ou module à micropiles à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de micropiles à combustible
(optional)	(facultatif)
(optional water)	(eau facultative)
Optional mass flow	Débit massique facultatif
Power conditioning	Conditionnement de l'énergie
Power signal interface	Interface signal de puissance
Power output	Puissance de sortie
Primary battery (optional)	Pile électrique (facultatif)
Rechargeable battery or capacitor (optional)	Batterie rechargeable ou condensateur (facultatif)
Thermal management	Gestion thermique
Total control system	Système global de commande
Usable power	Puissance utile
Waste cartridge (optional)	Cartouche usagée (facultatif)
Waste cartridge/Filter (optional)	Cartouche / filtre usagés (Facultatif)
Waste heat	Chaleur résiduelle
Waste product and/or unused fuel	Déchets et/ou combustible inutilisé
Water and/or by-products management unit (optional)	Unité de gestion de l'eau et/ou des sous-produits (facultatif)

Figure C.1 – Schéma de principe général d'un système à micropile à combustible à méthanol reformé – Remplace la Figure 1

C.3 Termes et définitions

Les termes supplémentaires et leurs définitions ci-dessous sont nécessaires pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe C en plus de ceux donnés dans l'Article 3.

C.3.37

réchauffeur catalytique

dispositif qui oxyde un combustible (par exemple, méthanol, hydrogène) et produit de la chaleur sans flamme pour les systèmes à micropiles à combustible applicables

C.3.38**perte non admissible de gaz hydrogène**

gaz hydrogène s'échappant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible en non-fonctionnement, à un débit supérieur ou égal à 0,0032 g/h

C.3.39**reformeur de combustible méthanol (également désigné par "reformeur")**

dispositif qui convertit le méthanol et l'eau en hydrogène reformé (hydrogène, dioxyde de carbone, méthanol, formaldéhyde, monoxyde de carbone et formiate de méthyle) pour les systèmes à micropiles à combustible applicables

C.3.40**«DISPOSITIF EN POSITION «ON»»**

dispositif avec son interrupteur d'alimentation électrique en position «ON» et fonctionnant pour produire de l'énergie électrique ou incapable de produire de l'énergie électrique en raison d'une défaillance ou d'autres causes

C.4 Matériaux et construction des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible**C.4.10 Protection contre les dangers d'incendie, d'explosion, de corrosivité et de toxicité**

Ces exigences s'appliquent aux systèmes à micropiles à combustible et aux blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe C. Ces exigences remplacent les exigences correspondantes de 4.10.

C.4.10.1 Les fluides inflammables, toxiques et corrosifs doivent être maintenus à l'intérieur d'un système de confinement fermé, par exemple dans une tuyauterie pour combustible, un réservoir, une cartouche de combustible ou une enveloppe similaire. La conformité doit être vérifiée par des essais de type, conformément à l'Article 7.

C.4.10.2 Un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible peut être équipé d'un dispositif permettant de détecter les niveaux de concentration des fluides, voir Tableau 7, et d'arrêter le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible avant que la limite de concentration ne soit dépassée.

C.4.10.3 Le câblage interne et l'isolation en général ne doivent pas être exposés au combustible, aux huiles, graisses ou substances similaires, à moins que l'isolation n'ait été évaluée pour un contact avec ces substances.

C.4.10.4 Les systèmes à micropiles à combustible doivent être conçus de manière à ce qu'il n'y ait pas de risque de flamme nue dans les réchauffeurs catalytiques (réchauffeurs catalytiques de démarrage, principaux et auxiliaires d'une section de reformeur, réchauffeurs catalytiques de gaz résiduels).

C.4.10.5 Si l'air pour le réchauffage catalytique est mélangé avec un gaz combustible, des moyens efficaces doivent être prévus pour empêcher que l'air ne retourne dans la canalisation de gaz combustible et pour éviter que le gaz combustible ne s'écoule dans l'alimentation d'air.

C.4.10.6 Des systèmes de commande pour les alimentations en combustible et en air des reformeurs et des réchauffeurs catalytiques doivent être conçus pour maintenir de manière fiable le rapport combustible/air.

C.4.10.7 Au cours de l'arrêt, les gaz dangereux présents dans les systèmes de traitement du reformeur et du réchauffeur catalytique doivent être contenus, oxydés ou éliminés de manière sûre.

C.4.10.8 Pour les systèmes de réchauffeurs catalytiques riches en air: Les alimentations en combustible et en air doivent être commandées de manière adéquate pour fournir de l'air avant l'amorce de la réaction, et pour empêcher le combustible d'entrer dans le réacteur avant que l'alimentation d'air ne soit disponible.

C.4.10.9 Pour les systèmes de réchauffeurs catalytiques riches en combustible: Les alimentations en combustible et en air doivent être commandées de manière adéquate pour fournir du combustible avant l'amorce de la réaction, et pour empêcher l'air d'entrer dans le réacteur avant que le combustible ne soit disponible.

C.4.10.10 Le temps d'amorce de réaction du réchauffeur catalytique doit être déterminé en évaluant le temps de réponse des appareils de commande du système et le temps nécessaire pour accumuler la quantité maximale autorisée de mélange inflammable qui peut être contenue sans risque dans le système, en fonction des débits, de l'inflammabilité du mélange combustible/air, et de la dynamique et de la géométrie du système.

C.4.10.11 Le fabricant doit assurer que la quantité maximale de mélange inflammable qui peut s'accumuler, si la combustion a lieu, produit des pressions et des températures qui peuvent être contenues dans les composants exposés à de telles conditions. Toutes les parties des systèmes de reformeurs et de réchauffeurs catalytiques doivent être réalisées selon une conception ouverte (c'est-à-dire que les gaz s'écoulent du reformeur à la pile à combustible au réchauffeur catalytique, jusqu'à l'échappement des gaz), et il ne doit pas être possible d'accumuler une pression élevée dans les composants exposés à ces conditions de conception ouverte.

C.4.10.12 Les canalisations et autres moyens de cheminement des combustibles doivent être conçus de telle sorte qu'il n'y ait pas de danger de fuite de gaz en provenance du reformeur de combustible ou du réchauffeur catalytique, au cours d'une utilisation normale et d'un emploi abusif raisonnablement prévisible généré par les vibrations, la chaleur, la pression, etc.

C.7 Essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

C.7.1 Généralités

Ce paragraphe C.7.1 remplace le 7.1 pour la présente annexe lors des essais relatifs aux systèmes à micropiles à combustible au méthanol reformé, aux blocs d'alimentation électrique des micropiles à combustible au méthanol reformé et aux cartouches de combustible au méthanol reformé.

- a) Les essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible doivent permettre de vérifier que ces systèmes à micropiles à combustible, blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible sont sûrs pour une utilisation normale.
- b) Le Tableau C.5 énumère les essais de type qui doivent être effectués. *Le Tableau C.5 remplace le Tableau 5.*
- c) Sauf exigence explicite contraire dans cet article, les conditions de laboratoire sont spécifiées dans le Tableau 6. *Le Tableau C.6 remplace le Tableau 6.*
- d) Le système à micropile à combustible, le bloc d'alimentation électrique de la micropile à combustible et/ou la cartouche de combustible doivent être conditionnés à une

température de laboratoire normalisée de $22\text{ °C} \pm 5\text{ °C}$ pendant au moins 3 h avant la réalisation de chaque essai.

- e) Avertissement: Ces essais de type utilisent des procédures qui peuvent entraîner des dommages si des précautions appropriées ne sont pas prises. Il convient que les essais ne soient effectués que par des techniciens qualifiés et expérimentés utilisant une protection appropriée.

Tableau C.5 – Liste des essais de type – Remplace le Tableau 5

Référence de l'essai	Entité d'essai	Échantillon d'essai
7.3.1	Essais de pression différentielle	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.2	Essai de vibrations	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.3	Essai de cycles de températures	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.4	Essai d'exposition à température élevée	Cartouche de combustible Cartouche de combustible remplie partiellement
7.3.5	Essai de chute	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.6	Essai de charge de compression	Cartouche de combustible Cartouche de combustible remplie partiellement Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.7	Essai de court-circuit externe	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.8	Essai de température de surface, de composant et de gaz d'échappement	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.9	Essai de stockage de longue durée	Cartouche de combustible Cartouche de combustible remplie partiellement
7.3.10	Essai de connexion à température élevée	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible remplie partiellement et bloc d'alimentation électrique de la micropile à combustible
7.3.11	Essai de cycles de connexion	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible
C.7.3.12	Essai d'émission	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
C.7.3.13	Essai de détection de pertes localisées de gaz hydrogène	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible, si exigé
C.7.3.15	Essai d'exploitation à température élevée	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Le Tableau C.5 remplace le Tableau 5.		

Référence de l'essai	Entité d'essai	Échantillon d'essai
Échantillon d'essai: Le nombre d'échantillons doit être au moins de six (6) cartouches de combustible, neuves ou partiellement remplies, comme spécifié pour les essais individuels ci-dessus, ou au moins de trois (3) systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible pour chaque essai de type. Séquence d'essai: Les essais 7.3.2 et 7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes cartouches de combustible. Les essais 7.3.1, 7.3.2, et 7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes systèmes à micropile à combustible ou des mêmes blocs d'alimentation électrique de micropiles à combustible. Réutilisation des échantillons: Les cartouches de combustible et les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible peuvent être réutilisés à l'initiative du fabricant, si ceci ne compromet pas l'essai individuel.		

Tableau C.6 – Conditions normalisées de laboratoire – Remplace le Tableau 6

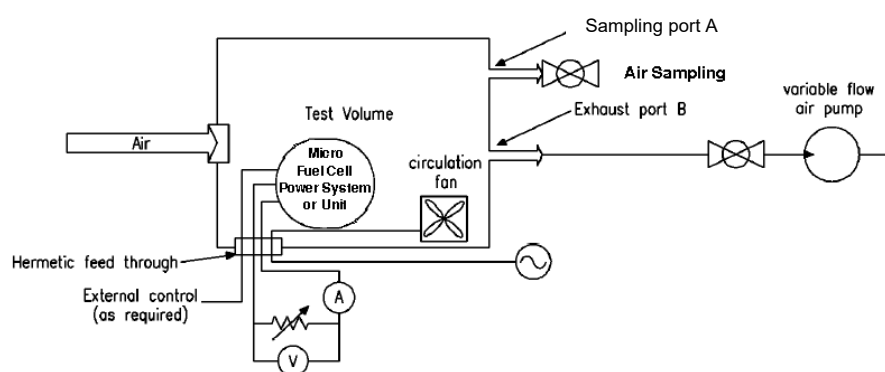
Élément	Condition
Température de laboratoire	La température de laboratoire est la «température ambiante» (condition de température normalisée, 22 °C ± 5 °C).
Atmosphère de la pièce du laboratoire; pour les essais du système à micropile à combustible et du bloc d'alimentation électrique de la micropile à combustible uniquement	L'atmosphère de la pièce du laboratoire contient 0,2 % de dioxyde de carbone au maximum, 0,002 % de monoxyde de carbone au maximum et 0,008 % d'hydrogène au maximum. L'atmosphère de la pièce du laboratoire contient au moins 18 % d'oxygène, mais pas plus de 21 % d'oxygène.
Le Tableau C.6 remplace le Tableau 6.	

C.7.3.12 Essai d'émissions

Ce paragraphe C.7.3.12 doit remplacer le 7.3.12 pour les systèmes à micropiles à combustible au méthanol reformé ou les blocs d'alimentation électrique des micropiles à combustible au méthanol reformé soumis à l'essai conformément à la présente Annexe C. Le Tableau C.7, Limites d'émissions, remplace le Tableau 7 de 7.3.12. La Figure C.10 remplace la Figure 10. Le nouveau Tableau C.8 supplémentaire, Limites d'exposition en milieu professionnel, est fourni pour donner à l'utilisateur des informations relatives aux limites d'exposition. Les émissions d'hydrogène sont évaluées séparément et la procédure pour les essais d'émissions d'hydrogène est détaillée à la Figure C.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe C.

Les systèmes à micropiles à combustible au méthanol reformé ne produisent ni ne stockent de l'hydrogène lorsqu'ils ne sont pas en fonctionnement. Tel étant le cas, le mesurage des pertes de gaz hydrogène n'est pas nécessaire pour les blocs d'alimentation électrique des micropiles à combustible au méthanol reformé en non-fonctionnement et les systèmes à micropiles à combustible au méthanol reformé en non-fonctionnement. L'essai d'émissions en C.7.3.12 est uniquement réalisé sur les systèmes en fonctionnement (ou en tentative de fonctionnement).

- Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) d'un système à micropile à combustible au méthanol reformé ou d'un bloc d'alimentation électrique de la micropile à combustible au méthanol reformé, les émissions de vapeurs de méthanol, de dioxyde de carbone (de monoxyde de carbone, de formaldéhyde, d'hydrogène et de vapeur d'eau doivent être maintenues à un niveau inférieur aux valeurs spécifiées. Le fait de maintenir ces limites empêche non seulement une exposition déconseillée, mais garantit aussi le maintien d'une alimentation adéquate en oxygène dans l'environnement de fonctionnement.

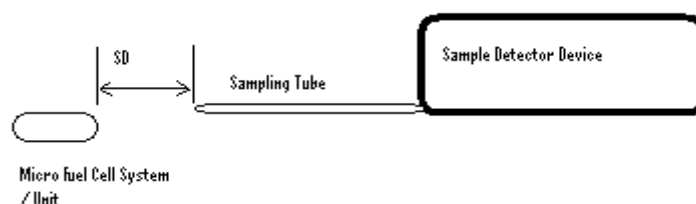


Anglais	Français
Air	Air
Sampling port	Orifice d'échantillonnage
Test volume	Volume d'essai
Micro fuel cell power system or unit	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Circulation fan	Ventilateur de brassage
Hermetic feed through	Passage hermétique
External control (as required)	Commande extérieure (si exigée)
Exhaust port	Orifice d'évacuation
Air sampling	Échantillonnage de l'air
Variable flow air pump	Pompe à air à débit variable

Figure C.10 – Appareillage d'essai du taux d'émission opérationnel – Remplace la Figure 10

- c) **Appareillage d'essai:** Un exemple d'appareillage d'essai d'émission opérationnel est représenté à la Figure C.10. La configuration représentée à la Figure C.10 sert aux essais de taux d'émission de tous les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe C. Les essais de taux d'émission conformément à C.7.3.12 d) 1) sont exigés pour tous les types de systèmes à micropiles à combustible et de blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe C.

Pour les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur (tels que les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible utilisés pour alimenter des téléphones cellulaires, des jeux tenus à la main, etc.), des essais complémentaires conformes à C.7.3.12 d) 3) et C.7.3.12 d) 4) sont exigés pour vérifier que les concentrations des émissions dans le voisinage de la bouche ou du nez d'un utilisateur sont maintenues dans des limites appropriées. Ces essais de concentrations d'émissions doivent être réalisés dans une grande salle ouverte en utilisant un appareillage d'essai de concentration d'émission différent. Un exemple d'appareillage d'essai de la concentration d'émission opérationnel est représenté à la Figure C.11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé) pour les essais de la limite de concentration des émissions.



Anglais	Français
Sampling tube	Tube d'échantillonnage
Sample detector device	Dispositif de détection d'échantillon
Micro fuel cell system/unit	Système à micropile à combustible / bloc d'alimentation de la micropile à combustible

Figure C.11 – Appareillage d'essai de concentration d'émission opérationnel – Remplace la Figure 11

Les gaz d'émission peuvent être composés de matières organiques toxiques, telles que les vapeurs de méthanol, le dioxyde de carbone, le monoxyde de carbone et le formaldéhyde, qui peuvent être évacuées d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible.

Pour analyser ces matières organiques, un chromatographe en phase gazeuse avec un détecteur à ionisation de flamme (GC/FID – *gas chromatograph/flame ionization detector*) ou avec un spectromètre de masse (GC/MS – *gas chromatograph/mass spectrometer*) doivent être utilisés en absorbant les gaz d'émission sur le tube à adsorption fixé sur l'orifice d'échantillonnage A de l'enceinte d'essai, ou directement sur un analyseur à travers l'orifice d'échantillonnage A de la Figure C.10. Toutefois, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus.

Un détecteur d'hydrogène étalonné pour la plage de concentration massique d'hydrogène de 0 % à 1 % peut être utilisé pour mesurer la concentration d'hydrogène.

La concentration de CO et de CO₂ peut être mesurée par un analyseur à absorption infrarouge non dispersif. Ces appareils de mesure analytiques doivent être conformes à l'ISO 16000-3, à l'ISO 16000-6 et à l'ISO 16017-1. Cependant, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus, en utilisant les normes mentionnées ci-dessus.

d) Procédure d'essai:

Les émissions d'hydrogène sont évaluées séparément. La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure C.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe C.

Les essais d'échantillonnage de taux d'émissions doivent être effectués avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit:

- 1) Pour tous les systèmes à micropiles à combustible et les blocs d'alimentation électrique de micropiles à combustible – aussi bien ceux destinés à être utilisés très près de la bouche ou du nez d'un consommateur que ceux qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur – l'essai suivant d'échantillonnage du taux d'émission doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit.
 - i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure C.10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la

micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).

- ii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
- iii) Les émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure C.10.
- iv) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
- v) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure C.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
- vi) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau C.7.
- vii) Calculer le taux d'émission des composés chimiques émis en multipliant la concentration stabilisée maximale de chaque constituant par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit en régime établi de la pompe à air à débit variable à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE 1 Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux d'émission.

Voir ci-dessous:

$$ER = (F_P + F_S) \times C$$

ou

$$ER = (F_i) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre normalisé.

- viii) Comparer le taux maximal d'émission mesuré avec le Tableau C.7. Si le taux d'émission n'est pas inférieur à la limite de taux d'émission dans le Tableau C.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite C.7.3.12 e) 1) i) et C.7.3.12 e) 2) i).
- ix) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de

fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.

- 2) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur, l'essai complémentaire suivant d'échantillonnage de concentration d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit.
 - i) Les essais de taux d'émission des systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible doivent être réalisés dans une grande salle ouverte. L'intention de cet essai est d'approcher et de mesurer la concentration d'émission attendue près de la bouche ou du nez d'une personne en air calme. Un mannequin ou autre simulateur peut être utilisé pour améliorer la précision de l'essai. L'air à l'intérieur de la salle doit être échantillonné avant les essais afin d'assurer la précision et éviter les résultats erronés non conformes. Veiller à s'assurer que les matières dans la salle ou dans le système d'échantillonnage n'apportent pas d'émissions (c'est-à-dire, de contaminants) à l'essai. Avant les essais, il est recommandé de rechercher les traces de contamination dans le système sans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, pour éviter les résultats erronés non conformes. Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
 - ii) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à la puissance assignée dans la grande salle ouverte lors de l'échantillonnage de concentrations d'émissions à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure C.11. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai de concentration d'émission doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible, et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
 - iii) Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
 - iv) Les concentrations des émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être échantillonnées à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure C.11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé).
 - v) La vitesse d'échantillonnage pour les mesurages de concentration d'émission très près doit être de 5 l par minute, ce qui représente la vitesse de respiration d'un être humain adulte.
 - vi) Laisser le débit d'échantillon se stabiliser.
 - vii) Échantillonner et enregistrer les émissions gazeuses du système à pile à combustible ou du bloc d'alimentation électrique de la pile à combustible qui se produisent à une distance représentative de la zone de respiration d'un consommateur.

- viii) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau C.7.
 - ix) Comparer les concentrations maximales mesurées avec le Tableau C.7. Si les concentrations d'émission ne sont pas inférieures aux limites de concentration d'émission dans le Tableau C.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite C.7.3.12 e) 2) ii).
 - x) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 3) À l'issue des mesurages d'émissions avec «DISPOSITIF EN POSITION «ON»» conformément au Tableau C.7, les émissions d'hydrogène en situation «DISPOSITIF EN POSITION «ON»» sont évaluées comme suit:
- i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure C.10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
 - ii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
 - iii) Les émissions de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure C.10.
 - iv) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
 - v) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure C.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
 - vi) Enregistrer la concentration d'hydrogène.
 - vii) Calculer le taux d'émission de l'hydrogène émis en multipliant la concentration stabilisée maximale d'hydrogène par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit en régime établi de la pompe à air à débit variable à travers le système au débit d'échantillon simultané ou en mesurant le débit d'air d'admission.

NOTE 2 Le débit total d'air entrant dans l'enceinte est égal à la somme des débits d'air sortant de l'enceinte. Par conséquent, le débit d'air à l'entrée de l'enceinte est égal au débit d'air à la sortie de l'enceinte plus le débit d'échantillonnage. Chacune des deux valeurs représente le débit d'air total à travers l'enceinte et l'une ou l'autre peut être utilisée pour calculer le taux d'émission.

Voir ci-dessous:

$$ER = (F_P + F_S) \times C$$

ou

$$ER = (F_i) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres normalisés par heure;

F_S est le débit d'échantillon en litres normalisés par heure;

F_i est le débit d'air à l'entrée de l'enceinte en litres normalisés par heure;

C est la concentration en grammes par litre normalisé;

- viii) Comparer le taux d'émission maximal mesuré d'hydrogène en situation [DISPOSITIF EN POSITION «ON»] par rapport au Tableau C.7.

NOTE 3 Il s'agit d'un mesurage de concentration stabilisée.

- ix) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente en électricité (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.

4) Évaluer le taux d'émission d'hydrogène comme suit:

- i) Si la valeur mesurée du taux d'émission d'hydrogène est inférieure à la valeur admissible, 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible satisfait à l'essai et aucun essai supplémentaire n'est nécessaire.
- ii) Si la valeur mesurée du taux d'émission d'hydrogène n'est pas inférieure à la valeur admissible totale 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système ou le bloc échoue à l'essai et aucun essai supplémentaire n'est nécessaire.
- iii) Si le taux d'émission d'hydrogène mesuré est inférieur à la valeur admissible totale 0,08 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), mais n'est pas inférieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), passer en C.7.3.13 Essai de détection de pertes localisées de gaz hydrogène pour vérifier qu'aucune source d'hydrogène ne dépasse 0,016 g/h.

e) **Critères de réussite:**

- 1) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau C.7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau 7 lorsqu'il est soumis à l'essai conformément à C.7.3.12 d) 1) pour le dispositif en marche («DISPOSITIF EN POSITION «ON»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
- 2) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible à utiliser très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau C.7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau 7 lorsqu'il est soumis à l'essai conformément à C.7.3.12 d) 1) pour la

situation dispositif en marche («DISPOSITIF EN POSITION «ON»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.

- ii) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur: En plus de la conformité à la limite de taux d'émission indiquée ci-dessus, la concentration maximale d'émission pour chacun des constituants concernés ne doit pas dépasser la limite de concentration d'émission indiquée dans le Tableau C.7 lorsqu'elle est vérifiée par essai conformément à 7.3.12 d) 3) pour la situation dispositif en marche («DISPOSITIF EN POSITION «ON»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
- 3) Les émissions d'hydrogène sont évaluées séparément. *La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure C.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe C.* À l'issue des mesurages d'émissions d'hydrogène conformément au Tableau C.7, les émissions d'hydrogène sont évaluées comme suit:
- i) **Critères de réussite pour les systèmes opérationnels:** Si le taux total d'émission d'hydrogène est inférieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible satisfait à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux total d'émission d'hydrogène n'est pas inférieur à 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible échoue à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux d'émission d'hydrogène est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), C.7.3.13, Essai de détection de pertes localisées de gaz hydrogène doit être effectué avec des résultats acceptables pour démontrer que les fuites d'hydrogène ne dépassent pas 0,016 g/h à partir d'une seule fuite localisée.

NOTE 4 Le niveau d'émission d'hydrogène inflammable admissible qui n'entretient pas de flammes est de 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain et M.N. Swain, Codes and Standards Analysis, 2001 (USA)). La limite d'émission d'hydrogène non inflammable est fondée sur les critères selon lesquels l'émission d'hydrogène n'augmente pas de plus de 25 % de la LII dans le volume de référence.

NOTE 5 L'hydrogène est défini comme un asphyxiant simple, mais, pour que ce risque existe, les niveaux d'oxygène doivent descendre à moins de 18 % à la pression atmosphérique normale. Le risque d'inflammabilité lié à l'hydrogène se produit à des concentrations d'hydrogène dans l'air supérieures à 4 %, tandis que le risque d'asphyxie survient à des concentrations d'hydrogène dans l'air supérieures à 12 %. Par conséquent, les limites d'inflammabilité sont utilisées en définissant les limites pour les émissions d'hydrogène.

NOTE 6 Les limites des niveaux d'émissions de vapeurs de dioxyde de carbone, de monoxyde de carbone et d'acide formique sont fondées sur les effets de la toxicité et de la corrosivité (acide formique uniquement) sur les humains, tandis que les limites des niveaux d'émissions d'hydrogène sont fondées sur le risque lié à la création d'une atmosphère inflammable dans des espaces confinés et sur le risque d'une flamme d'hydrogène qui peut être entretenue.

NOTE 7 Le risque d'inflammabilité de l'acide formique, basé sur les critères liés au maintien d'une concentration dans l'air en dessous de 25 % de la LII, est d'un ordre de grandeur inférieur au risque de toxicité (limite d'inflammabilité = 42 500 ppmv, et limite de toxicité = 5 ppmv). Ainsi, le niveau de toxicité de l'acide formique est utilisé pour établir les limites de ses émissions.

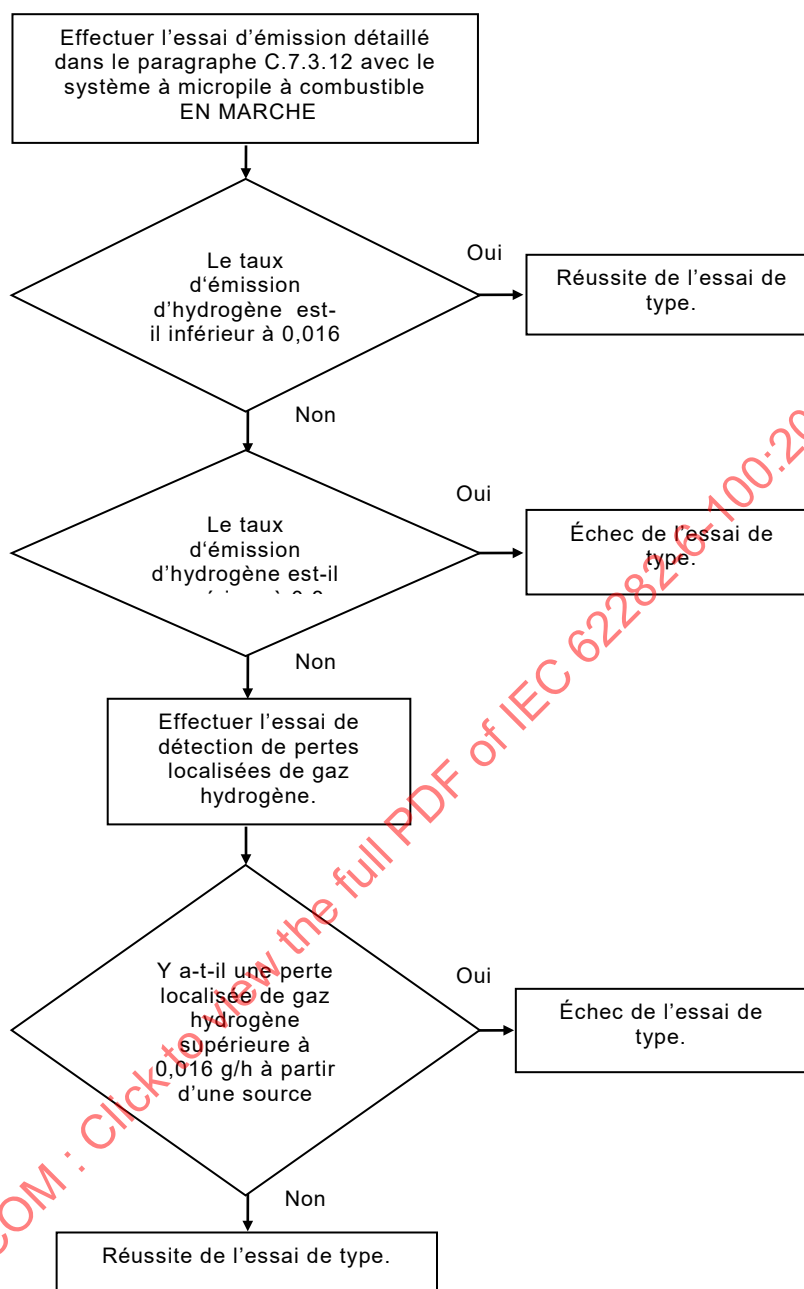


Figure C.12 – Procédure pour l'essai d'émission d'hydrogène pour le système à micropile à combustible en fonctionnement

Tableau C.7 – Limites d'émissions – Remplace le Tableau 7

	Limite de concentration	Limite du taux d'émission ^a
Eau	Illimitée	Pas de limite
Méthanol	0,26 g/m ³	2,6 g/h
Formaldéhyde	0,000 1 g/m ³ ^b	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Acide formique	0,009 g/m ³	0,09 g/h
Formiate de méthyle	0,245 g/m ³	2,45 g/h
Hydrogène	Non applicable	0,8 g/h total 0,016 g/h à partir d'une seule fuite localisée

^a La limite du taux d'émission était basée sur la valeur 10 m³ ACH, choisie comme le produit du volume de référence par les renouvellements d'air par heure (ACH), parce qu'elle couvre les environnements raisonnablement prévisibles dans lesquels les systèmes à micropiles à combustible sont utilisés. L'espace intérieur dans une petite voiture et le volume minimal par personne à bord d'un avion commercial sont fixés à 1 m³. L'ACH minimal utilisé à bord d'un avion de passagers est de 10 et le réglage de ventilation le plus faible dans les voitures est de 10 ACH. Les maisons et les bureaux peuvent présenter des niveaux d'ACH aussi bas que 0,5, mais le volume par personne est supérieur à 20 m³, et donc un produit de 10 est satisfaisant.

^b La limite fixée par l'OMS est de 0,000 1 g/m³. Les niveaux de fond sont de 0,000 03 g/m³. La limite d'émission ne peut pas faire passer le niveau de fond au-dessus de la limite fixée.

^c Un être humain adulte assis a un taux d'émission de CO₂ de 30 g/h. Les taux d'émission des piles à combustible, mais aussi des adultes sont limités, de telle sorte que la concentration de CO₂ n'atteigne pas la limite de concentration sur huit heures fixée par l'OMS de 9 g/m³. Dans un environnement avec 10 m³ ACH, ceci limite la contribution de la pile à combustible à 60 g/h.

Tableau C.8 – Limites d'exposition en milieu professionnel

Émissions	Limite d'exposition TWA (TWA – moyenne pondérée dans le temps sur 8 h de fonctionnement)	Valeur de STEL (expositions de 15 min à une fréquence maximale de 4 fois par jour)
CO₂	< 5 000 ppmv	< 30 000 ppmv
Acide formique	< 5 ppmv	< 10 ppmv
CO	< 25 ppmv	< 200 ppmv

C.7.3.13 Essai de détection de pertes localisées de gaz hydrogène

La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure C.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe C. Ce paragraphe s'ajoute aux exigences de l'Article 7.

Ce paragraphe doit être utilisé si cela est exigé par le C.7.3.12 d) 4) iii) pour démontrer la conformité au Tableau C.7, pour les systèmes à micropiles à combustible au méthanol reformé et les blocs d'alimentation électrique des micropiles à combustible au méthanol reformé. Il est nécessaire d'exécuter ce paragraphe pour satisfaire aux critères de réussite de C.7.3.12 e) 3) i) si le taux total d'émission d'hydrogène provenant d'un système à micropile à combustible à l'acide formique opérationnel ou d'un bloc d'alimentation électrique de la micropile à combustible au méthanol reformé opérationnel est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»).

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible, l'émission de l'hydrogène doit être maintenue à un niveau inférieur aux valeurs spécifiées dans le Tableau C.7. L'essai de détection de pertes localisées de gaz hydrogène doit être effectué pour déterminer qu'aucune source sur le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne peut entretenir une flamme dans tous les cas où une telle conformité ne peut être définitivement déterminée par l'essai d'émission d'hydrogène. Le fait de maintenir ces limites assure qu'il n'y aura ni accumulation de la concentration inflammable dans le volume de référence ni pertes de gaz hydrogène provenant de l'éprouvette qui pourraient entretenir une flamme. Ce maintien garantit également avec les autres essais d'émissions qu'une alimentation adéquate en oxygène sera maintenue dans l'environnement de fonctionnement.
- c) **Appareillage d'essai:** La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25% de la LII. La réponse des détecteurs d'hydrogène susmentionnés est généralement lente, le temps de réponse étant de plusieurs secondes, et donc des vitesses de balayage élevées peuvent causer une sous-estimation de la concentration d'hydrogène. Un élément d'importance est que la vitesse de balayage doit être suffisamment lente pour mesurer précisément la concentration d'hydrogène.
- d) **Procédure d'essai:**
 - 1) Le système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible doit rester en marche («DISPOSITIF EN POSITION «ON»») pendant toute la durée de l'essai de détection de pertes localisées de gaz hydrogène.
 - 2) L'essai doit être réalisé dans un espace sans circulation d'air importante. La vitesse mesurée du vent à 10 cm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ne doit pas dépasser 0,02 m/s. La concentration locale de la diffusion d'hydrogène mesurée dans cet essai est très sensible à l'effet du vent. Il est souhaitable que la vitesse du vent en n'importe quel endroit de l'espace d'essai soit aussi proche que possible de zéro. Les essais réalisés dans un espace clos, tel qu'une boîte à gants ou enceinte équivalente, constituent un moyen disponible de satisfaire à cette exigence.
 - 3) La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25 % de la LII.
 - 4) Le capteur du détecteur d'hydrogène doit balayer le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à une distance inférieure ou égale à 3 mm, perpendiculairement à la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les balayages linéaires consécutifs ne doivent pas être éloignés de plus de 8 mm le long de la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. La surface totale du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être balayée de cette manière.
 - 5) Une méthode efficace pour réaliser ces balayages consisterait à fixer une cale sur le capteur, qui assure le maintien en toutes circonstances d'un espacement de 3 mm

depuis le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Un stylo ou autre ustensile de marquage fixé sur la cale pourrait être utilisé pour identifier les zones balayées et pour garantir que la distance entre les balayages ne dépasse pas 8 mm.

- 6) Il convient que le capteur soit toujours dirigé directement vers le bas, et que le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible soit déplacé sous ce dernier de telle sorte que la surface juste en dessous du capteur soit toujours horizontale.
 - 7) Si aucun point n'est détecté lorsque la concentration d'hydrogène est supérieure à 25 % de la LII, l'essai est terminé et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être considéré comme ayant satisfait à l'essai.
 - 8) Lorsqu'un certain nombre de balayages de source ponctuelle présentent une vaste région de 25 % ou plus de la LII dans les balayages linéaires initiaux, le fait d'enregistrer les valeurs mesurées de la concentration permet de déterminer le point de départ des balayages en spirale secondaires. Les sources ponctuelles sont censées se trouver aux endroits auxquels il existe des valeurs maximales locales dans la distribution des valeurs mesurées de la concentration.
 - 9) S'il est détecté que des points ont une concentration d'hydrogène de 25 % de la LII ou plus, un deuxième essai doit être réalisé pour garantir que l'émission ne dépasse pas 0,016 g/h d'hydrogène pur depuis une source quelconque.
 - 10) Le deuxième essai doit être réalisé avec la hauteur du capteur réglée à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.
 - 11) Un balayage en spirale doit alors être réalisé, depuis le point auquel a eu lieu la détection de 25 % de la LII ou plus de l'hydrogène au cours du balayage linéaire initial. Le balayage en spirale doit présenter un espacement de 1 mm ou moins entre les balayages et doit former une spirale sur une distance radiale d'au moins 4 mm et suffisamment loin pour détecter le niveau maximal d'hydrogène à partir de la source d'hydrogène particulière.
 - 12) Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Si le balayage en spirale ne détecte pas de concentrations d'hydrogène supérieures ou égales à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible satisfait à l'essai.
- e) **Critères de réussite:** Aucune perte de gaz hydrogène provenant d'une source quelconque à plus de 0,016 g/h telle qu'indiquée par les essais de balayage. Aucune indication d'hydrogène qui soit à 25 % de la LII pendant les essais de balayage primaire ni aucune indication d'hydrogène à 25 % de la LII pendant les essais de balayage secondaire à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Voir Tableau C.7.

C.7.3.14 Essai d'arrêt à température élevée

Ce paragraphe s'ajoute aux exigences de l'Article 7.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.

- b) **Objet:** vérifier que le système à micropile à combustible provoque une séquence d'arrêt dans une période de temps raisonnable si le reformeur atteint une température anormalement élevée.
- c) **Procédure d'essai:**
 - 1) Tandis que le bloc d'alimentation électrique de la micropile à combustible fonctionne à la puissance de sortie assignée, utiliser la méthode de réglage de température spécifiée par le fabricant pour régler une température à 10 °C au-dessus de la température maximale de fonctionnement à l'intérieur du reformeur.
 - 2) Vérifier que la séquence d'arrêt du système à micropile à combustible est initiée dans les 5 s qui suivent l'obtention du point de réglage de température par le reformeur.
- d) **Critères de réussite:** La séquence d'arrêt du système à micropile à combustible est initiée dans les 5 s qui suivent l'obtention du point de réglage de température par le reformeur.

C.7.3.15 Essai d'exploitation à température élevée

Ce paragraphe s'ajoute aux exigences de l'Article 7.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** vérifier que le système à micropile à combustible fonctionne en toute sécurité, même si le reformeur est à une température de 30 °C au-dessus de la température maximale de fonctionnement.
- c) **Procédure d'essai:**
 - 1) Désactiver le mécanisme d'arrêt automatique décrit en C.7.3.14. Régler la température du reformeur à 30 °C au-dessus de la température maximale de fonctionnement.
 - 2) Faire fonctionner le système à micropile à combustible à pleine charge, comme spécifié par le fabricant, pendant 1 h à cette température élevée.
- d) **Critères de réussite:** Il ne doit se produire aucune émission de flammes, et le système à micropile à combustible doit être conforme aux exigences d'émission du Tableau 7 et de C.7.3.12.

Annexe D (normative)

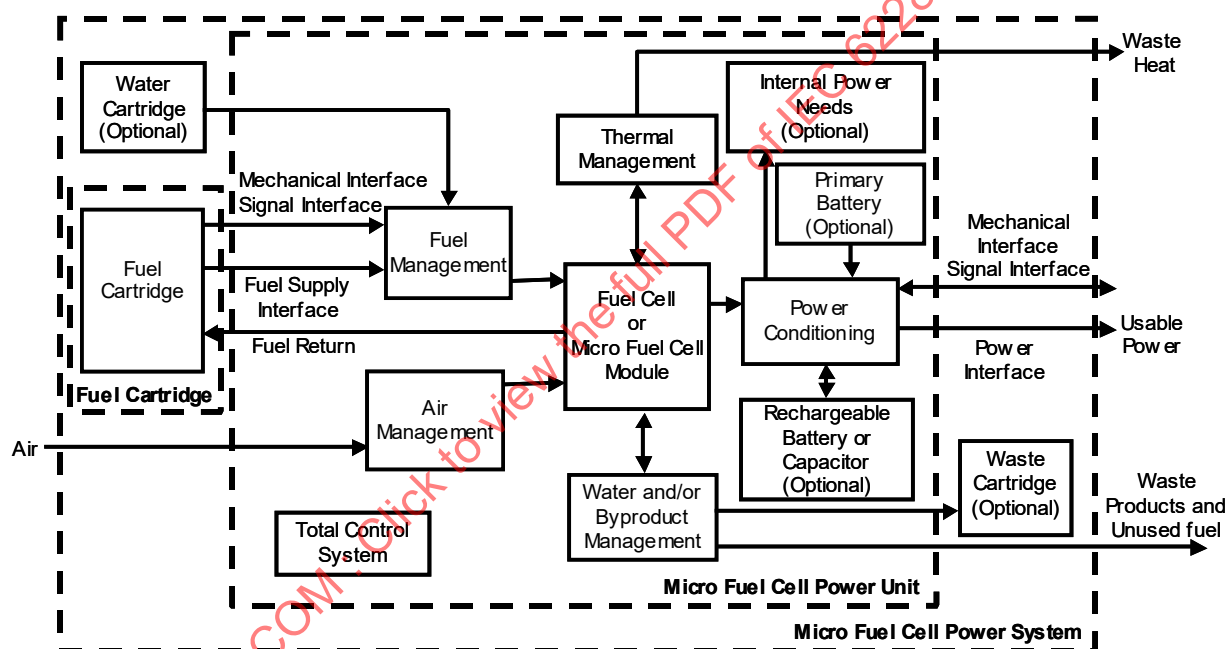
Systèmes à micropiles à combustible au clathrate de méthanol

D.1 Domaine d'application

D.1.2 Combustibles et technologies traités par la présente annexe

L'Annexe D traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible des solutions de méthanol ou de méthanol et d'eau (dérivées de composés de clathrate de méthanol). Ces systèmes et blocs d'alimentations utilisent des technologies de piles à combustible au méthanol direct.

La Figure D.1 remplace la Figure 1 présentant un schéma de principe du système à micropile à combustible au clathrate de méthanol à utiliser avec la présente annexe.



Anglais	Français
Air	Air
Air management	Gestion de l'air
Fuel cartridge	Cartouche de combustible
Fuel management	Gestion du combustible
Fuel return	Retour de combustible
Fuel supply interface	Interface d'alimentation en combustible
Internal power needs (Optional)	Besoins internes en énergie (Facultatif)
Mechanical interface	Interface mécanique
Fuel cell or micro fuel cell module	Pile à combustible ou module à micropile à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de la micropile à combustible
Power conditioning	Conditionnement de l'énergie
Power interface	Interface de puissance
Primary battery (Optional)	Pile électrique (Facultatif)

Anglais	Français
Rechargeable battery or capacitor (Optional)	Batterie rechargeable ou condensateur (Facultatif)
Signal interface	Interface signal
Thermal management	Gestion thermique
Total control system	Système global de commande
Usable power	Puissance utile
Waste cartridge (Optional)	Cartouche usagée (Facultatif)
Waste heat	Chaleur résiduelle
Waste products and unused fuel	Déchets et combustible inutilisé
Water and/or byproduct management	Gestion de l'eau et/ou sous-produits
Water cartridge (Optional)	Cartouche d'eau (Facultatif)

Figure D.1 – Schéma de principe des systèmes à micropiles à combustible au clathrate de méthanol – Remplace la Figure 1

D.1.3 Niveau de sécurité équivalent

Ce paragraphe remplace le 1.3.

- a) Les exigences de la présente norme ne sont pas destinées à limiter l'innovation. Le fabricant peut prendre en considération des combustibles, des matériaux, des conceptions ou des constructions qui ne sont pas spécifiquement traités dans la présente norme. Il convient d'évaluer ces alternatives selon leur aptitude à fournir des niveaux de sécurité équivalents à ceux définis dans la présente norme.
- b) Il est évident que tous les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible doivent être conformes aux exigences locales et nationales, y compris, entre autres, à celles relatives au transport, la protection des enfants, et le stockage, le cas échéant.
- c) Le débat suivant fournit des informations supplémentaires concernant les systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible des solutions de méthanol ou des solutions de méthanol et d'eau dérivées de composés de clathrate de méthanol.
 - 1) Le clathrate de méthanol (MCC)³ est un solide⁴ qui comprend du méthanol. La cartouche de combustible contenant du MCC ne contient pas de liquide avant l'utilisation; par conséquent, il ne peut pas se produire de fuite de liquide d'une cartouche inutilisée. Le MCC n'est pas classé comme substance dangereuse par les Recommandations des Nations-Unies relatives au transport des marchandises dangereuses: Manuel d'épreuves et de critères, quatrième édition révisée,

**Methanol clathrate compound
(solid)**

MCC fuel cartridge

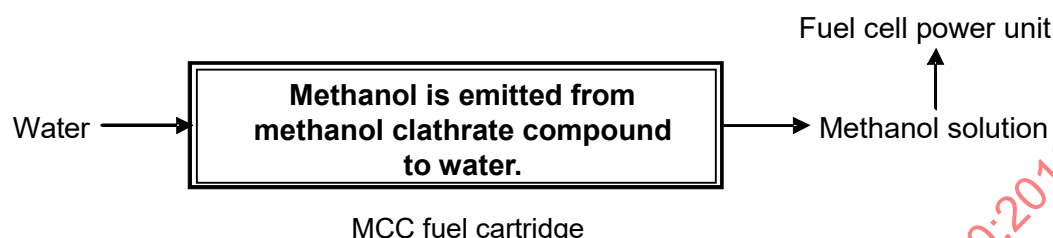
Anglais	Français
Methanol clathrate compound (solid)	Clathrate de méthanol (solide)
MCC fuel cartridge	Cartouche de combustible MCC

³ Composé d'addition organique qui a un espace interne complètement fermé. Il est formé par l'inclusion de molécules de méthanol dans des cavités formées par des réseaux cristallins ou présentes dans des molécules de grandes dimensions

⁴ Examiné par l'ASTM D 4359-90: *Standard test method for determining whether a material is a liquid or a solid.*

Figure D.12 – Cartouche de combustible composée de clathrate de méthanol

- 2) Lorsque la cartouche de combustible remplie de MCC est installée dans le bloc d'alimentation électrique de la micropile à combustible, de l'eau est injectée dans la cartouche de combustible. Une solution de méthanol est formée par l'émission de méthanol du MCC vers l'eau injectée. La solution de méthanol est ensuite utilisée comme combustible (Figure D.13).



Anglais	Français
Water	Eau
Methanol is emitted from methanol clathrate compound to water	Le méthanol est émis du clathrate de méthanol vers l'eau
Micro fuel cell power unit	Bloc d'alimentation électrique de la micropile à combustible
Methanol solution	Solution de méthanol
MCC fuel cartridge	Cartouche de combustible à MCC

Figure D.13 — Utilisation du clathrate de méthanol avec un bloc d'alimentation électrique de la micropile à combustible

- 3) Une cartouche de combustible inutilisée ne contient qu'un matériau solide et donc, aucune fuite de liquide ne peut se produire. Cependant, dans la mesure où une cartouche de combustible utilisée dans un système à micropile à combustible à méthanol direct (DMFC) contient une solution de méthanol, une évaluation des fuites d'une cartouche de combustible contenant de l'eau est effectuée. Une cartouche de combustible inutilisée et une cartouche de combustible usagée (telle que définie par D.3.40) sont utilisées pour les essais de type.

D.3 Termes et définitions

Les termes et définitions ci-dessous remplacent les termes et définitions correspondants de l'Article 3 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe D. Tous les termes et conditions de l'Article 3 qui ne sont pas spécifiquement mentionnés ici s'appliquent également.

D.3.5 combustible

solution de méthanol et d'eau formée par le contact du clathrate de méthanol (MCC) et de l'eau

Le MCC est une substance solide et se compose de méthanol et de matériaux non dangereux qui forment une matrice pour inclure un MCC

D.3.23 cartouche satellite

non applicable à la présente Annexe D

Les termes supplémentaires et leurs définitions ci-dessous sont nécessaires pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à

combustible et les cartouches de combustible traités par la présente Annexe D en plus de ceux donnés dans l'Article D.3 et dans l'Article 3.

D.3.37

MCC en poudre non accessible

combustible de MCC en poudre qui n'est pas en contact avec les consommateurs

D.3.38

absence de fuite de MCC en poudre

MCC en poudre non accessible à l'extérieur du système à micropile à combustible ou de la cartouche de combustible

D.3.39

non dangereux

matériaux qui, lorsqu'ils sont soumis à l'essai conformément au manuel d'épreuves et de critères des Nations Unies, ne sont pas classés comme marchandises dangereuses

D.3.40

cartouche de combustible usagée

cartouche de combustible à utiliser dans les essais de type au lieu de la cartouche de combustible réellement usagée

NOTE Une cartouche de combustible usagée est préparée en remplissant d'eau une cartouche de combustible inutilisée, formant ainsi une solution de méthanol

D.4.12 Construction de l'alimentation en combustible

D.4.12.1 Construction de la cartouche de combustible

Ces exigences s'appliquent aux systèmes à micropiles à combustible et aux blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe D. Ces exigences remplacent les exigences correspondantes de 4.12.1.

Les cartouches de combustible doivent être conformes aux exigences suivantes.

D.4.12.1.1 Il ne doit pas y avoir de fuite de la cartouche de combustible dans la plage de températures comprise entre $-40\text{ }^{\circ}\text{C}$ et $+70\text{ }^{\circ}\text{C}$. La conformité doit être déterminée par des essais de type conformément à 7.3.3 et 7.3.4.

D.4.12.1.2 Il ne doit pas y avoir de fuite de la cartouche de combustible à une pression manométrique interne de 95 kPa et à une pression normale de fonctionnement à $22\text{ }^{\circ}\text{C}$ ou à deux fois la pression de la cartouche de combustible à $55\text{ }^{\circ}\text{C}$, en prenant celle des deux valeurs qui est la plus élevée. La conformité doit être déterminée par des essais de type conformes à D.7.3.1

D.4.12.1.3 Le volume de combustible maximal dans la cartouche de combustible ne doit pas dépasser 1 l.

D.4.12.1.4 Pour l'utilisation normale, le mauvais usage raisonnablement prévisible et le transport pour la vente d'une cartouche de combustible avec un bloc d'alimentation électrique de la micropile à combustible par un consommateur, des dispositifs doivent être prévus pour éviter une fuite de combustible avant, pendant et après la connexion ou le transfert de combustible vers le bloc d'alimentation électrique de la micropile à combustible. La conformité est vérifiée par D.7.3.11.

D.4.12.1.5 Une cartouche de combustible doit résister à la corrosion dans son environnement d'utilisation.

D.4.12.1.6 Une cartouche de combustible doit être équipée de dispositifs pour empêcher une mauvaise connexion qui entraînerait une fuite de combustible lorsqu'elle est installée dans un système à micropile à combustible. La conformité est vérifiée par l'essai de cycles de connexion, D.7.3.11.

D.4.12.1.7 Les connecteurs d'alimentation en combustible prévus sur la cartouche de combustible doivent être construits de telle sorte qu'ils empêchent la fuite de combustible lorsqu'ils ne sont pas fixés sur une micropile à combustible au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible et du transport pour la vente. La conformité est vérifiée par l'essai de chute, D.7.3.5 et l'essai de cycles de connexion, D.7.3.11.

D.4.12.1.8 Dans le cas où une vanne régulatrice de pression ou un dispositif similaire sont prévus, une vanne régulatrice de pression de ce type doit satisfaire aux exigences de performance pour chaque essai de type. Cette vanne doit réussir tous les essais de type sans fuite.

D.4.12.1.9 La structure au niveau de la connexion à la cartouche de combustible ne doit pas permettre de fuite de combustible.

D.4.12.1.10 Une cartouche de combustible, y compris l'interface entre la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible y compris la vanne doit présenter une construction suffisamment solide pour résister à une utilisation normale et à un mauvais usage raisonnablement prévisible généré par les vibrations, la chaleur, la pression, les chutes ou les chocs mécaniques, etc. La conformité est vérifiée par:

- les essais de pression différentielle, D.7.3.1;
- l'essai de vibrations, D.7.3.2;
- l'essai de cycles de températures, D.7.3.3;
- l'essai d'exposition à température élevée, D.7.3.4;
- l'essai de chute, D.7.3.5;
- l'essai de charge de compression, D.7.3.6;
- l'essai de stockage de longue durée, D.7.3.9;
- l'essai de connexion à température élevée, D.7.3.10;
- les essais de cycles de connexion, D.7.3.11.

D.4.12.1.11 Les vannes de la cartouche de combustible doivent fonctionner comme prévu, sans l'utilisation d'outils et sans force excessive nécessaire pour la connexion ou la déconnexion.

D.4.12.2 Exigences de remplissage de la cartouche de combustible

La conception de la cartouche de combustible et la quantité de remplissage de combustible doivent permettre une libération du combustible sans fuite, à une température de cartouche de combustible de 70 °C dans le cas d'une cartouche de combustible seule et lorsque la cartouche de combustible est limitée par le système à micropile à combustible ou par un dispositif d'essai comparable.

D.7 Essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

D.7.1 Généralités

Ce paragraphe D.7.1 remplace le 7.1 pour la présente annexe lors des essais concernant les systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible

et des cartouches de combustible qui utilisent comme combustible des solutions de méthanol ou des solutions de méthanol et d'eau dérivées de composés de clathrate de méthanol.

- e) Les essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible doivent permettre de vérifier que ces systèmes à micropiles à combustible, blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible sont sûrs pour une utilisation normale.
- f) Le Tableau D.5 énumère les essais de type qui doivent être effectués. *Le Tableau D.5 remplace le Tableau 5.*
- g) Sauf exigence explicite contraire dans cet article, les conditions de laboratoire sont spécifiées dans le Tableau D.6. *Le Tableau D.6 remplace le Tableau 6.*
- h) Le système à micropile à combustible, le bloc d'alimentation électrique de la micropile à combustible et/ou la cartouche de combustible doivent être conditionnés à une température de laboratoire normalisée de $22\text{ °C} \pm 5\text{ °C}$ pendant au moins 3 h avant la réalisation de chaque essai.
- i) Avertissement: Ces essais de type utilisent des procédures qui peuvent entraîner des dommages si des précautions appropriées ne sont pas prises. Il convient que les essais ne soient effectués que par des techniciens qualifiés et expérimentés utilisant une protection appropriée.

Tableau D.5 – Liste des essais de type – Remplace le Tableau 5

Référence de l'essai	Entité d'essai	Échantillon d'essai
D.7.3.1	Essais de pression différentielle	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
D.7.3.2	Essai de vibrations	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
D.7.3.3	Essai de cycles de températures	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
D.7.3.4	Essai d'exposition à température élevée	Cartouche de combustible Cartouche de combustible usagée
D.7.3.5	Essai de chute	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
D.7.3.6	Essai de charge de compression	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
D.7.3.7	Essai de court-circuit externe	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.8	Essai de température de surface, de composant et de gaz d'échappement	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
D.7.3.9	Essai de stockage de longue durée	Cartouche de combustible Cartouche de combustible usagée

Référence de l'essai	Entité d'essai	Échantillon d'essai
D.7.3.10	Essai de connexion à température élevée	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible usagés
D.7.3.11	Essai de cycles de connexion	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible usagés
7.3.12	Essai d'émission	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Le Tableau D.5 remplace le Tableau 5. Échantillon d'essai: Le nombre d'échantillons doit être au moins de six (6) cartouches de combustible, neuves ou usagées, comme spécifié pour les essais individuels ci-dessus, ou un minimum de trois (3) systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible pour chaque essai de type. Séquence d'essai: Les essais D.7.3.2 et D.7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes cartouches de combustible. Les essais D.7.3.1, D.7.3.2, et D.7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes systèmes à micropile à combustible ou des mêmes blocs d'alimentation électrique de micropiles à combustible. Réutilisation des échantillons: Les cartouches de combustible et les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible peuvent être réutilisés à l'initiative du fabricant, si ceci ne compromet pas l'essai individuel.		

Tableau D.6 – Conditions normalisées de laboratoire – Remplace le Tableau 6.

Élément	Condition
Température de laboratoire	La température de laboratoire est la «température ambiante» (condition de température normalisée, 22 °C ± 5 °C)
Atmosphère de la pièce du laboratoire; pour les essais du système à micropile à combustible et du bloc d'alimentation électrique de la micropile à combustible uniquement	L'atmosphère de la pièce du laboratoire ne contient pas plus de 0,2 % de dioxyde de carbone et pas plus de 0,002 % de monoxyde de carbone. L'atmosphère de la pièce du laboratoire contient au moins 18 % d'oxygène, mais pas plus de 21 % d'oxygène.
Le Tableau D.6 remplace le Tableau 6.	

D.7.2 Mesurage des fuites de MCC et de méthanol, et procédure de mesure

Ce paragraphe D.7.2 remplace le 7.2 pour la présente annexe lors des essais concernant les systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible des solutions de méthanol ou des solutions de méthanol et d'eau dérivées de composés de clathrate de méthanol.

Ces figures et leurs procédures remplacent les figures correspondantes présentées en 7.2.

L'examen des fuites de MCC en poudre doit être effectué lors des essais de type parce que le MCC en poudre est emballé dans une cartouche de combustible inutilisée. Le mesurage des fuites de MCC en poudre et de méthanol doit être effectué en principe conformément à la procédure présentée respectivement dans les Figures D.2 à D.5.

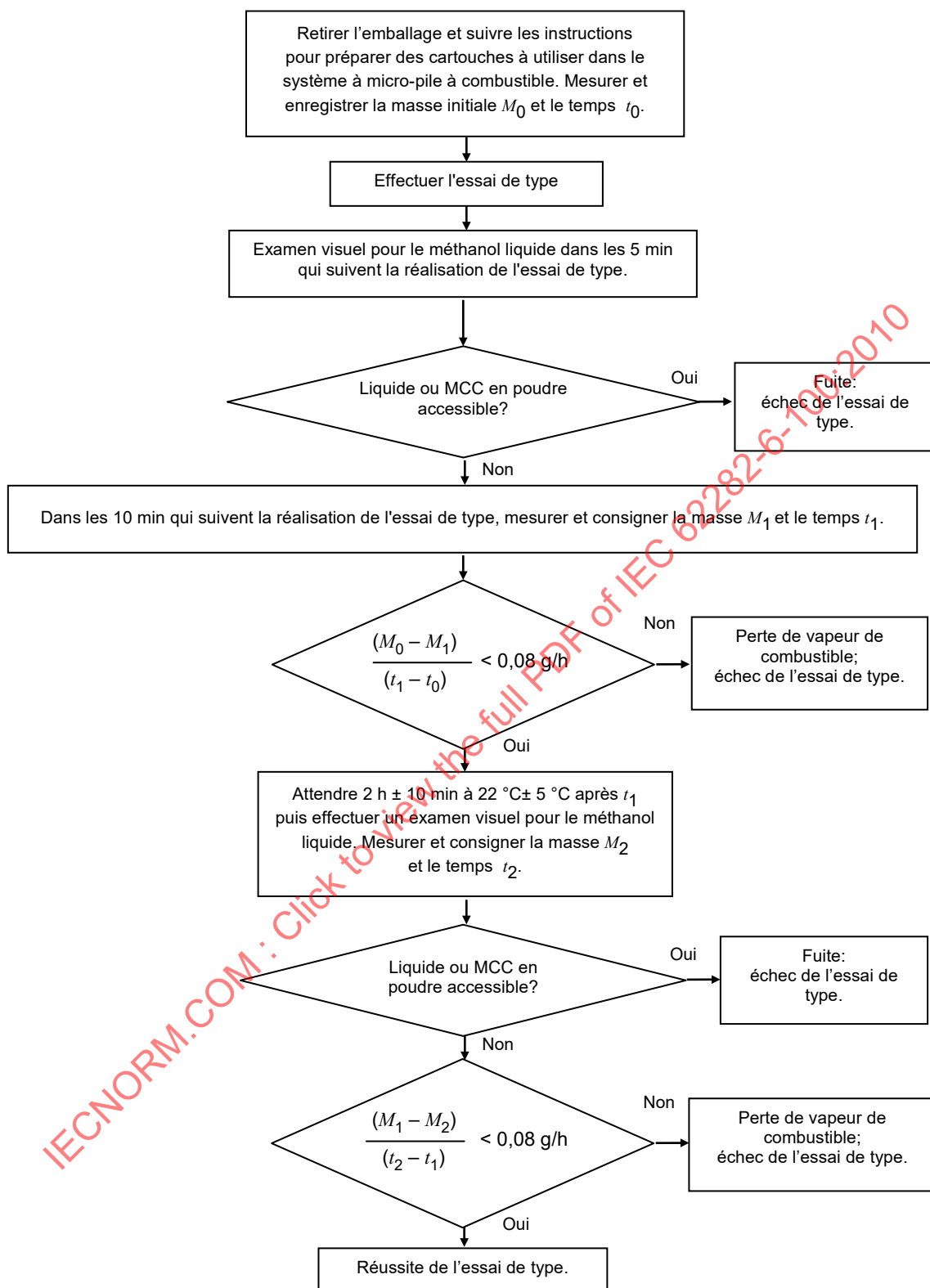


Figure D.2 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour les essais de pression différentielle, de vibrations, de chutes et de charge de compression – Remplace la Figure 2

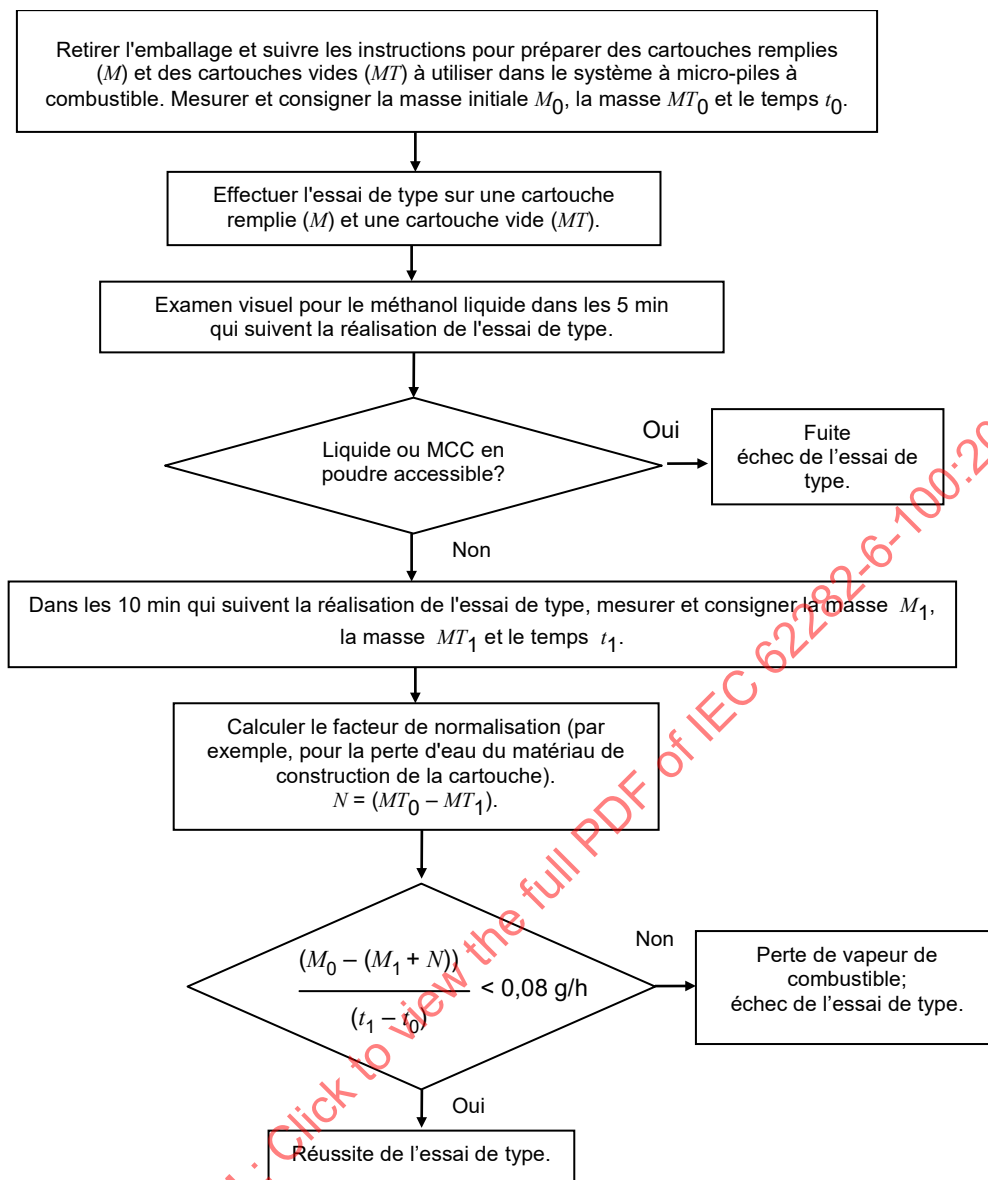


Figure D.3 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour l'essai de cycles de températures et l'essai d'exposition à température élevée – Remplace la Figure 3.

L'intervalle de temps maximal $t_1 - t_0$ doit être établi, de telle sorte que pas plus de la moitié du combustible ne soit perdue si la fuite de combustible se produisait au taux de perte de masse maximal admissible.

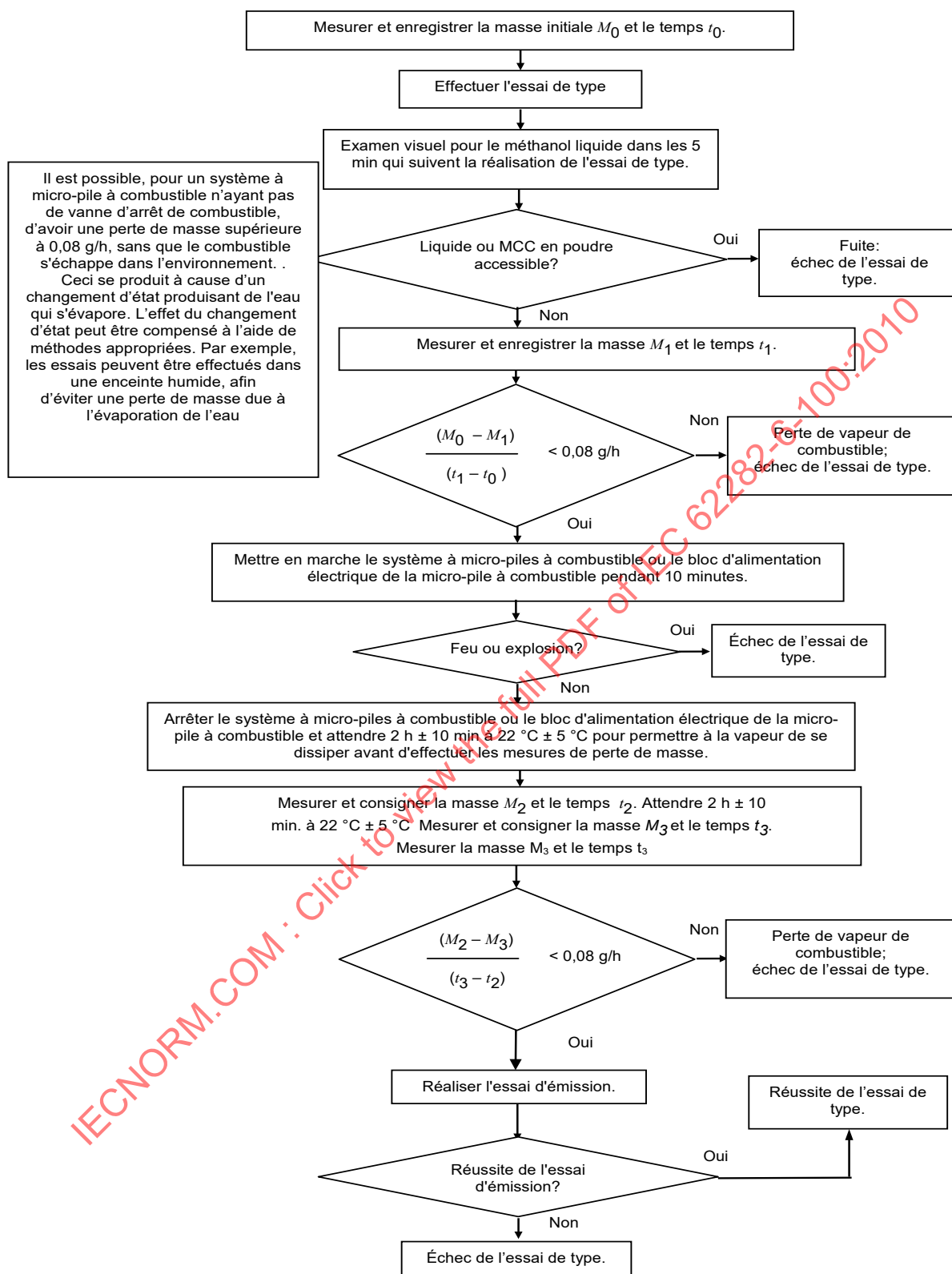


Figure D.4 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour les essais de pression différentielle, de vibrations, de cycles de température, de chute et de charge de compression – Remplace la Figure 4.

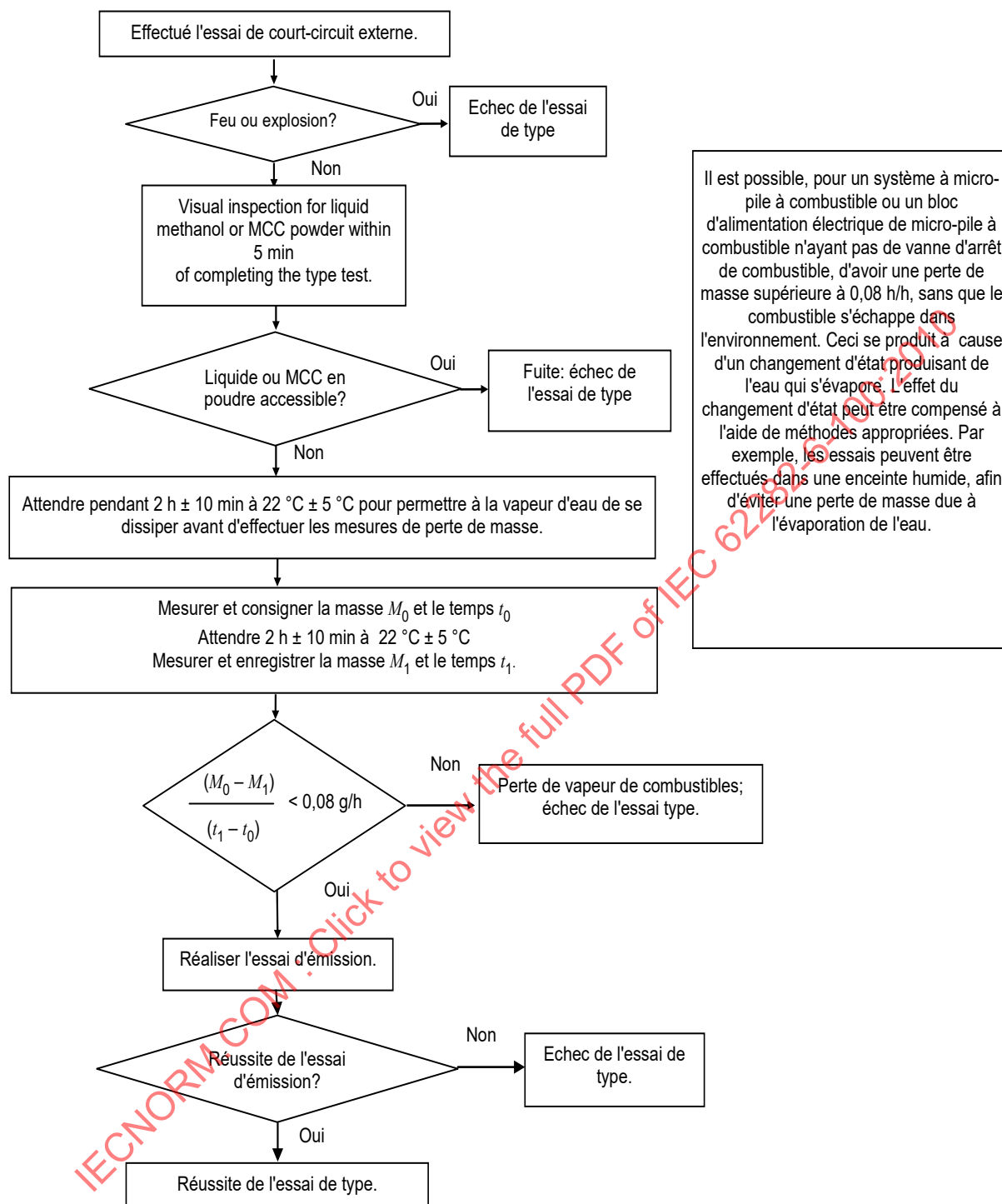


Figure D.5 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai de court-circuit externe – Remplace la Figure 5.

D.7.3 Essais de type

D.7.3.1 Essais de pression différentielle

D.7.3.1.1 Généralités

Le D.7.3.1 remplace le 7.3.1.

Certaines parties de cet essai sont conformes à 4.12.1.2 utilisé pour confirmer qu'il ne doit pas y avoir de fuite au niveau de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. Deux options d'essai sont proposées, en fonction des conditions de pression donnant la valeur la plus élevée:

- a) Si la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C donne une valeur supérieure à deux fois la pression manométrique de la cartouche de combustible à 55 °C, le D.7.3.1.2 ou le D.7.3.1.3 peut être utilisé pour vérifier la conformité à 4.12.1.2.
- b) Si deux fois la pression manométrique de la cartouche de combustible à 55 °C donne une valeur supérieure à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, le D.7.3.1.2 doit être utilisé pour vérifier la conformité à 4.12.1.2.

D.7.3.1.2 Essai de mise sous pression interne de la cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée et vanne de la cartouche de combustible.
- b) **Objet:** simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**

Pour l'essai de mise sous pression interne, le corps de la cartouche de combustible et la vanne de la cartouche de combustible doivent être soumis à l'essai séparément.

- 1) À l'aide d'un milieu liquide adapté comme l'eau, mettre sous pression le corps de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
- 2) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
- 3) À l'aide d'un milieu liquide adapté comme l'eau, mettre sous pression la vanne fermée de la cartouche de combustible à une pression égale soit à la pression manométrique de 95 kPa plus la pression normale de service à 22 °C de la cartouche, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
- 4) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
- d) **Critères de réussite:** Aucune fuite du milieu d'essai liquide accessible et aucune chute soudaine de pression au cours de l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et la vanne de la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue.

D.7.3.1.3 Essai de la cartouche de combustible à basse pression externe

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**

Effectuer cet essai conformément à la Figure D.2.

- 1) L'échantillon doit être placé dans une chambre à vide, et la pression dans la chambre à vide doit être réduite à 95 kPa en dessous de la pression atmosphérique normale.

2) Maintenir le vide pendant 30 min.

- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible, aucune fuite de MCC en poudre accessible et aucune perte de vapeur de combustible. Voir la Figure D.2. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. La présence de feu ou de flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

D.7.3.1.4 Essais de pression différentielle du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

D.7.3.1.4.1 Essai à basse pression externe à 68 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

Cet essai est exigé pour tous les systèmes à micropiles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe D.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
- 1) Effectuer cet essai conformément à la Figure 6.
 - 2) Les échantillons d'essai doivent être stockés à basse pression externe à 68 kPa de pression absolue pendant 6 h à la température ambiante du laboratoire. La fuite doit être mesurée en se basant sur la procédure décrite à la Figure 6.
 - 3) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible et aucune fuite de MCC en poudre accessible. Voir Figure 6. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. L'essai d'émission doit satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, le résultat de l'essai d'émission est acceptable. Pendant l'essai de 6 h à 68 kPa de pression externe absolue, la perte de vapeur de combustible doit être inférieure à 0,08 g/h.

D.7.3.1.4.2 Essai à basse pression externe à 11,6 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

Cet essai est exigé pour tous les systèmes à micropiles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe D.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer cet essai conformément à la Figure 7.
 - 2) Les échantillons d'essai doivent être stockés à basse pression externe à 11,6 kPa de pression absolue pendant 1 h à la température ambiante du laboratoire. La fuite doit être mesurée en se basant sur la procédure décrite à la Figure 7, avec pour critère de réussite OUI/NON une perte de vapeur de combustible à 11,6 kPa inférieure à 2,0 g/h en ne dépassant pas 25 % de la limite inférieure d'inflammabilité (LFL – *Lower Flammability Limit*).
 - 3) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible et aucune fuite de MCC en poudre accessible. Voir Figure 7. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. L'essai d'émission doit satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, le résultat de l'essai d'émission est acceptable. Pendant l'essai de 1 h à 11,6 kPa de pression externe absolue, la perte de vapeur de combustible doit être inférieure à 2,0 g/h.

D.7.3.2 Essai de vibrations

Le D.7.3.2 remplace le 7.3.2.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible usagée, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible utilisé en D.7.3.1.
- b) **Objet:** simuler les effets des vibrations au cours de conditions normales de transport, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure D.2 pour la cartouche de combustible et conformément à la Figure D.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) L'échantillon d'essai doit être fixé solidement à la plate-forme du générateur de vibrations, sans déformer l'échantillon, et de manière à émettre correctement les vibrations.
 - 3) Les vibrations doivent être de forme d'onde sinusoïdale avec un balayage logarithmique entre 7 Hz et 200 Hz et de nouveau à 7 Hz, traversé en 15 min.
 - 4) Ce cycle doit être répété 12 fois pendant 3 h au total pour chacune des trois positions de montage perpendiculaires des échantillons d'essai.
 - 5) Le balayage en fréquence logarithmique se déroule comme suit: à partir de 7 Hz, une accélération de crête de 1 g_n est maintenue jusqu'à ce que la valeur de 18 Hz soit atteinte. L'amplitude est ensuite maintenue à 0,8 mm (excursion totale de 1,6 mm) et

la fréquence est augmentée jusqu'à ce qu'une accélération de crête de $8 g_n$ se produise (environ 50 Hz). Une accélération de crête de $8 g_n$ est ensuite maintenue jusqu'à ce que la fréquence soit portée à 200 Hz.

- 6) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible, aucune fuite de MCC en poudre accessible et aucune perte de vapeur de combustible. La fuite et la perte de vapeur doivent être mesurées en se basant sur la Figure D.2 pour la cartouche de combustible et sur la Figure D.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.

D.7.3.3 Essai de cycles de températures

Le D.7.3.3 remplace le 7.3.3.

- a) **Échantillon d'essai:** cartouche de combustible utilisée en D.7.3.2, cartouche de combustible usagée en D.7.3.2, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant utilisé en D.7.3.2, ou système à micropile à combustible utilisé en D.7.3.2.
- b) **Objet:** simuler les effets d'une exposition à basse température et à température élevée et les effets de variations extrêmes de températures.
- c) **Procédure d'essai:**
- 1) Effectuer ces essais conformément à la Figure D.3 pour la cartouche de combustible et conformément à la Figure D.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) Pour une cartouche de combustible, deux orientations de cartouches de combustible doivent être soumises à l'essai – vanne vers le haut et vanne vers le bas. Pour un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible il n'est pas nécessaire de vérifier par essai plus d'une orientation.
 - 3) Voir Figure 8 pour le profil de température à utiliser.
 - 4) Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, et augmenter la température de l'enceinte de la température de laboratoire à $55\text{ °C} \pm 2\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$, et la maintenir à $55\text{ °C} \pm 2\text{ °C}$ pendant au moins 4 h.
 - 5) Diminuer la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$, puis diminuer la température de l'enceinte à $-40\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$, et la maintenir à $-40\text{ °C} \pm 5\text{ °C}$ pendant au moins 4 h.
 - 6) Augmenter la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$.
 - 7) Le processus ci-dessus doit être réalisé deux fois.
 - 8) Après 1 h à $22\text{ °C} \pm 5\text{ °C}$, la fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure 3 (pour la cartouche de combustible) et d'après la procédure décrite à la Figure 4 (pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible).

- 9) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide accessible, aucune fuite de MCC en poudre accessible et aucune perte de vapeur de combustible. La fuite et la perte de vapeur doivent être mesurées en se basant sur la Figure D.3 pour la cartouche de combustible et sur la Figure D.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.

D.7.3.4 Essai d'exposition à température élevée

Le D.7.3.4 remplace le 7.3.4.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets d'une cartouche de combustible laissée dans des environnements à température élevée.
- c) **Procédure d'essai:**
- 1) Deux orientations doivent être soumises à l'essai – vanne vers le haut et vanne vers le bas.
 - 2) Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, à une température de $70\text{ °C} \pm 2\text{ °C}$, et laisser la température de l'enceinte revenir à $70\text{ °C} \pm 2\text{ °C}$, et maintenir cette température pendant au moins 4 h avec l'échantillon dans l'enceinte.
 - 3) Retirer l'échantillon d'essai à la température de laboratoire.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide, aucune fuite de MCC en poudre et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure D.3 pour une cartouche de combustible. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

D.7.3.5 Essai de chute

Le D.7.3.5 remplace le 7.3.5.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible usagée, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets d'une chute involontaire, et garantir l'absence de fuite.
- c) **Procédure d'essai:**

- 1) L'échantillon d'essai doit chuter sur une surface horizontale se composant de bois dur d'au moins 13 mm d'épaisseur monté sur deux couches de contreplaqué, chacune d'une épaisseur de 18 mm à 20 mm, le tout sur un sol en béton ou en matériau équivalent non élastique, à partir d'une hauteur prédéterminée.
 - 2) La hauteur de chute doit être de:
 - i) 1 200 mm $\pm$ 10 mm: dans le cas d'un bloc d'alimentation électrique de la micropile à combustible et/ou d'un système à micropile à combustible.
 - ii) 1 500 mm $\pm$ 10 mm: dans le cas d'une cartouche de combustible contenant plus de 200 ml.
 - iii) 1 800 mm $\pm$ 10 mm: dans le cas d'une cartouche de combustible contenant jusqu'à 200 ml.
 - 3) Pour les essais de la cartouche de combustible, l'essai de chute doit être effectué dans quatre orientations de chute avec le même échantillon.
 - 4) Pour le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible, un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible peut être utilisé pour chacune des quatre orientations de chute, ou plusieurs systèmes à micropiles à combustible ou blocs d'alimentation électrique de micropiles à combustible peuvent être utilisés pour les chutes suivantes, à l'initiative du fabricant.
 - 5) Pour tous les essais, les orientations de chute doivent être les suivantes:
 - i) vanne vers le haut;
 - ii) vanne vers le bas;
 - iii) deux autres orientations perpendiculaires.
 - 6) Pour les essais du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à 7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide, aucune fuite de MCC en poudre et aucune perte de vapeur de combustible. La fuite et la perte de vapeur doivent être mesurées en se basant sur la Figure D.2 pour la cartouche de combustible et sur la Figure D.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible est toujours en état de fonctionnement, les circuits de protection spécifiés par l'AMDE en tant que parties des systèmes de sécurité doivent toujours être pleinement fonctionnels. Il ne doit pas y avoir d'exposition des parties dangereuses.

D.7.3.6 Essai de charge de compression

Le D.7.3.6 remplace le 7.3.6.

D.7.3.6.1 Système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée ou usagée.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur le bloc d'alimentation électrique de la micropile à combustible, ou le système à micropile à combustible.
- c) **Procédure d'essai:**
 - 1) L'échantillon d'essai du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer sur l'échantillon une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$.
 - 2) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).
 - 3) Une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 4) L'essai doit en général être effectué dans trois orientations perpendiculaires. Si l'échantillon n'est pas stable de lui-même, il n'est pas nécessaire qu'il soit soumis à l'essai dans cette orientation.
 - 5) Effectuer l'essai d'émission conformément à 7.3.12, après l'essai de charge de compression.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide, aucune fuite de MCC en poudre et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure D.4. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la ou les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. La présence de feu ou de flamme doit être vérifiée à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions provenant du système à micropile à combustible ou du bloc d'alimentation électrique des micropiles à combustible doivent satisfaire aux critères de réussite en 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.

D.7.3.6.2 Cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur la cartouche de combustible.
- c) **Procédure d'essai:**
 - 1) L'échantillon d'essai de la cartouche de combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer à l'échantillon une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$.
 - 2) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).

- 3) Une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 4) Les orientations de la cartouche de combustible doivent être choisies d'après les positions de repos en principe stables lors de chutes accidentelles (par exemple, les orientations ayant les centres de gravité les plus bas par rapport à la surface de repos). Il est acceptable de soumettre aux essais une seule surface d'une cartouche de combustible prismatique qui soit suffisamment cubique et la surface incurvée d'une cartouche de combustible cylindrique avec une longueur d'axe longitudinal supérieure à deux fois le diamètre.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide, aucune fuite de MCC en poudre et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure D.2. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

D.7.3.7 Essai de court-circuit externe

Le D.7.3.7 remplace le 7.3.7.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée ou usagée.
- b) **Objet:** simuler les effets d'un court-circuit externe.
- c) **Procédure d'essai:**
 - 1) L'essai de court-circuit externe doit être effectué séparément et respectivement à la fois sur les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible en fonctionnement [DISPOSITIF EN POSITION «ON»] et sur les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible en état de non-fonctionnement [DISPOSITIF EN POSITION «OFF»].
 - 2) Chaque échantillon d'essai doit être court-circuité en reliant les bornes positive et négative du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible avec des conducteurs ayant une charge de résistance maximale de $0,1 \Omega$ pendant au moins 5 min.
 - 3) Effectuer l'essai d'émission conformément à 7.3.12 après chaque essai de court-circuit.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite de liquide, aucune fuite de MCC en poudre et aucune perte de vapeur de combustible. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure D.5. La fuite doit être vérifiée visuellement. Retirer la cartouche de combustible, si elle est présente, du système à micropile à combustible. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que les vannes soient dirigées vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

Les surfaces externes ne doivent pas dépasser les températures du Tableau 2, pendant ou après les essais de court-circuit.

Les émissions doivent satisfaire aux critères de réussite de 7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible

ne fonctionne pas, mais les émissions ne dépassent pas les limites de 7.3.12, l'essai d'émission est acceptable.

NOTE L'essai de court-circuit externe peut être réalisé de manière séquentielle avec l'essai de température de surface, de composant et de gaz d'échappement, en utilisant le même échantillon.

D.7.3.9 Essai de stockage de longue durée

Le D.7.3.9 remplace le 7.3.9.

D.7.3.9.1 Généralités

D.7.3.9.2 (Option 1), D.7.3.9.3 (Option 2) ou D.7.3.9.4 (Option 3) peut être utilisé.

D.7.3.9.2 Option 1 – Mesurage du poids en continu

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai** (Voir Figure D.9):
 - 1) Utiliser un dynamomètre (dispositif de pesage électronique continu) conçu et étalonné pour une utilisation à 50 °C à l'intérieur de l'enceinte de température.
 - 2) Placer le dynamomètre dans une enceinte de température à 50 °C ± 2 °C. Placer la cartouche de combustible sur la partie supérieure du dynamomètre, de sorte que toute la masse soit appliquée sur le dynamomètre. Un dispositif de fixation peut être utilisé pour contrôler la position de la cartouche de combustible, pour garantir que toute la masse est appliquée sur le dynamomètre.
 - 3) Connecter un affichage numérique sur le dynamomètre et collecter les données manuellement ou automatiquement. Il convient de collecter les données avec un degré de confiance élevé, pour assurer que la perte de vapeur de combustible ne dépasse pas 0,08 g/h.
 - 4) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
 - 5) L'échantillon doit rester dans l'enceinte d'essai de température à 50 °C ± 2 °C pendant au moins 28 jours.
 - 6) Si la cartouche de combustible a toujours du combustible dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,08 g/h alors l'échantillon d'essai satisfait à l'essai de perte de vapeur de combustible.

$$\text{i) Perte de vapeur de combustible} = \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$$

$$\text{ii) } \Delta t = t_f - t_i = 28 \text{ jours} \times 24 \text{ h/jour} = 672 \text{ h.}$$

$$\text{iii) } M_{\text{initiale}} = \text{masse initiale de la cartouche de combustible.}$$

$$\text{iv) } M_{\text{finale}} = \text{masse finale de la cartouche de combustible.}$$

- 7) Si la cartouche de combustible est vide avant la fin de l'essai, le taux de perte de masse doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que la cartouche de combustible ne soit vide. L'essai est réussi si la perte de vapeur de combustible est inférieure à 0,08 g/h.

$$\text{i) Perte de vapeur de combustible} = \frac{M_{\text{initiale}} - M_{\text{dernière}}}{\Delta t_{\text{dernier}}}$$

- ii) $\Delta t_{\text{dernier}}$ = le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) $M_{\text{dernière}}$ = le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible, aucune fuite de liquide et aucune fuite de MCC en poudre. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure D.9. Si la cartouche de combustible dépasse les critères de perte de vapeur de combustible de 0,08 g/h, alors l'échantillon d'essai échoue à l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

D.7.3.9.3 Option 2 – Mesurages périodiques du poids

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai** (Voir Figure D.9):
 - 1) Placer la cartouche de combustible dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$. Il convient de recueillir les mesurages du poids avec un degré de confiance élevé, afin de déterminer si la perte de vapeur de combustible ne dépasse pas 0,08 g/h, avec une fréquence minimale d'une fois tous les trois jours.
 - 2) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
 - 3) L'échantillon doit rester dans l'enceinte d'essai de température à $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 28 jours.
 - 4) La durée pendant laquelle les échantillons d'essai sont retirés de l'enceinte pour le mesurage ne doit pas être incluse dans la durée pendant laquelle l'échantillon d'essai doit être soumis à l'essai (28 jours). Il convient d'ajouter une durée supplémentaire pour que l'échantillon d'essai soit à la température d'essai ($50\text{ °C} \pm 2\text{ °C}$), à chaque fois que l'échantillon d'essai est retiré de l'enceinte. Il convient que les échantillons d'essai ne soient stabilisés à la température ambiante du laboratoire que si la perte de masse est affectée.
 - 5) Si la cartouche de combustible a toujours du combustible dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,08 g/h alors l'échantillon d'essai satisfait à l'essai de perte de vapeur de combustible.
 - i) Perte de vapeur de combustible $= \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}$.
 - ii) $\Delta t = t_f - t_i = 28\text{ jours} \times 24\text{ h/jour} = 672\text{ h}$.
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) M_{finale} = masse finale de la cartouche de combustible.
 - 6) Si la cartouche de combustible est vide avant la fin de l'essai, le taux de perte de masse doit être calculé d'après le temps écoulé au dernier point de données mesuré ($\Delta t_{\text{dernier}}$) et la masse finale ($M_{\text{dernière}}$) au dernier point de données mesuré avant que

la cartouche de combustible ne soit vide. L'essai est réussi si la perte de vapeur de combustible est inférieure à 0,08 g/h.

- i) Perte de vapeur de combustible
$$= \frac{M_{\text{initiale}} - M_{\text{dernière}}}{\Delta t_{\text{dernier}}}.$$
 - ii) $\Delta t_{\text{dernier}}$ = le temps écoulé entre le mesurage du poids initial au début de l'essai et le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) $M_{\text{dernière}}$ = le dernier mesurage du poids alors qu'il reste encore du combustible dans la cartouche de combustible.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible, aucune fuite de liquide et aucune fuite de MCC en poudre. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure D.9. Si la cartouche de combustible dépasse les critères de perte de vapeur de combustible de 0,08 g/h, alors l'échantillon d'essai échoue à l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

D.7.3.9.4 Option 3 – Un seul mesurage du poids

Cette option est destinée aux cartouches de combustible avec des taux de fuite très faibles.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) Procédure d'essai (Voir Figure D.9):
 - 1) Mesurer et enregistrer la masse initiale M_{initiale} et le temps t_i .
 - 2) Placer les cartouches de combustible dans une enceinte de température à $50\text{ °C} \pm 2\text{ °C}$. Après 28 jours, les cartouches de combustible sont retirées de l'enceinte pour le mesurage. Il convient que les échantillons d'essai soient stabilisés à la température ambiante du laboratoire si la perte de masse est affectée. Le mesurage de la masse est ensuite effectué.
 - 3) Si la cartouche de combustible a toujours du combustible liquide dans l'échantillon d'essai à la fin de l'essai, calculer la perte de vapeur de combustible en divisant la perte de masse par le nombre d'heures de présence de l'échantillon d'essai dans l'enceinte. Dans un délai de cinq minutes après l'essai, mesurer et enregistrer la masse M_{finale} et enregistrer le temps t_f . Si le taux de perte de masse moyenne est inférieur à 0,08 g/h alors l'échantillon d'essai satisfait à l'essai de perte de vapeur de combustible.
 - i) Perte de vapeur de combustible
$$= \frac{M_{\text{initiale}} - M_{\text{finale}}}{\Delta t}.$$
 - ii) $\Delta t = t_f - t_i = 28\text{ jours} \times 24\text{ h/jour} = 672\text{ h}.$
 - iii) M_{initiale} = masse initiale de la cartouche de combustible.
 - iv) M_{finale} = masse finale de la cartouche de combustible.
 - 4) Si la cartouche de combustible est vide après 28 jours, alors l'essai de type conformément à D.7.3.9.2 Option 1 ou D.7.3.9.3 Option 2 doit être effectué.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte de vapeur de combustible, aucune fuite de liquide et aucune

fuite de MCC en poudre. La fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure D.9. Si la cartouche de combustible a dépassé les critères de perte de vapeur de combustible de 0,08 g/h, alors l'échantillon d'essai échoue à l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

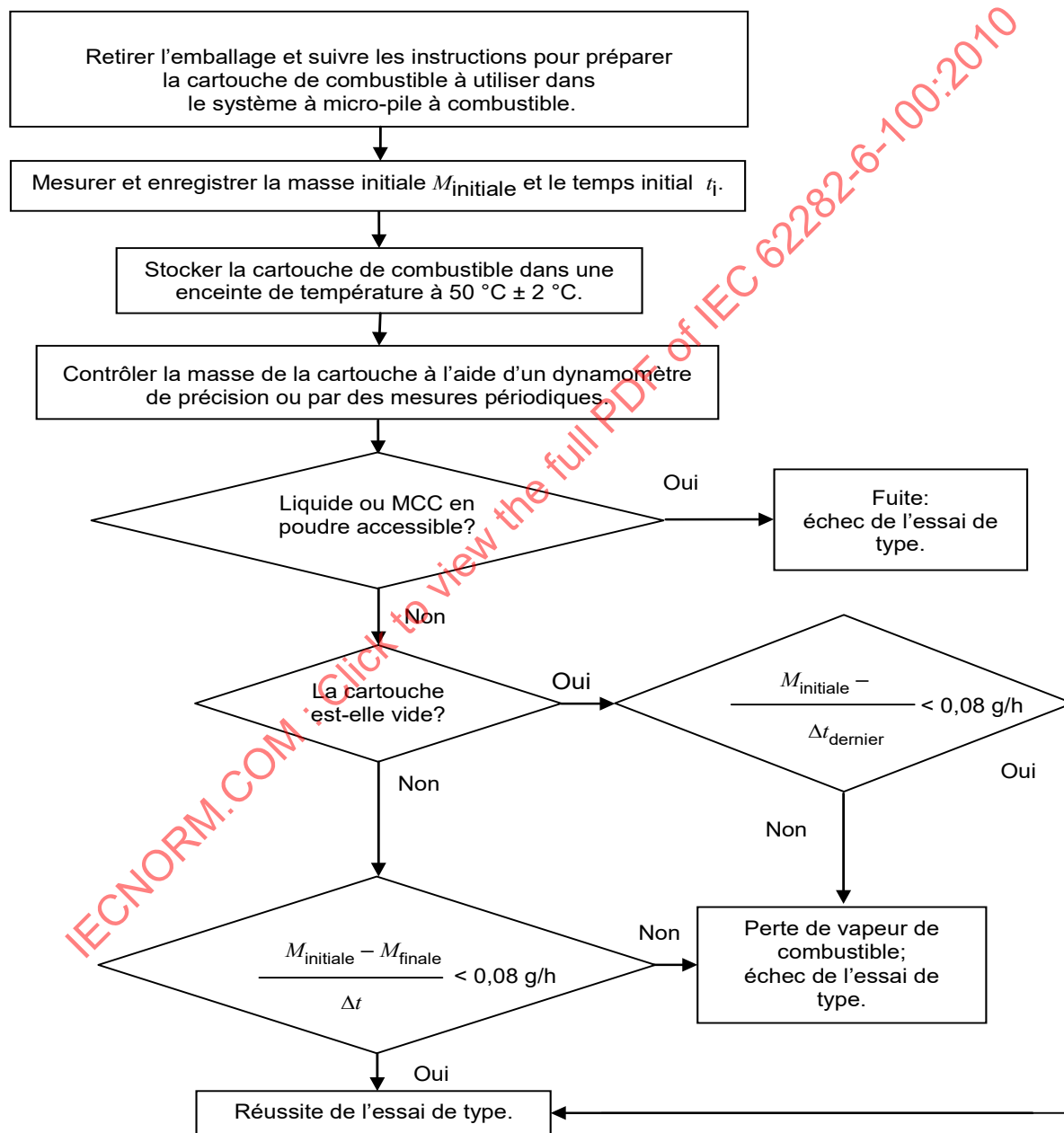


Figure D.9 – Diagramme d'essai de fuite de la cartouche de combustible et de perte de masse pour l'essai de stockage de longue durée – Remplace la Figure 9

D.7.3.10 Essai de connexion à température élevée

Le D.7.3.10 remplace le 7.3.10.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, ou cartouche de combustible usagée et bloc d'alimentation électrique de la micropile à combustible, ou une installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible, la cartouche de combustible étant à une température élevée, et garantir l'absence de fuite, de feu et d'explosion.
- c) Procédure d'essai:
 - 1) Placer l'échantillon d'essai de la cartouche de combustible dans une enceinte d'essai à température contrôlée, c'est-à-dire à une température de $50\text{ °C} \pm 2\text{ °C}$ pendant au moins 4 h.
 - 2) Le bloc d'alimentation électrique de la micropile à combustible ou l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible sont maintenus à la température ambiante du laboratoire.
 - 3) Retirer l'échantillon d'essai de l'enceinte et connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible, dans les 5 min qui suivent le retrait de l'enceinte.
 - 4) Vérifier s'il y a des fuites lors de la connexion.
 - 5) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- d) **Critères de réussite:** Aucune de fuite, aucune fuite de MCC en poudre. Aucun feu ni flamme, et aucune explosion. Si, en utilisant une force normale, la cartouche de combustible ne peut pas être connectée, et qu'aucune fuite, aucun feu et aucune explosion ne se produisent, ceci est acceptable. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou la vanne du bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du bloc d'alimentation électrique de la micropile à combustible.

D.7.3.11 Essais de cycles de connexion

D.7.3.11.1 Cartouche de combustible

D.7.3.11.1.1 Cartouche insérable, cartouche externe ou cartouche fixée

- a) **Échantillon d'essai:** cartouche insérable, cartouche externe ou cartouche fixée inutilisée ou usagée, et bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux instructions du fabricant ou installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible et alimentée en combustible conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite.

c) Procédure d'essai:

- 1) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites lors de la connexion.
- 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 4) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- 5) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
- 6) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 7) Connecter et déconnecter la cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 8) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 9) Connecter et déconnecter la cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
- 10) Renverser la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif, et rechercher des signes de fuite.
- 11) Connecter la cartouche de combustible et faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 12) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 13) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.

- d) **Critères de réussite:** Aucune de fuite, aucune fuite de MCC en poudre. Aucun feu ni flamme, et aucune explosion. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible ou la vanne du bloc d'alimentation électrique de la micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif, et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du bloc d'alimentation électrique de la micropile à combustible.

D.7.3.11.1.2 Cartouche satellite

Non applicable à la présente Annexe D.

D.7.3.11.2 Bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** au moins deux cartouches de combustible inutilisées ou usagées et 98 autres cartouches de combustible ou installations d'essai fixes comportant des vannes de cartouches de combustible supplémentaires et un bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie et du matériau de la vanne de la cartouche de combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir

l'absence de fuite, à la fois lors de l'utilisation initiale et après un vieillissement adapté de la connexion du bloc d'alimentation électrique de la micropile à combustible.

La première cartouche de combustible (#1) et la dernière cartouche de combustible (#100) sont examinées; les 980 cycles restants sont uniquement destinés à faire vieillir le bloc d'alimentation électrique de la micropile à combustible.

Dans le cas d'un bloc d'alimentation électrique de la micropile à combustible qui utilise une cartouche satellite, il doit être soumis à l'essai conformément à la procédure ci-dessous en simulant le débit de combustible entre la cartouche satellite et le bloc d'alimentation électrique de la micropile à combustible.

c) Procédure d'essai:

- 1) Connecter la première cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites lors de la connexion.
- 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 4) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- 5) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
- 6) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 7) Connecter et déconnecter la première cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 8) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 9) Connecter et déconnecter la première cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
- 10) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
- 11) Connecter la première cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et vérifier s'il y a des fuites lors de la connexion.
- 12) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 13) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 14) Déconnecter la première cartouche de combustible et vérifier s'il y a des fuites.
- 15) Pour un vieillissement de la connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible, suivre les étapes suivantes:
 - i) En utilisant soit des cartouches de combustible soit une installation d'essai fixe comportant des vannes de cartouche de combustible, lancer des cycles de connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible pour un total de 980 cycles de connexions et déconnexions.
 - ii) Simuler le débit de combustible après chaque série de 50 cycles de connexion/déconnexion.
 - iii) Le renversement du bloc d'alimentation électrique de la micropile à combustible du système à micropile à combustible ou des cartouches de combustible n'est pas nécessaire, mais si une fuite est détectée, l'essai échoue.

- iv) Après ce vieillissement, une dernière cartouche de combustible inutilisée est soumise à l'essai.
- 16) Connecter la dernière cartouche de combustible inutilisée au bloc d'alimentation électrique de la micropile à combustible et vérifier s'il y a des fuites lors de la connexion.
 - 17) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 18) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 19) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
 - 20) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
 - 21) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 22) Connecter et déconnecter la dernière cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
 - 23) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 24) Connecter et déconnecter la dernière cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
 - 25) Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite.
 - 26) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible et vérifier s'il y a des fuites lors de la connexion.
 - 27) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 28) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 29) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites.
- d) **Critères de réussite:** Aucune de fuite, aucune fuite de MCC en poudre. Aucun feu ni flamme, et aucune explosion. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et le système à micropile à combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible ou une fuite de MCC en poudre accessible est détectée, l'essai échoue. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du bloc d'alimentation électrique de la micropile à combustible.

Annexe E (normative)

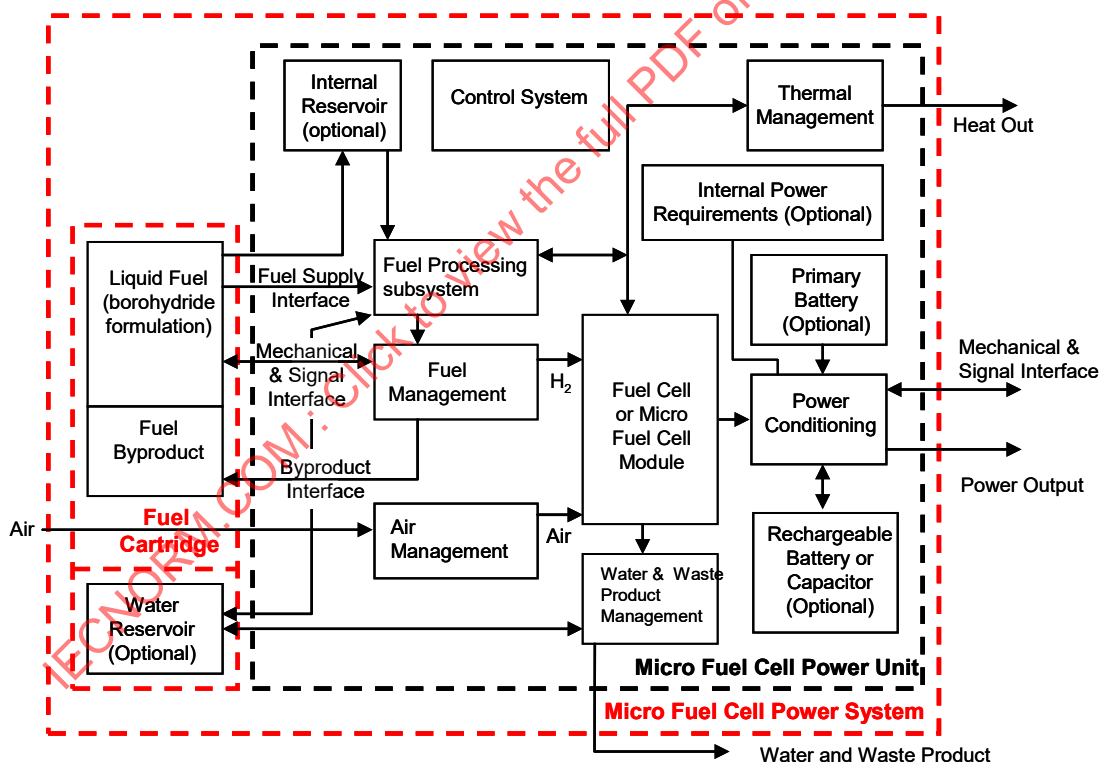
Systèmes à micropiles à combustible à borohydrure: Composés de classe 8 (corrosifs) dans les piles à combustible à borohydrure indirect

E.1 Domaine d'application

E.1.2 Combustibles et technologies traités par la présente annexe

L'Annexe E traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible l'hydrogène produit à partir de formulations de borohydrure de classe 8 (corrosifs). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de proton. Les conceptions peuvent inclure des sous-systèmes de traitement de combustibles pour obtenir un gaz hydrogène à partir du combustible à base de composés à borohydrure.

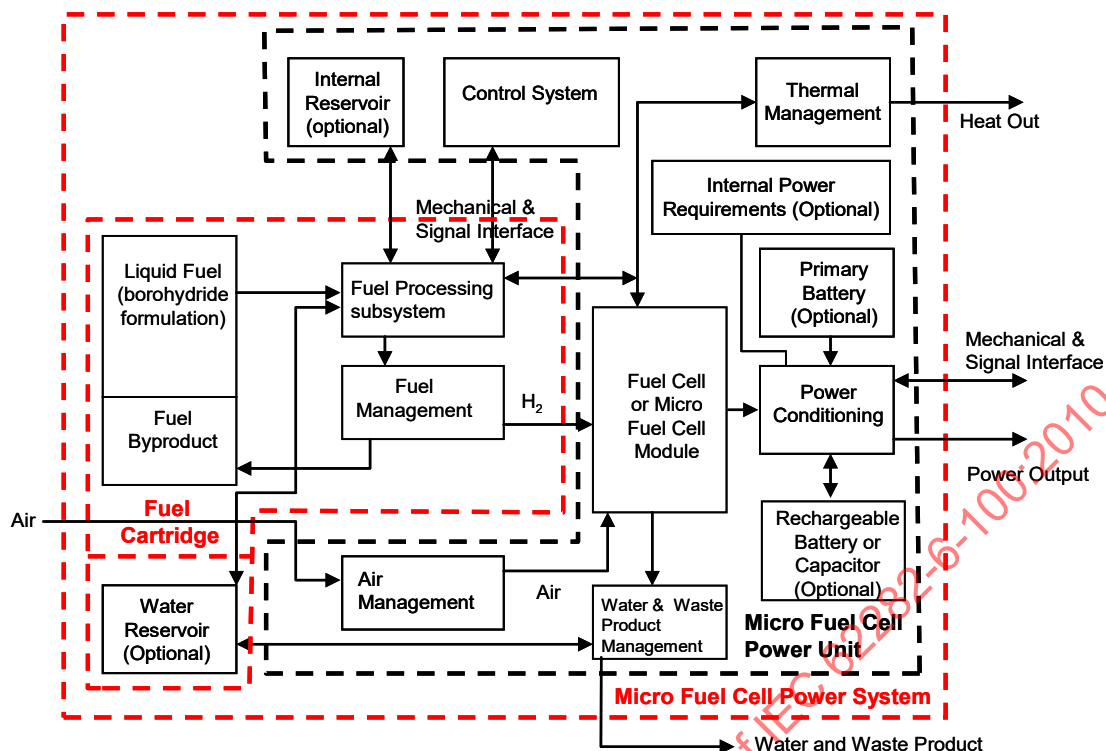
La Figure E.1 remplace la Figure 1 tandis que les Figures E.13, E.14 et E.15 sont des figures supplémentaires présentant des schémas de principe des systèmes à micropiles à combustible à utiliser avec la présente annexe.



Anglais	Français
Air	Air
Air management	Gestion de l'air
Byproduct interface	Interface de sous-produit
Control system	Système de commande
Fuel byproduct	Sous-produit combustible
Fuel cartridge	Cartouche de combustible
Fuel management	Gestion du combustible

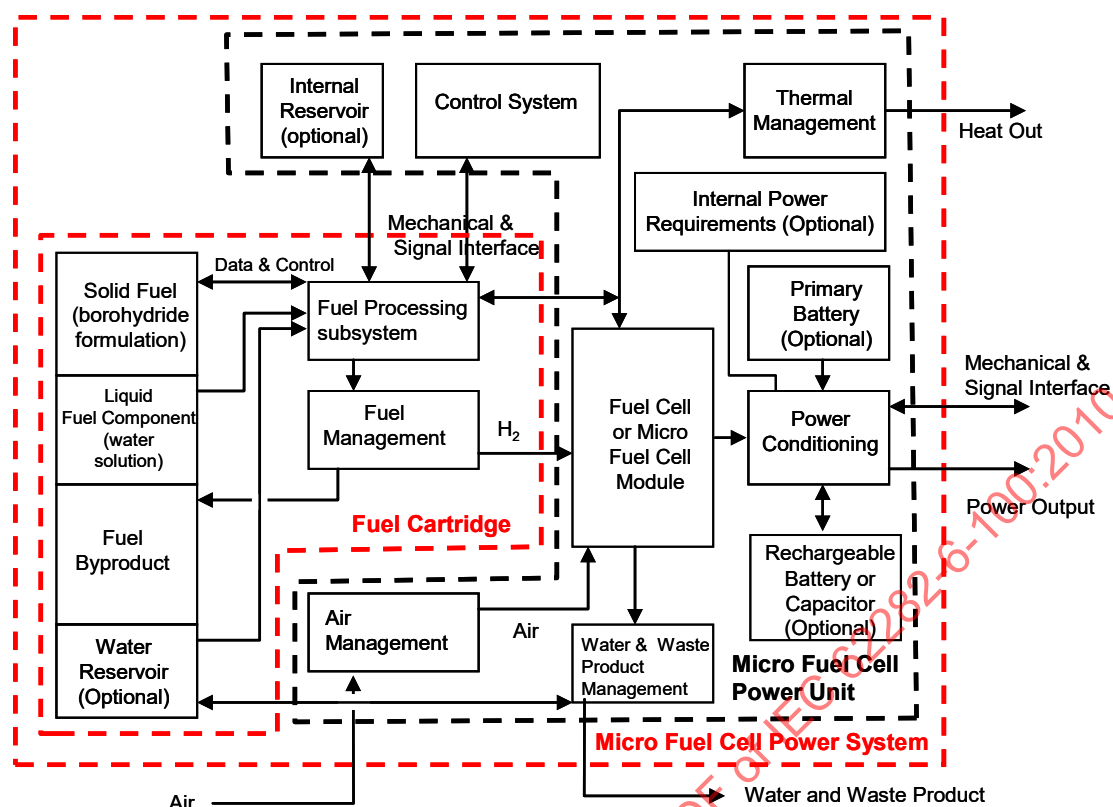
Anglais	Français
Fuel processing subsystem	Sous-système de traitement de combustible
Fuel supply interface	Interface d'alimentation en combustible
Heat out	Chaleur produite
Internal power requirements (Optional)	Exigences internes en énergie (Facultatif)
Internal reservoir (Optional)	Réservoir interne (Facultatif)
Liquid fuel (borohydride formulation)	Combustible liquide (formulation du borohydrure)
Mechanical & signal interface	Interface mécanique et signal
Micro fuel cell or micro fuel cell module	Micropile à combustible ou module à micropile à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de la micropile à combustible
Power conditioning	Conditionnement de l'énergie
Power output	Puissance de sortie
Primary battery (Optional)	Pile électrique (Facultatif)
Rechargeable battery or capacitor (Optional)	Batterie rechargeable ou condensateur (Facultatif)
Thermal management	Gestion thermique
Water and waste product	Eau et déchets
Water & waste product management	Gestion de l'eau et des déchets
Water reservoir (Optional)	Réservoir d'eau (Facultatif)

Figure E.1 – Schéma de principe d'un système à micropile à combustible pour les combustibles liquides à base de composés à borohydrure indirect de classe 8 (corrosifs) avec système intégré de traitement des combustibles – Remplace la Figure 1



Anglais	Français
Air	Air
Air management	Gestion de l'air
Control system	Système de commande
Fuel byproduct	Sous-produit combustible
Fuel cartridge	Cartouche de combustible
Fuel management	Gestion du combustible
Fuel processing subsystem	Sous-système de traitement de combustible
Heat out	Chaleur produite
Internal power requirements (Optional)	Exigences internes en énergie (Facultatif)
Internal reservoir (Optional)	Réservoir interne (Facultatif)
Liquid fuel (borohydride formulation)	Combustible liquide (formulation du borohydrure)
Mechanical & signal interface	Interface mécanique et signal
Micro fuel cell or micro fuel cell module	Micropile à combustible ou module à micropile à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de la micropile à combustible
Power conditioning	Conditionnement de l'énergie
Power output	Puissance de sortie
Primary battery (Optional)	Pile électrique (Facultatif)
Rechargeable battery or capacitor (Optional)	Batterie rechargeable ou condensateur (Facultatif)
Thermal management	Gestion thermique
Water and waste product	Eau et déchets
Water & waste product management	Gestion de l'eau et des déchets
Water reservoir (Optional)	Réservoir d'eau (Facultatif)

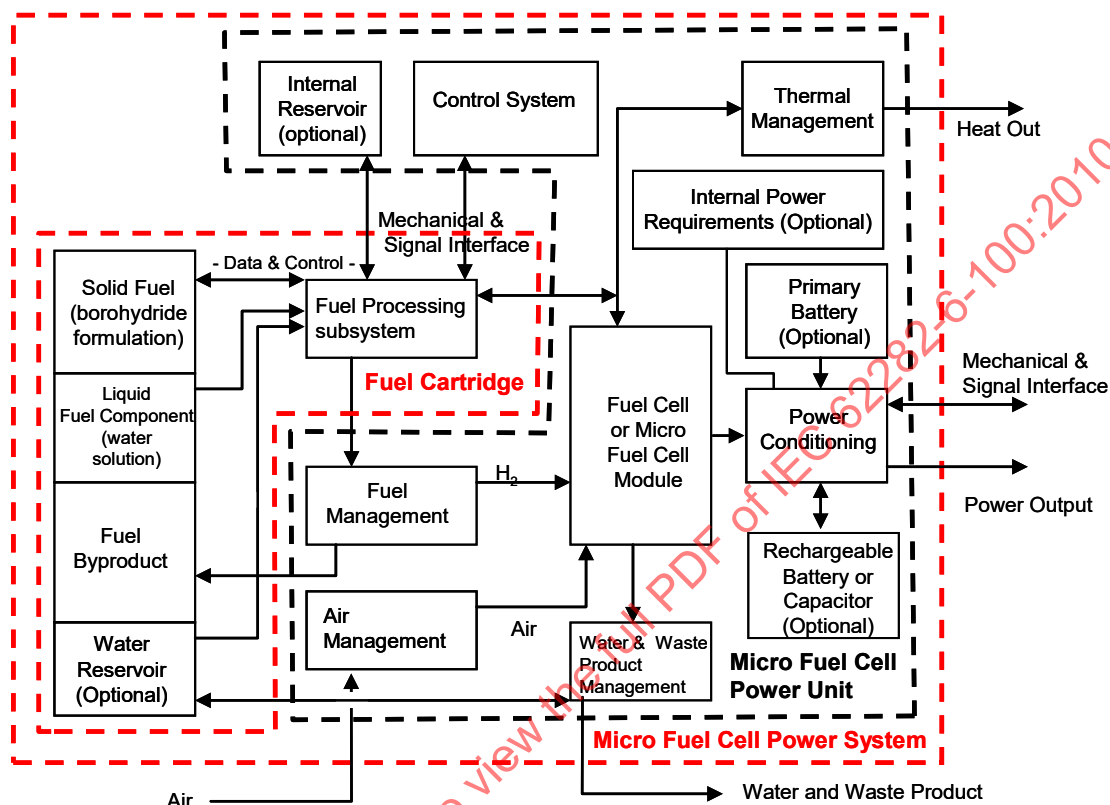
Figure E.13 – Schéma de principe d'un système à micropile à combustible pour les combustibles liquides à base de composés à borohydrure indirect de classe 8 (corrosifs) avec traitement des combustibles de la cartouche de combustible



Anglais	Français
Air	Air
Air management	Gestion de l'air
Control system	Système de commande
Data & control	Données et commande
Fuel byproduct	Sous-produit combustible
Fuel cartridge	Cartouche de combustible
Fuel management	Gestion du combustible
Fuel processing subsystem	Sous-système de traitement de combustible
Heat out	Chaleur produite
Internal power requirements (Optional)	Exigences internes en énergie (Facultatif)
Internal reservoir (Optional)	Réservoir interne (Facultatif)
Liquid fuel component (water solution)	Composant de combustible liquide (solution d'eau)
Mechanical & signal interface	Interface mécanique et signal
Micro fuel cell or micro fuel cell module	Micropile à combustible ou module à micropile à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de la micropile à combustible
Power conditioning	Conditionnement de l'énergie
Power output	Puissance de sortie
Primary battery (Optional)	Pile électrique (Facultatif)
Rechargeable battery or capacitor (Optional)	Batterie rechargeable ou condensateur (Facultatif)
Solid fuel (borohydride formulation)	Combustible solide (formulation du borohydrure)
Thermal management	Gestion thermique
Water and waste product	Eau et déchets
Water and waste product management	Gestion de l'eau et des déchets

Anglais	Français
Water reservoir (Optional)	Réservoir d'eau (Facultatif)

Figure E.14 – Schéma de principe d'un système à micropile à combustible pour les combustibles solides à base de composés à borohydrure indirect de classe 8 (corrosifs) avec traitement des combustibles de la cartouche de combustible et gestion des combustibles de la cartouche



Anglais	Français
Air	Air
Air management	Gestion de l'air
Control system	Système de commande
Data & control	Données et commande
Fuel byproduct	Sous-produit combustible
Fuel cartridge	Cartouche de combustible
Fuel management	Gestion du combustible
Fuel processing subsystem	Sous-système de traitement de combustible
Heat out	Chaleur produite
Internal power requirements (Optional)	Exigences internes en énergie (Facultatif)
Internal reservoir (Optional)	Réservoir interne (Facultatif)
Liquid fuel component (water solution)	Composant de combustible liquide (solution d'eau)
Mechanical & signal interface	Interface mécanique et signal
Micro fuel cell or micro fuel cell module	Micropile à combustible ou module à micropile à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de la micropile à combustible
Power conditioning	Conditionnement de l'énergie
Power output	Puissance de sortie

Anglais	Français
Primary battery (Optional)	Pile électrique (Facultatif)
Rechargeable battery or capacitor (Optional)	Batterie rechargeable ou condensateur (Facultatif)
Solid fuel (borohydride formulation)	Combustible solide (formulation du borohydrure)
Thermal management	Gestion thermique
Water and waste product	Eau et déchets
Water and waste product management	Gestion de l'eau et des déchets
Water reservoir (Optional)	Réservoir d'eau (Facultatif)

Figure E.15 – Schéma de principe d'un système à micropile à combustible pour les combustibles solides à base de composés à borohydrure de classe 8 (corrosifs) avec système de traitement des combustibles de la cartouche et de gestion des combustibles intégré au bloc d'alimentation électrique de la micropile à combustible

E.2 Références normatives

En plus des références normatives spécifiées dans l'Article 2, les documents de référence suivants sont indispensables pour l'application du présent document.

Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

ISO 16111:2008, *Appareils de stockage de gaz transportables — Hydrogène absorbé dans un hydrure métallique réversible*

E.3 Termes et définitions

Les termes et définitions ci-dessous remplacent les termes et définitions correspondants de l'Article 3 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E. Tous les termes et conditions de l'Article 3 qui ne sont pas spécifiquement mentionnés ici s'appliquent également.

E.3.5 combustible

formulation de classe 8 (corrosive) des composés à borohydrure utilisés pour produire de l'électricité indirectement dans un système à micropile à combustible

E.3.8 combustible liquide, corrosif

formulation liquide de classe 8 (corrosive) des composés à borohydrure et d'un ou de plusieurs hydroxydes de métaux alcalins utilisés comme combustibles pour un système à micropile à combustible à borohydrure indirect

E.3.11 fuite

combustible, sous-produits combustibles, électrolyte ou composants de combustibles liquides accessibles, à l'extérieur du système à micropile à combustible ou de la cartouche de combustible; fuite d'hydrogène ou perte non admissible de gaz hydrogène

Les termes supplémentaires et leurs définitions ci-dessous sont nécessaires pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E en plus de ceux donnés dans l'Article E.3 et dans l'Article 3.

E.3.37

combustible solide, corrosif

formulation solide de classe 8 (corrosive) des composés à borohydrure et d'un ou de plusieurs hydroxydes de métaux alcalins utilisés comme combustibles pour un système à micropile à combustible à borohydrure indirect

E.3.38

système à micropile à combustible à borohydrure indirect

système à micropile à combustible dans lequel une formulation solide ou liquide des composés à borohydrure est traitée pour produire de l'hydrogène qui réagit sur l'anode d'une pile à combustible, pour produire de l'électricité dans un système à micropile à combustible

E.3.39

composés à borohydrure

borohydrure de sodium ou de potassium, ou mélange des deux

E.3.40

composant de combustible liquide

solutions d'eau de classe 8 (corrosives), ou non dangereuses, utilisées pour produire de l'hydrogène à l'intérieur du sous-système de traitement des combustibles

E.3.41

électrolyte

membrane conductrice d'ions utilisée pour compléter un circuit électrique à l'intérieur d'une pile à combustible

E.3.42

sous-produits combustibles

composés de classe 8 (corrosifs), ou non dangereux, produits après la production d'hydrogène et/ou d'électricité à partir du combustible

E.3.43

perte non admissible de gaz hydrogène

gaz hydrogène s'échappant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible en non-fonctionnement, à un débit supérieur ou égal à 0,003 2 g/h

E.3.44

combustible, sous-produits combustibles, électrolyte ou composants de combustibles liquides accessibles

combustible, sous-produits combustibles, électrolyte ou composants de combustibles liquides, avec lesquels le consommateur peut entrer en contact physique au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible et du transport pour la vente

E.3.45

sous-système de traitement de combustible

sous-système à l'intérieur du bloc d'alimentation électrique de la micropile à combustible ou de la cartouche de combustible, utilisé pour produire de l'hydrogène à partir des formulations des composés à borohydrure

E.3.46

matériaux incompatibles

matériaux susceptibles de produire une évolution dangereuse de chaleur, ou des gaz ou des vapeurs inflammables ou nocifs, s'ils sont mélangés d'une manière différente de celle spécifiquement prévue par la conception du système à micropile à combustible

E.3.47

mélange non contrôlé

mélange de matériaux incompatibles se produisant d'une manière différente de celle spécifiquement prévue par la conception du système à micropile à combustible

E.3.48**de classe 8 (corrosif)**

matériaux classés en classe 8: substance corrosive, d'après les lignes directrices de la 15^e édition des Recommandations des Nations Unies relatives au transport des marchandises dangereuses, Règlement type

E.3.49**non dangereux**

matériaux qui ne sont pas soumis aux lignes directrices de la 15^e édition des Recommandations des Nations Unies relatives au transport des marchandises dangereuses, Règlement type

E.3.50**hydroxyde de métal alcalin**

hydroxydes de sodium, de potassium et de lithium, utilisés dans les formulations des combustibles solides et liquides de classe 8 (corrosifs)

E.3.51**cartouche de combustible usagée**

cartouche de combustible qui a été mise en fonctionnement, de telle sorte qu'au moins 45 % du combustible initial a été utilisé et que le fonctionnement du système à micropile à combustible a été interrompu pendant au moins 1 heure

E.3.52**fuite d'hydrogène**

gaz hydrogène à l'extérieur du système de confinement de combustible, y compris la cartouche de combustible, la gestion du combustible et le réservoir interne (voir E.7.2.2)

E.3.53**indication de pH positive du combustible à borohydrure et sous-produit liquides**

indication positive de la présence d'acide (pH inférieur à 3,0) ou de base (pH supérieur à 10) sur le papier réactif acido-basique fixé sur les zones de fuite possibles du système à micropile à combustible au cours de l'essai de type

E.4 Matériaux et construction des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible

E.4.4 Sélection des matériaux

Ces exigences remplacent les exigences correspondantes de 4.4.

Ces exigences de E.4.4 ci-dessous s'appliquent aux systèmes à micropiles à combustible, aux blocs d'alimentation électrique de micropiles à combustible et aux cartouches de combustible traités par la présente Annexe E.

E.4.4.1 Les systèmes à micropiles à combustible et les blocs d'alimentations électriques des micropiles à combustible sont susceptibles d'être exposés à un certain nombre de conditions environnementales pendant la durée de vie du produit définie par le fabricant, telles que les vibrations, les chocs, les niveaux d'humidité variables et les environnements corrosifs. Les matériaux utilisés dans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doivent résister à ces conditions environnementales. Si un système à micropile à combustible ou un bloc d'alimentation électrique d'une micropile à combustible doit être utilisé en service, où les conditions environnementales spécifiques sont au-delà de celles prises en compte dans les essais exigés de la présente norme, des essais supplémentaires doivent alors être effectués pour vérifier la sécurité dans ces conditions environnementales.

E.4.4.2 Les matériaux métalliques et non métalliques utilisés pour construire des pièces extérieures ou intérieures du système à micropile à combustible ou du bloc d'alimentation

électrique de la micropile à combustible, en particulier ceux étant exposés directement ou indirectement à l'humidité, au combustible et/ou aux sous-produits sous forme gazeuse ou liquide, ainsi que toutes les pièces et tous les matériaux utilisés pour les souder ou les raccorder, par exemple les consommables pour le soudage, doivent être adaptés à toutes les conditions physiques, chimiques et thermiques raisonnablement prévisibles dans les conditions habituelles de transport et d'utilisation au cours de la durée de vie du produit définie par le fabricant, et à toutes les conditions d'essai, en particulier, ils doivent être conçus pour conserver leur stabilité mécanique dans les conditions d'utilisation normale; en particulier, ils doivent être conçus pour conserver leur stabilité mécanique dans les conditions d'utilisation normale;

- ils doivent être suffisamment résistants à l'action chimique et physique des fluides qu'ils contiennent et à la dégradation environnementale;
- les propriétés physiques et chimiques nécessaires à un fonctionnement sans risque ne doivent pas être considérablement affectées au cours de la durée de vie du produit définie par le fabricant; en particulier, lors du choix des matériaux et des méthodes de fabrication, la résistance à l'usure et à la corrosion, la conductivité électrique, la force d'impact, la résistance au vieillissement, les effets des variations de température, les effets de l'assemblage de certains matériaux (par exemple la corrosion galvanique), et les effets du rayonnement ultraviolet, doivent être pris en considération;
- lorsque des conditions d'érosion, d'abrasion, de corrosion ou d'autres attaques chimiques sont possibles, des mesures appropriées doivent être prises pour:
 - réduire le plus possible cet effet à l'aide d'une conception appropriée, par exemple une épaisseur supplémentaire, ou par une protection adaptée, par exemple l'utilisation de coussinets, de matériaux de parement ou de revêtements de surface, en prenant en compte l'utilisation normale;
 - permettre le remplacement des pièces les plus affectées;
 - et attirer l'attention, dans le manuel auquel il est fait référence à l'Article 6, sur le type et la fréquence des mesures d'inspection et de maintenance nécessaires pour une utilisation sûre et continue; les pièces sujettes à l'usure et les critères pour un remplacement doivent être spécifiés si nécessaire.

E.4.4.3 Les matériaux élastomères tels que les joints et les tuyaux flexibles en contact avec les combustibles doivent résister à la détérioration lorsqu'ils sont en contact avec ces combustibles et doivent être adaptés aux températures auxquelles ils sont exposés au cours d'une utilisation normale. La conformité doit être déterminée par les normes suivantes: ISO 188 et ISO 1817.

E.4.4.4 Les matériaux polymères en contact avec les combustibles doivent résister à la détérioration lorsqu'ils sont en contact avec ces combustibles et doivent être adaptés aux températures auxquelles ils sont exposés au cours d'une utilisation normale. La conformité doit être déterminée par l'ISO 175.

E.4.4.5 Les systèmes de tuyauterie exposés à l'hydrogène doivent utiliser des matériaux adaptés à une exposition à l'hydrogène, tel que défini dans l'ISO 16111.

E.4.7 Matériaux et construction — système

E.4.7.1 *Ces exigences de E.4.7 s'appliquent aux systèmes à micropiles à combustible et aux blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe E. Ces exigences remplacent les exigences correspondantes de 4.7.* La quantité maximale de combustibles liquides ou de composants de combustibles liquides stockés dans le bloc d'alimentation électrique de la micropile à combustible ne doit pas être supérieure à 1 l. Il ne doit pas y avoir de combustibles solides dans le bloc d'alimentation électrique de la micropile à combustible.

E.4.7.2 Le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être conçu de telle sorte qu'une explosion ne puisse pas se produire, même en cas de fuite de combustible en provenance du système à micropile à combustible ou à l'intérieur de ce dernier. Les critères de conception de ces dispositifs (par

exemple, débit de ventilation nécessaire) doivent être fournis par le fabricant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les dispositifs doivent être fournis soit par le fabricant du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, soit par le fabricant du dispositif alimenté par le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.

E.4.7.3 Les composants et les matériaux à l'intérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être construits ou doivent utiliser des matériaux tels que la propagation du feu et l'inflammation soient atténuées. L'inflammabilité des matériaux doit être telle qu'un feu soutenu ne perdure pas après coupure du courant électrique et de l'alimentation en combustible et en oxydant. Ceci peut être démontré en choisissant des matériaux FV 0, FV 1 ou FV 2 conformes à l'IEC 60695-1-1 et à l'IEC 60695-11-10.

E.4.7.4 Il n'est pas exigé que les membranes des micropiles à combustible aient des caractéristiques assignées d'inflammabilité.

E.4.7.5 Les autres matériaux à l'intérieur de la micropile à combustible qui représentent moins de 30 % de la masse totale de la micropile à combustible sont considérés comme une quantité limitée et sont admissibles sans tenir compte de leurs caractéristiques assignées d'inflammabilité.

E.4.12 Construction de l'alimentation en combustible

E.4.12.1 Construction de la cartouche de combustible

Ces exigences de E.4.12.1 s'appliquent aux cartouches à micropiles à combustible traitées par la présente Annexe E. Ces exigences remplacent les exigences correspondantes de 4.12.1.

Les cartouches de combustible doivent être conformes aux exigences suivantes.

E.4.12.1.1 Il ne doit pas y avoir de fuite de la cartouche de combustible dans la plage de températures comprise entre -40 °C et $+70\text{ °C}$. La conformité doit être déterminée par des essais de type conformément à E.7.3.3 et E.7.3.4.

E.4.12.1.2 Il ne doit pas y avoir de fuite de la cartouche de combustible à une pression manométrique interne de 95 kPa et à une pression normale de fonctionnement à 22 °C ou à deux fois la pression de la cartouche de combustible à 55 °C , en prenant celle des deux valeurs qui est la plus élevée. La conformité doit être déterminée par des essais de type conformes à E.7.3.1.

E.4.12.1.3 La charge de combustible maximale est limitée à 1 l pour les combustibles liquides ou les composants de combustibles liquides, et à 200 g pour les combustibles solides.

E.4.12.1.4 Pour l'utilisation normale, le mauvais usage raisonnablement prévisible et le transport pour la vente d'une cartouche de combustible avec un bloc d'alimentation électrique de la micropile à combustible par un consommateur, des dispositifs doivent être prévus pour éviter une fuite de combustible avant, pendant et après la connexion ou le transfert de combustible vers le bloc d'alimentation électrique de la micropile à combustible. La conformité est vérifiée par E.7.3.11.

E.4.12.1.5 Une cartouche de combustible doit résister à la corrosion dans son environnement d'utilisation.

E.4.12.1.6 Une cartouche de combustible doit être équipée de dispositifs pour empêcher une mauvaise connexion qui entraînerait une fuite de combustible lorsqu'elle est installée dans un

système à micropile à combustible. La conformité est vérifiée par l'essai de cycles de connexion, E.7.3.11.

E.4.12.1.7 Les connecteurs d'alimentation en combustible prévus sur la cartouche de combustible doivent être construits de telle sorte qu'ils empêchent la fuite de combustible lorsqu'ils ne sont pas fixés sur une micropile à combustible au cours d'une utilisation normale, d'un mauvais usage raisonnablement prévisible et du transport pour la vente. La conformité est vérifiée par l'essai de chute, E.7.3.5 et l'essai de cycles de connexion, E.7.3.11.

E.4.12.1.8 Dans le cas où une vanne régulatrice de pression ou un dispositif similaire sont prévus, une vanne régulatrice de pression de ce type doit satisfaire aux exigences de performance pour chaque essai de type. Cette vanne doit réussir tous les essais de type sans fuite.

E.4.12.1.9 La structure au niveau de la connexion à la cartouche de combustible ne doit pas permettre de fuite de combustible.

E.4.12.1.10 Une cartouche de combustible, y compris l'interface entre la cartouche de combustible et le bloc d'alimentation électrique de la micropile à combustible y compris la vanne doit présenter une construction suffisamment solide pour résister à une utilisation normale et à un mauvais usage raisonnablement prévisible généré par les vibrations, la chaleur, la pression, les chutes ou les chocs mécaniques, etc. La conformité est vérifiée par:

- les essais de pression différentielle, E.7.3.1;
- l'essai de vibrations, E.7.3.2;
- l'essai de cycles de températures, E.7.3.3;
- l'essai d'exposition à température élevée, E.7.3.4;
- l'essai de chute, E.7.3.5;
- l'essai de charge de compression, E.7.3.6;
- l'essai de court-circuit externe, E.7.3.7;
- l'essai de stockage de longue durée, E.7.3.9;
- l'essai de connexion à température élevée, E.7.3.10;
- les essais de cycles de connexion, E.7.3.11.
- l'essai d'émissions, E.7.3.12.

E.4.12.1.11 Les vannes de la cartouche de combustible doivent fonctionner comme prévu, sans l'utilisation d'outils et sans force excessive nécessaire pour la connexion ou la déconnexion.

E.4.12.1.12 Dans les cas où il existe des matériaux (solides ou liquides) incompatibles avec le combustible à borohydrure ou avec le composant de combustible liquide, la conception de la cartouche de combustible et du système à micropile à combustible doit prévoir un moyen pour empêcher un mélange involontaire ou non contrôlé de ces matériaux.

Deux moyens indépendants pour empêcher un mélange involontaire ou non contrôlé de ces matériaux doivent être prévus au cours du transport et du stockage avant utilisation. Des exemples d'illustration de ces moyens incluent, sans que l'énumération ne soit exhaustive: une activation positive par le système de commande; le retrait physique d'une barrière étanche, empêchant tout contact; l'ouverture d'une vanne à commande manuelle normalement fermée, empêchant tout contact. Pour au moins un de ces moyens visant à empêcher un mélange non contrôlé, il doit être nécessaire pour l'utilisateur d'agir de manière positive pour le ou les retirer ou désactiver avant utilisation.

Au moins un moyen pour empêcher un mélange non contrôlé de ces matériaux doit être prévu au cours de l'utilisation et du stockage après utilisation. Ce moyen peut comprendre la commande active par des systèmes électroniques, soumis à l'analyse AMDE de 4.2.

E.6 Instructions et avertissements pour les cartouches de combustible, les blocs d'alimentation électrique des micropiles à combustible et les systèmes à micropiles à combustible

E.6.2 Marquages minimaux exigés sur la cartouche de combustible

Ces marquages remplacent les marquages exigés par le 6.2.

Au minimum, la cartouche de combustible doit porter les marquages suivants:

- a) CONTENU CORROSIF ET TOXIQUE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) GARDER HORS DE PORTÉE DES ENFANTS.
- d) NE PAS EXPOSER À DES TEMPERATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES.
- e) NE PAS EXPOSER À DES ACIDES, DES OXYDANTS, DE L'ALCOOL OU DES PRODUITS D'ENTRETIEN DOMESTIQUE.
- f) NE PAS IMMERGER DANS L'EAU OU DANS D'AUTRES LIQUIDES.
- g) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- h) EN CAS D'INGESTION OU D'INHALATION DE COMBUSTIBLE OU DE CONTACT AVEC LES YEUX, CONSULTER UN MÉDECIN.
- i) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT.
- j) COMPOSITION ET QUANTITÉ DE COMBUSTIBLE.
- k) TEXTE OU MARQUAGE INDiquANT QUE LA CARTOUCHE DE COMBUSTIBLE EST CONFORME À L'IEC 62282-6-100.
- l) PEUT CONTENIR DES GAZ INFLAMMABLES.

Si le contenu de la cartouche de combustible peut être inflammable, le marquage exigé en "a)" ci-dessus doit être modifié comme suit:

- a) CONTENU INFLAMMABLE, CORROSIF ET TOXIQUE. NE PAS DÉMONTER.

E.6.3 Marquages minimaux exigés sur le système à micropile à combustible

Ces marquages remplacent les marquages exigés par le 6.3.

De plus, au minimum, le système à micropile à combustible doit également porter les marquages suivants:

- a) CONTENU CORROSIF ET TOXIQUE, NE PAS DÉMONTER.
- b) ÉVITER TOUT CONTACT AVEC LE CONTENU.
- c) NE PAS EXPOSER À DES TEMPERATURES SUPÉRIEURES À 50 °C NI À DES FLAMMES NUES.
- d) NE PAS IMMERGER DANS L'EAU OU DANS D'AUTRES LIQUIDES.
- e) SUIVRE LES INSTRUCTIONS D'UTILISATION.
- f) EN CAS D'INGESTION DE COMBUSTIBLE OU DE CONTACT AVEC LES YEUX, CONSULTER UN MÉDECIN.

- g) MARQUE COMMERCIALE ET/OU NOM DU FABRICANT, DÉSIGNATION DU MODÈLE ET TRAÇABILITÉ EXIGÉE PAR LE FABRICANT.
- h) COMPOSITION DU COMBUSTIBLE.
- i) CAPACITÉ MAXIMALE DE COMBUSTIBLE DANS LE RÉSERVOIR INTERNE, SI APPLICABLE.
- j) TEXTE OU MARQUAGE INDIQUANT QUE LE SYSTÈME À MICROPILE À COMBUSTIBLE EST CONFORME À L'IEC 62282-6-100.
- k) PEUT CONTENIR DES GAZ INFLAMMABLES.
- l) SORTIE ÉLECTRIQUE (TENSION, COURANT, PUISSANCE ASSIGNÉE).

Si le contenu de la cartouche de combustible est corrosif, le marquage exigé en "a)" ci-dessus doit être modifié comme suit:

- a) CONTENU HYDROREACTIF, CORROSIF ET TOXIQUE. NE PAS DÉMONTER.

Si le contenu de la cartouche de combustible est inflammable, le marquage exigé en "a)" ci-dessus doit être modifié comme suit:

- a) CONTENU HYDROREACTIF, CORROSIF, TOXIQUE ET INFLAMMABLE. NE PAS DÉMONTER.

E.7 Essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible

E.7.1 Généralités

Ce paragraphe E.7.1 remplace le 7.1 pour la présente annexe lors des essais des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible utilisant comme combustible l'hydrogène produit à partir de composés à borohydrure de classe 8 (corrosifs).

- a) Les essais de type pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible doivent permettre de vérifier que ces systèmes à micropiles à combustible, blocs d'alimentation électrique des micropiles à combustible et cartouches de combustible sont sûrs pour une utilisation normale.
- b) Le Tableau E.5 énumère les essais de type qui doivent être effectués. *Le Tableau E.5 remplace le Tableau 5.*
- c) Sauf exigence explicite contraire dans cet article, les conditions de laboratoire sont spécifiées dans le Tableau E.6. *Le Tableau E.6 remplace le Tableau 6.*
- d) Le système à micropile à combustible, le bloc d'alimentation électrique de la micropile à combustible et/ou la cartouche de combustible doivent être conditionnés à une température de laboratoire normalisée de $22\text{ °C} \pm 5\text{ °C}$ pendant au moins 3 h avant la réalisation de chaque essai.
- e) Avertissement: Ces essais de type utilisent des procédures qui peuvent entraîner des dommages si des précautions appropriées ne sont pas prises. Il convient que les essais ne soient effectués que par des techniciens qualifiés et expérimentés utilisant une protection appropriée.

Tableau E.5 – Liste des essais de type – Remplace le Tableau 5

Référence de l'essai	Entité d'essai	Échantillon d'essai
E.7.3.1	Essais de pression différentielle	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
E.7.3.2	Essai de vibrations	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
E.7.3.3	Essai de cycles de températures	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
E.7.3.4	Essai d'exposition à température élevée	Cartouche de combustible Cartouche de combustible usagée
E.7.3.5	Essai de chute	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
E.7.3.6	Essai de charge de compression	Cartouche de combustible Cartouche de combustible usagée Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
E.7.3.7	Essai de court-circuit externe	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
7.3.8	Essai de température de surface, de composant et de gaz d'échappement	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
E.7.3.9	Essai de stockage de longue durée	Cartouche de combustible Cartouche de combustible usagée
E.7.3.10	Essai de connexion à température élevée	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible usagés
E.7.3.11	Essai de cycles de connexion	Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible Cartouche de combustible et bloc d'alimentation électrique de la micropile à combustible usagés
E.7.3.12	Essai d'émission	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
E.7.3.13	Effectuer l'essai de détection de pertes localisées de gaz hydrogène.	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible

Le Tableau E.5 remplace le Tableau 5.

Échantillon d'essai: Le nombre d'échantillons doit être au moins de six (6) cartouches de combustible, neuves ou usagées, comme spécifié pour les essais individuels ci-dessus, ou un minimum de trois (3) systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible pour chaque essai de type.

Séquence d'essai: Les essais E.7.3.2 et E.7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes cartouches de combustible. Les essais E.7.3.1, E.7.3.2, et E.7.3.3 doivent être réalisés de manière séquentielle pour les essais des mêmes systèmes à micropile à combustible ou des mêmes blocs d'alimentation électrique de micropiles à combustible.

Réutilisation des échantillons: Les cartouches de combustible et les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible peuvent être réutilisés à l'initiative du fabricant, si ceci ne compromet pas l'essai individuel.

Tableau E.6 – Conditions normalisées de laboratoire – Remplace le Tableau 6

Élément	Condition
Température de laboratoire	La température de laboratoire est la «température ambiante» (condition de température normalisée, 22 °C ± 5 °C)
Atmosphère de laboratoire pour les essais du système à micropile à combustible et du bloc d'alimentation électrique de la micropile à combustible uniquement	L'atmosphère de la pièce du laboratoire ne contient pas plus de 0,2 % de dioxyde de carbone et pas plus de 0,002 % de monoxyde de carbone. L'atmosphère de la pièce du laboratoire contient au moins 18 %, mais pas plus de 21 %, d'oxygène. L'atmosphère de laboratoire ne contient pas plus de 0,008 % d'hydrogène
Le Tableau E.6 remplace le Tableau 6.	

E.7.2 Mesurage des fuites, des fuites d'hydrogène et des pertes de gaz hydrogène et procédure de mesure

Ce paragraphe E.7.2 remplace le 7.2 pour la présente annexe lors des essais des systèmes à micropiles à combustible, des blocs d'alimentation électrique des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible les composés à borohydrure de classe 8 (corrosifs).

- Le mesurage des fuites doit être effectué en principe conformément aux procédures présentées dans les Figures E.2 à E.5. Ces figures et leurs procédures remplacent les figures correspondantes présentées en 7.2.*
- La conformité à l'exigence «aucune fuite», «aucune fuite d'hydrogène» et «aucune perte non admissible de gaz hydrogène» pour tous les essais de type spécifiés en E.7.3 doit être déterminée par la procédure de mesure de fuite de E.7.2.1, la procédure de mesure de fuites d'hydrogène de E.7.2.2 et la procédure de mesure des pertes de gaz hydrogène de E.7.3.13 conjointement à la définition de «fuite» donnée en E.3.11, de «fuite d'hydrogène» donnée en E.3.52 et à la définition de «perte non admissible de gaz hydrogène» donnée en E.3.43, sauf spécification contraire.

E.7.2.1 Essai de fuite et procédures de mesure

- Pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible contenant du combustible à borohydrure de classe 8 (corrosif), le mesurage des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doit être effectué à la suite de chaque essai de type par un examen visuel de tous les emplacements de fuite éventuels. La présence de toute goutte de combustible, de sous-produits combustibles, d'électrolyte ou de composant de combustible liquide et/ou de tout cristal blanc sur l'extérieur du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ou de la cartouche de combustibles indique une fuite. Si les cristaux sont accessibles, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ou la cartouche de combustible échoue à l'essai de fuite. Comme outil supplémentaire permettant de trouver les fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composant de combustible liquide, un papier pH, fixé sur les zones de fuite possibles du système à micropile à combustible, doit être utilisé pour faciliter la vérification visuelle des fuites. Il s'agit d'une exigence supplémentaire de l'Annexe F pour les combustibles à borohydrure de classe 8 (corrosifs), les sous-produits combustibles, l'électrolyte et les composants de combustibles liquides. L'existence éventuelle d'une substance avec un pH inférieur à 3,5 ou supérieur à 10,5 permet d'indiquer une fuite. Voir Figure E.2 et Figure E.3. Pour les essais opérationnels, il convient que les conduites d'air des produits réactifs vers le système à micropile à combustible et les orifices d'évacuation ne soient pas bloqués par le papier pH.

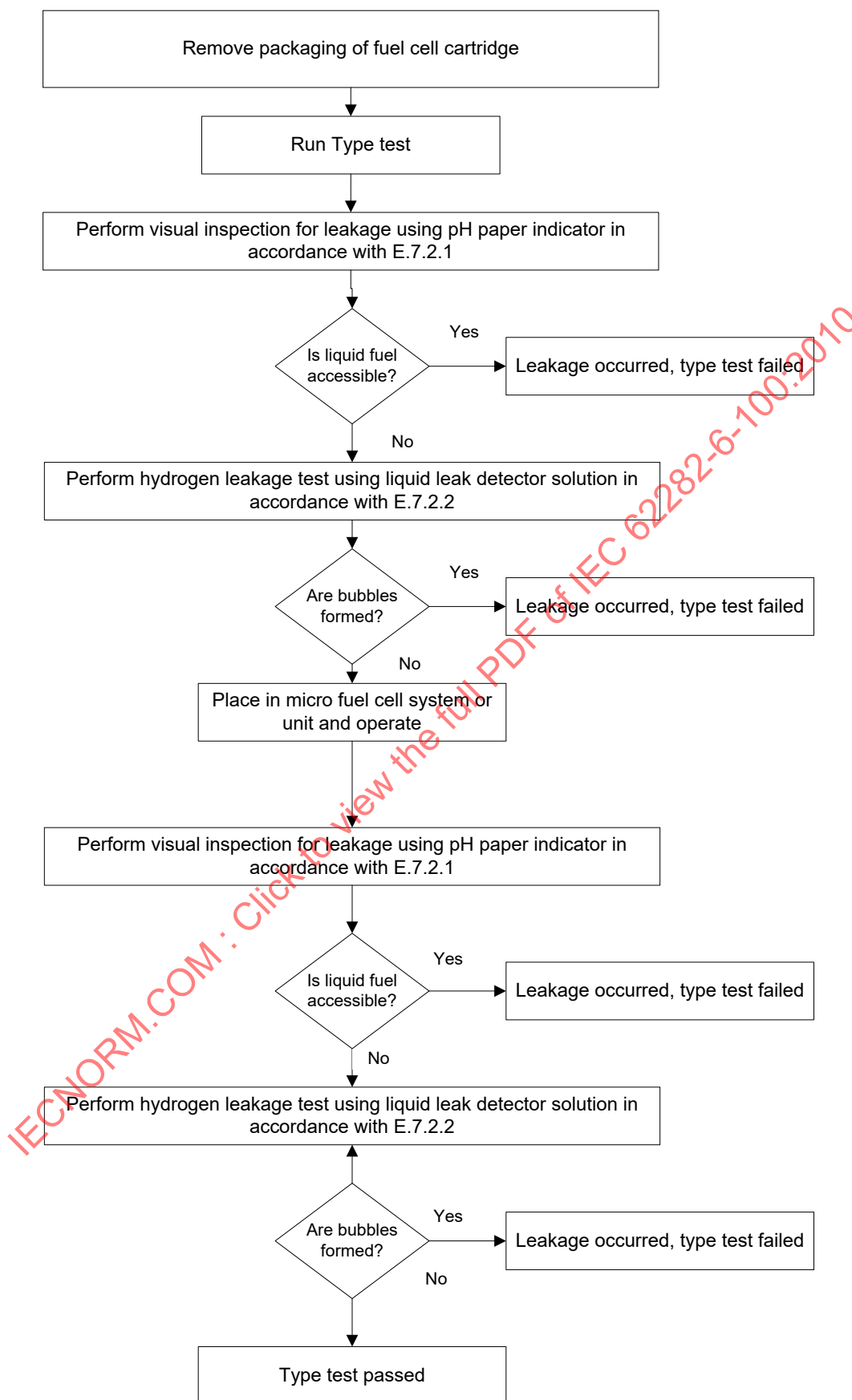
E.7.2.2 Mesurage des fuites d'hydrogène des cartouches de combustible et procédures de mesure

Pour les cartouches de combustible contenant des composés à borohydrure de classe 8 (corrosifs), le mesurage des fuites d'hydrogène doit être effectué à la suite de chaque essai de type à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) ou autre dispositif équivalent sur tous les emplacements de fuite éventuels de la cartouche de combustible. Voir Figure E.2 et Figure E.3.

E.7.2.3 Mesurages des pertes de gaz hydrogène à partir des systèmes à micropiles à combustible et des blocs d'alimentation électrique des micropiles à combustible, et procédures de mesure

Pour les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible, à la fin de chaque essai de type, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être soumis à l'essai pour détecter d'éventuelles pertes de gaz hydrogène, conformément à la Figure E.4 comme suit.

- a) Effectuer les essais d'émission d'hydrogène conformément à E.7.3.12, à l'exception du fait que le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être à l'arrêt «DISPOSITIF EN POSITION «OFF»». Les essais de source localisée d'hydrogène conformément à E.7.3.13 ne sont pas applicables. La perte de gaz hydrogène doit être inférieure à 0,0032 g/h. Voir Tableau E.7.
- b) Effectuer les essais d'émission d'hydrogène conformément à E.7.3.12 avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») pour rechercher les émissions d'hydrogène, que le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible soit opérationnel ou non. Les émissions d'hydrogène doivent être inférieures à 0,8 g/h et les fuites d'hydrogène à partir d'une seule fuite localisée doivent être inférieures à 0,016 g/h. Voir Tableau E.7.

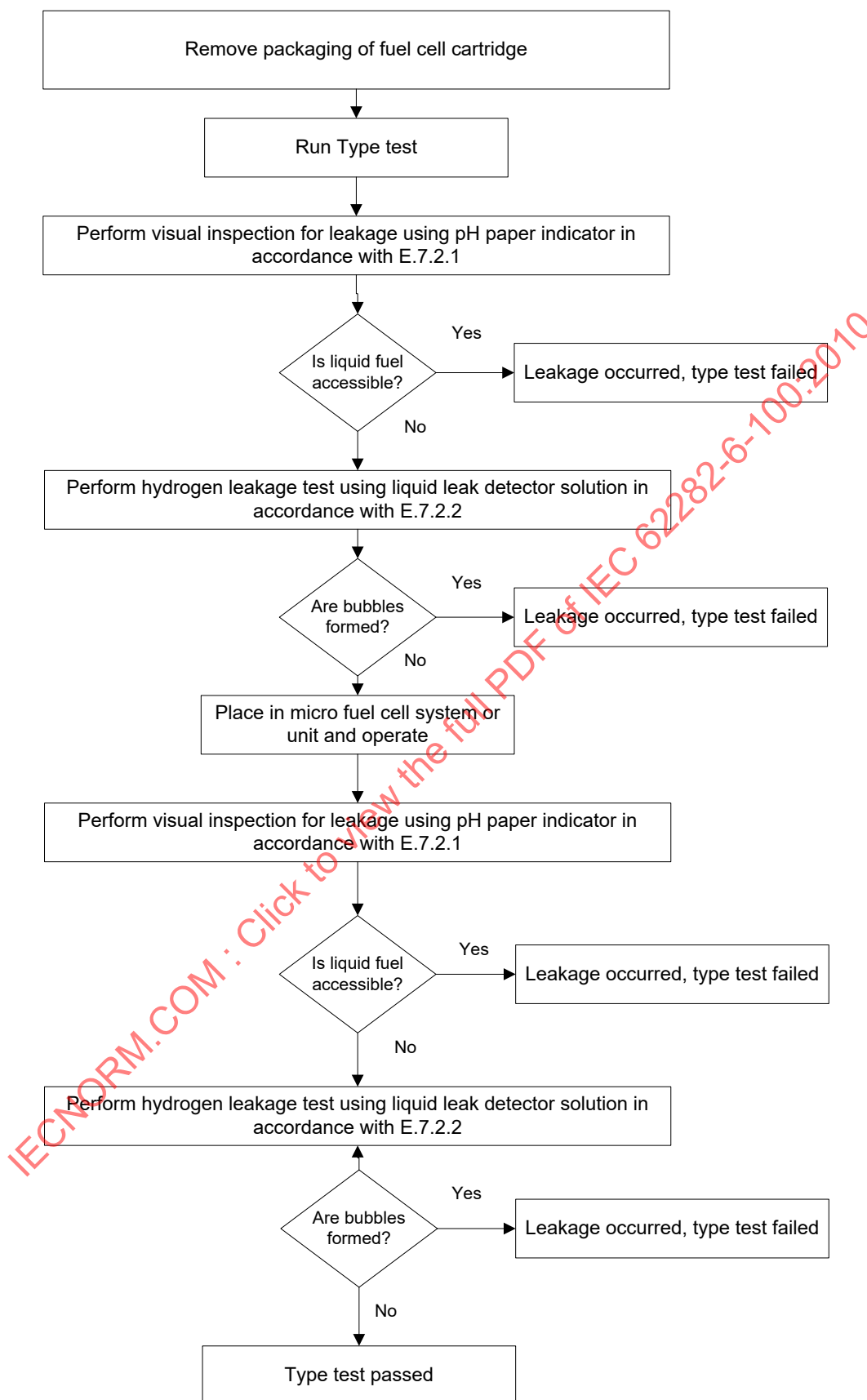


Anglais	Français
Remove packaging of fuel cell cartridge	Retirer l'emballage de la cartouche à micropile à combustible
Run type test	Réaliser l'essai de type

Anglais	Français
Perform visual inspection for leakage using pH paper indicator in accordance with E.7.2.1	Effectuer un examen visuel pour rechercher les fuites à l'aide d'un papier indicateur de pH conformément à E.7.2.1
Is liquid fuel accessible?	Combustible liquide accessible?
Yes	Oui
No	Non
Leakage occurred, type test failed	Fuite, échec de l'essai de type
Perform hydrogen leakage test using liquid leak detector solution in accordance with E.7.2.2	Effectuer un essai de fuite d'hydrogène à l'aide d'une solution de détecteur de fuite liquide conformément à E.7.2.2
Are bubbles formed ?	Formation de bulles?
Type test passed	Réussite de l'essai de type

Figure E.2 – Diagramme d'essai de fuite des cartouches de combustible pour les essais de vibrations, de chute et de charge de compression – Remplace la Figure 2

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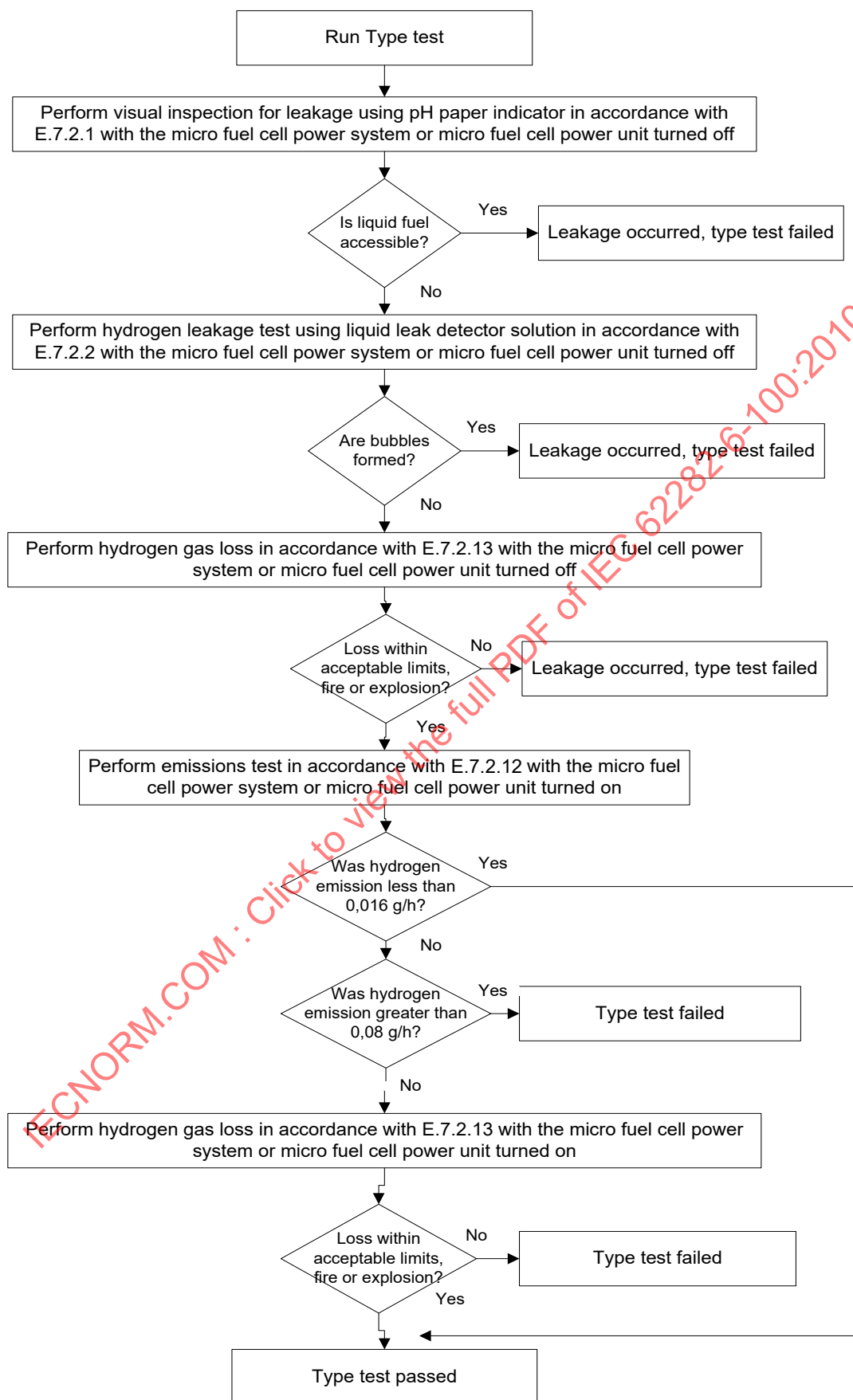


Anglais	Français
Remove packaging of fuel cell cartridge	Retirer l'emballage de la cartouche à micropile à combustible
Run type test	Réaliser l'essai de type
Perform visual inspection for leakage using pH	Effectuer un examen visuel pour rechercher les fuites à l'aide

Anglais	Français
paper indicator in accordance with E.7.2.1	d'un papier indicateur de pH conformément à E.7.2.1
Is liquid fuel accessible?	Combustible liquide accessible?
Yes	Oui
No	Non
Leakage occurred, type test failed	Fuite, échec de l'essai de type
Perform hydrogen leakage test using liquid leak detector solution in accordance with E.7.2.2	Effectuer un essai de fuite d'hydrogène à l'aide d'une solution de détecteur de fuite liquide conformément à E.7.2.2
Are bubbles formed ?	Formation de bulles?
Place in micro fuel cell system or unit and operate	Placer dans le système à micropile à combustible ou dans le bloc d'alimentation de la micropile à combustible et faire fonctionner
Type test passed	Réussite de l'essai de type

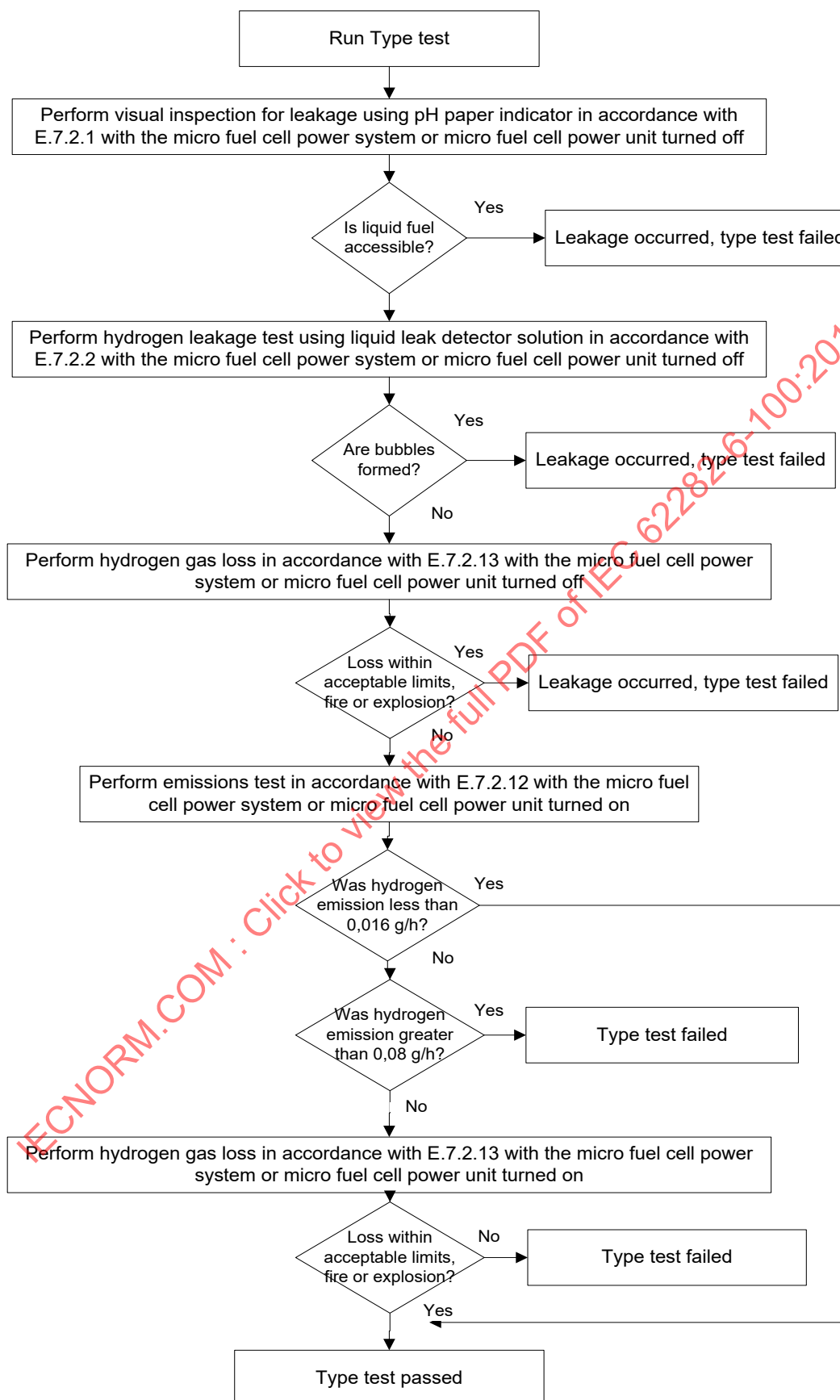
Figure E.3 – Diagramme d'essai de fuite et de perte de masse de la cartouche de combustible pour l'essai de cycles de températures et l'essai d'exposition à température élevée – Remplace la Figure 3

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Anglais	Français
Run type test	Réaliser l'essai de type
Perform visual inspection for leakage using pH paper indicator in accordance with E.7.2.1 with the micro fuel cell power system or micro fuel cell power unit turned off	Effectuer un examen visuel pour rechercher les fuites à l'aide d'un papier indicateur de pH conformément à E.7.2.1 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de micropile à combustible arrêté.
Is liquid fuel accessible?	Combustible liquide accessible ?
Yes	Oui
No	Non
Perform hydrogen leakage test using liquid leak detector solution in accordance with E.7.2.2 with the micro fuel cell power system or micro fuel cell power unit turned off	Effectuer un essai de fuite d'hydrogène à l'aide d'une solution de détecteur de fuite liquide conformément à E.7.2.2 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de micropile à combustible arrêté
Are bubbles formed?	Formation de bulles?
Leakage occurred, type test failed	Fuite, échec de l'essai de type
Perform hydrogen gas loss test in accordance with E.7.2.13 with the micro fuel cell power system or micro fuel cell power unit turned off	Effectuer un essai de perte de gaz hydrogène conformément à E.7.2.13 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de micropile à combustible arrêté
Loss within acceptable limits, fire or explosion?	Pertes dans les limites acceptables, feu ou explosion?
Perform emissions test in accordance with E.7.2.12 with the micro fuel cell power system or micro fuel cell power unit turned on	Effectuer un essai d'émissions conformément à E.7.2.12 avec le système à micropile à combustible en marche ou avec le bloc d'alimentation électrique de micropile à combustible en marche
Was hydrogen emission less than 0,016 g/h?	Émission d'hydrogène inférieure à 0,016 g/h?
Was hydrogen emission greater than 0,08 g/h?	Émission d'hydrogène supérieure à 0,08 g/h?
Perform hydrogen gas loss test in accordance with E.7.2.13 with the micro fuel cell power system or micro fuel cell power unit turned on	Effectuer un essai de perte de gaz hydrogène conformément à E.7.2.13 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de micropile à combustible en marche
Type test passed	Réussite de l'essai de type

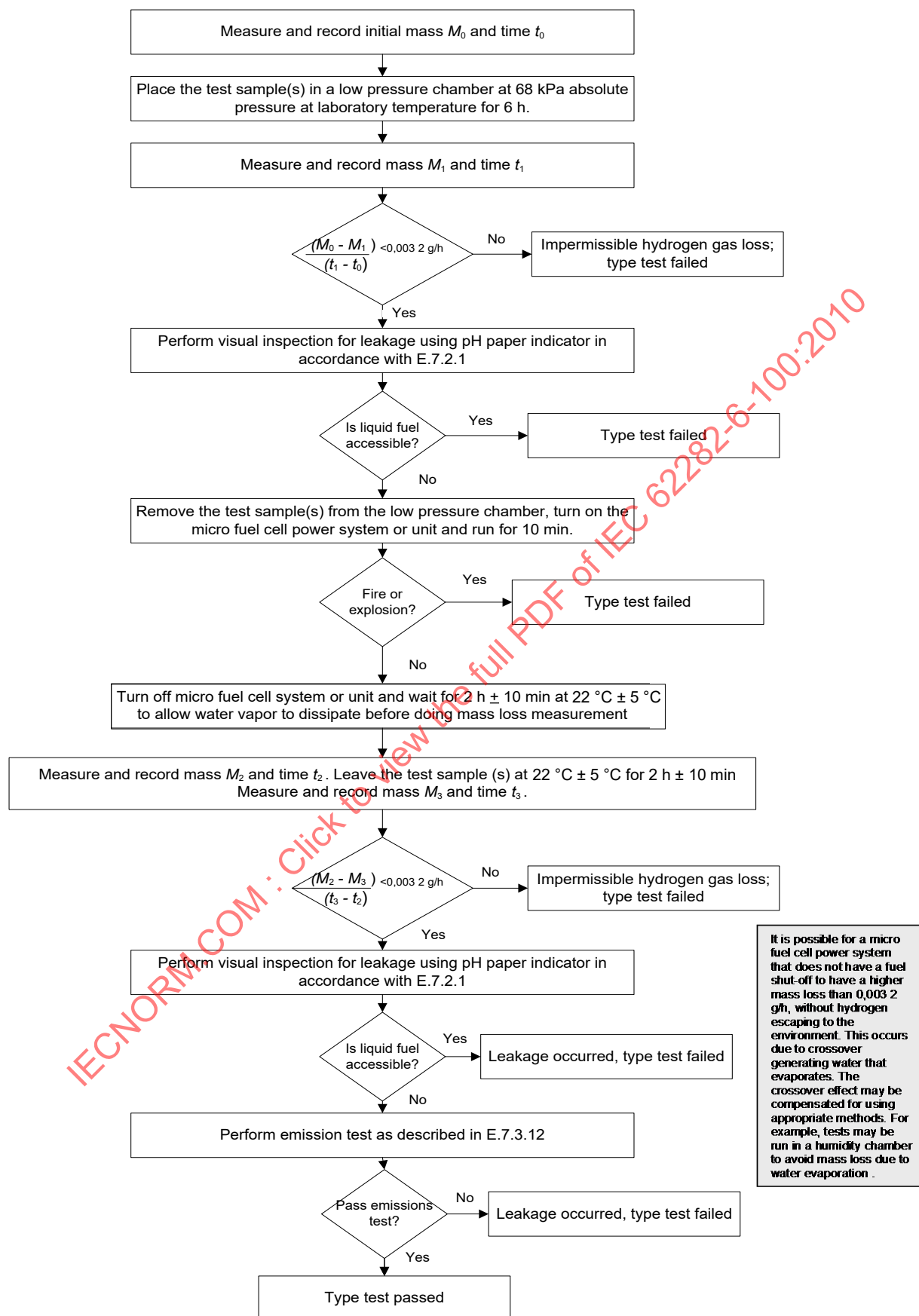
Figure E.4 – Diagramme d'essai de fuite et de perte de masse du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible pour les essais de pression différentielle, de vibrations, de cycles de températures, de chute et de charge de compression – Remplace la Figure 4



Anglais	Français
Run type test	Réaliser l'essai de type
Perform visual inspection for leakage using pH paper	Effectuer un examen visuel pour rechercher les fuites à

Anglais	Français
indicator in accordance with E.7.2.1 with the micro fuel cell power system or micro fuel cell power unit turned off	l'aide d'un papier indicateur de pH conformément à E.7.2.1 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de la micropile à combustible arrêté.
Is liquid fuel accessible?	Combustible liquide accessible ?
Yes	Oui
No	Non
Perform hydrogen leakage test using liquid leak detector solution in accordance with E.7.2.2 with the micro fuel cell power system or micro fuel cell power unit turned off	Effectuer un essai de fuite d'hydrogène à l'aide d'une solution de détecteur de fuite liquide conformément à E.7.2.2 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de la micropile à combustible arrêté
Are bubbles formed?	Formation de bulles?
Leakage occurred, type test failed	Fuite, échec de l'essai de type
Perform hydrogen gas loss test in accordance with E.7.2.13 with the micro fuel cell power system or micro fuel cell power unit turned off	Effectuer un essai de perte de gaz hydrogène conformément à E.7.2.13 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de la micropile à combustible arrêté
Loss within acceptable limits, fire or explosion?	Pertes dans les limites acceptables, feu ou explosion?
Perform emissions test in accordance with E.7.2.12 with the micro fuel cell power system or micro fuel cell power unit turned on	Effectuer un essai d'émissions conformément à E.7.2.12 avec le système à micropile à combustible en marche ou avec le bloc d'alimentation électrique de la micropile à combustible en marche
Was hydrogen emission less than 0,016 g/h?	Émission d'hydrogène inférieure à 0,016 g/h?
Was hydrogen emission greater than 0,08 g/h?	Émission d'hydrogène supérieure à 0,08 g/h?
Perform hydrogen gas loss test in accordance with E.7.2.13 with the micro fuel cell power system or micro fuel cell power unit turned on	Effectuer un essai de perte de gaz hydrogène conformément à E.7.2.13 avec le système à micropile à combustible arrêté ou avec le bloc d'alimentation électrique de la micropile à combustible en marche
Type test passed	Réussite de l'essai de type

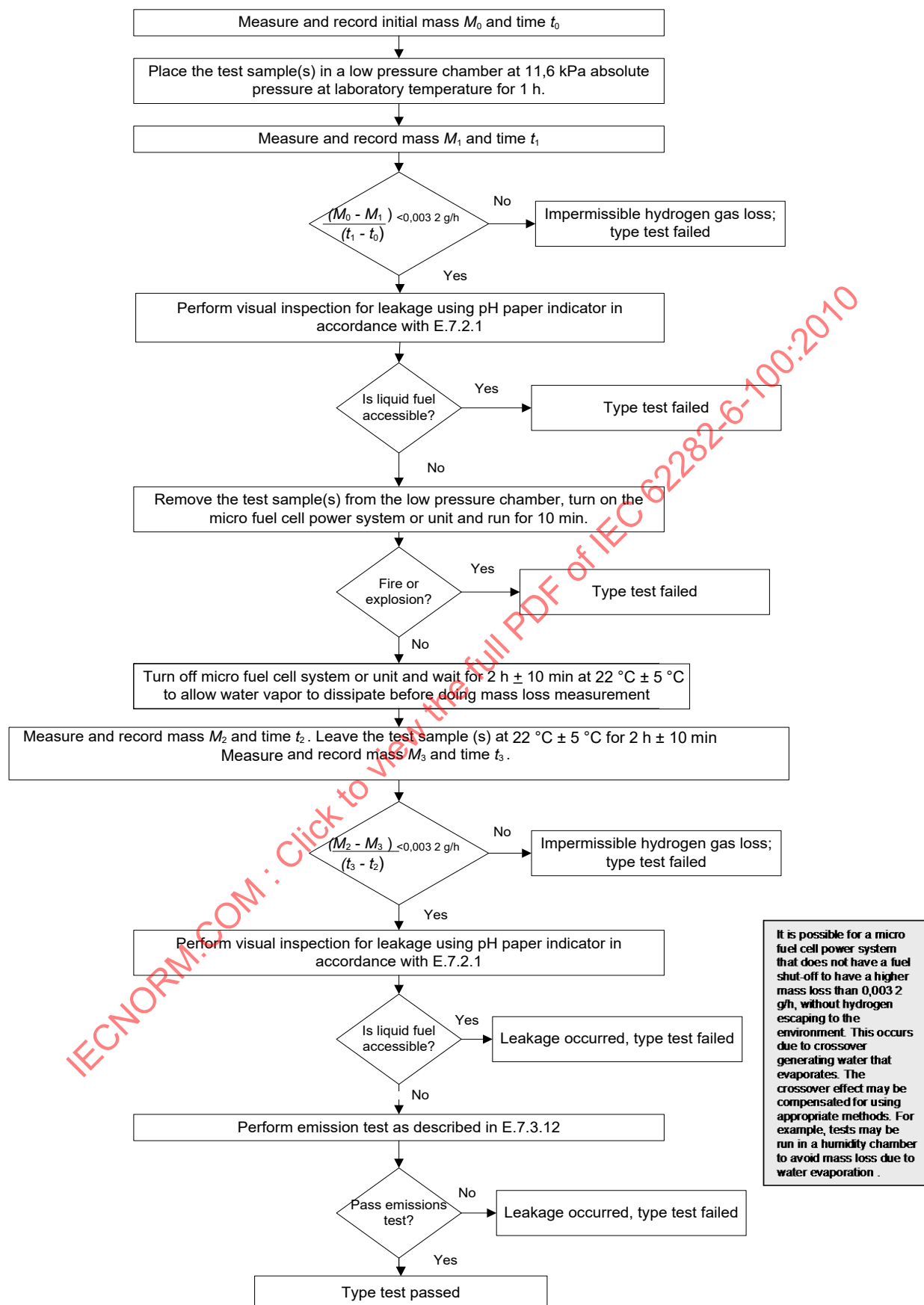
Figure E.5 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai de court-circuit externe – Remplace la Figure 5



Anglais	Français
Measure and record initial mass M_0 and time t_0	Mesurer et enregistrer la masse initiale M_0 et le temps initial t_0

Anglais	Français
Place the test sample(s) in a low pressure chamber at 68 kPa absolute pressure at laboratory temperature for 6 h	Placer le ou les échantillons d'essai dans une enceinte basse pression à 68 kPa de pression absolue pendant 6 h à la température du laboratoire
Measure and record mass M_1 and time t_1	Mesurer et enregistrer la masse M_1 et le temps t_1
No	Non
Impermissible hydrogen gas loss, type test failed	Perte non admissible de gaz hydrogène, échec de l'essai de type
Yes	Oui
Perform visual inspection for leakage using pH indicator paper in accordance with E.7.2.1	Effectuer un examen visuel pour rechercher les fuites à l'aide d'un papier indicateur de pH conformément à E.7.2.1
Is liquid fuel accessible?	Combustible liquide accessible?
Remove the test sample(s) from the low pressure chamber, turn on the micro fuel power system or unit and run for 10 min	Retirer le ou les échantillons de l'enceinte basse pression; mettre en marche le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible pendant 10 min
Fire or explosion?	Feu ou explosion?
Turn off micro fuel system or unit and wait for 2 h $\pm$ 10 min at 22 °C $\pm$ 5°C to allow water vapor to dissipate before doing mass loss measurement	Arrêter le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible pendant 2 h $\pm$ 10 min à 22 °C $\pm$ 5 °C pour permettre à la vapeur d'eau de se dissiper avant d'effectuer les mesurages de perte de masse
Measure and record mass M_2 and time t_2 . Leave the test sample(s) at 22 °C $\pm$ 5°C for 2 h $\pm$ 10 min. Measure and record mass M_3 and time t_3	Mesurer et enregistrer la masse M_2 et le temps t_2 . Laisser le ou les échantillons à une température de 22 °C $\pm$ 5°C pendant 2 h $\pm$ 10 min. Mesurer et enregistrer la masse M_3 et le temps t_3
Leakage occurred	Fuite
Perform emissions test as described in E.7.3.12	Effectuer l'essai d'émission tel que décrit en E.7.3.12
Pass emissions test ?	Réussite de l'essai d'émission?
Type test passed	Réussite de l'essai de type
It is possible for a micro fuel cell power system that does not have a fuel shut-off to have a higher mass load than 0,003 2 g/h, without hydrogen escaping to the environment. This occurs due to crossover generating water that evaporates. The crossover effect may be compensated for using appropriate methods. For example, tests may be run in a humidity chamber to avoid mass loss due to water evaporation.	Il est possible, pour un système à micropile à combustible n'ayant pas de vanne d'arrêt de combustible, d'avoir une perte de masse supérieure à 0,003 2 g/h, sans que l'hydrogène s'échappe dans l'environnement. Ceci se produit à cause d'un changement d'état produisant de l'eau qui s'évapore. L'effet du changement d'état peut être compensé à l'aide de méthodes appropriées. Par exemple, les essais peuvent être effectués dans une enceinte humide, afin d'éviter une perte de masse due à l'évaporation de l'eau

Figure E.6 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai à basse pression externe à 68 kPa –
Remplace la Figure 6



Anglais	Français
Measure and record initial mass M_0 and time t_0	Mesurer et enregistrer la masse initiale M_0 et le temps initial t_0
Place the test sample(s) in a low pressure chamber at	Placer le ou les échantillons d'essai dans une enceinte

Anglais	Français
11,6 kPa absolute pressure at laboratory temperature for 1 h	basse pression à 11,6 kPa de pression absolue pendant 1 h à la température du laboratoire
Measure and record mass M_1 and time t_1	Mesurer et enregistrer la masse M_1 et le temps t_1
No	Non
Impermissible hydrogen gas loss, type test failed	Perte non admissible de gaz hydrogène, échec de l'essai de type
Yes	Oui
Perform visual inspection for leakage using pH indicator paper in accordance with E.7.2.1	Effectuer un examen visuel pour rechercher les fuites à l'aide d'un papier indicateur de pH conformément à E.7.2.1
Is liquid fuel accessible?	Combustible liquide accessible?
Type test failed	Échec de l'essai de type
Remove the test sample(s) from the low pressure chamber, turn on the micro fuel power system or unit and run for 10 min	Retirer le ou les échantillons de l'enceinte basse pression; mettre en marche le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible pendant 10 min
Fire or explosion?	Feu ou explosion?
Turn off micro fuel system or unit and wait for 2 h ± 10 min at 22 °C ± 5 °C to allow water vapor to dissipate before doing mass loss measurement	Arrêter le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible pendant 2 h ± 10 min à 22 °C ± 5 °C pour permettre à la vapeur d'eau de se dissiper avant d'effectuer les mesurages de perte de masse
Measure and record mass M_2 and time t_2 . Leave the test sample(s) at 22 °C ± 5 °C for 2 h ± 10 min. Measure and record mass M_3 and time t_3	Mesurer et enregistrer la masse M_2 et le temps t_2 . Laisser le ou les échantillons à une température de 22 °C ± 5 °C pendant 2 h ± 10 min. Mesurer et enregistrer la masse M_3 et le temps t_3
Leakage occurred	Fuite
Perform emissions test as described in E.7.3.12	Effectuer l'essai d'émission tel que décrit en E.7.3.12
Pass emissions test ?	Réussite de l'essai d'émission?
Type test passed	Réussite de l'essai de type
It is possible for a micro fuel cell power system that does not have a fuel shut-off to have a higher mass load than 0,003 2 g/h, without hydrogen escaping to the environment. This occurs due to crossover generating water that evaporates. The crossover effect may be compensated for using appropriate methods. For example, tests may be run in a humidity chamber to avoid mass loss due to water evaporation.	Il est possible, pour un système à micropile à combustible n'ayant pas de vanne d'arrêt de combustible, d'avoir une perte de masse supérieure à 0,003 2 g/h, sans que l'hydrogène s'échappe dans l'environnement. Ceci se produit à cause d'un changement d'état produisant de l'eau qui s'évapore. L'effet du changement d'état peut être compensé à l'aide de méthodes appropriées. Par exemple, les essais peuvent être effectués dans une enceinte humide, afin d'éviter une perte de masse due à l'évaporation de l'eau

Figure E.7 – Diagramme d'essai de fuite du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, et de perte de masse pour l'essai à basse pression externe à 11,6 kPa – Remplace la Figure 7

E.7.3 Essais de type

E.7.3.1 Essais de pression différentielle

E.7.3.1.1 Généralités

Le E.7.3.1 remplace le 7.3.1.

Certaines parties de cet essai sont conformes à E.4.12.1.2 utilisé pour confirmer qu'il ne doit pas y avoir de fuite au niveau de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en

prenant celle des deux valeurs qui est la plus élevée. Deux options d'essai sont proposées, en fonction des conditions de pression donnant la valeur la plus élevée:

- a) Si la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C donne une valeur supérieure à deux fois la pression manométrique de la cartouche de combustible à 55 °C, le E.7.3.1.2 ou le E.7.3.1.3 peut être utilisé pour vérifier la conformité à E.4.12.1.2.
- b) Si deux fois la pression manométrique de la cartouche de combustible à 55 °C donne une valeur supérieure à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, le E.7.3.1.2 doit être utilisé pour vérifier la conformité à 4.12.1.2.

E.7.3.1.2 Essai de mise sous pression interne de la cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée et vanne de la cartouche de combustible.
- b) **Objet:** simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**

Pour l'essai de mise sous pression interne, le corps de la cartouche de combustible et la vanne de la cartouche de combustible doivent être soumis à l'essai séparément.

- 1) À l'aide d'un milieu liquide, mettre sous pression le corps de la cartouche de combustible à une pression interne égale soit à la pression manométrique interne de 95 kPa plus la pression normale de service à 22 °C, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
- 2) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
- 3) À l'aide d'un milieu liquide adapté, mettre sous pression la vanne fermée de la cartouche de combustible à une pression égale soit à la pression manométrique de 95 kPa plus la pression normale de service à 22 °C de la cartouche, soit à deux fois la pression manométrique de la cartouche de combustible à 55 °C, en prenant celle des deux valeurs qui est la plus élevée. L'augmentation de la pression ne doit pas dépasser un taux de 60 kPa/s.
- 4) Maintenir la pression maximale pendant 30 min à la température ambiante du laboratoire.
- d) **Critères de réussite:** aucune fuite du milieu d'essai liquide accessible et aucune chute soudaine de pression au cours de l'essai. La fuite doit être vérifiée visuellement. Retourner la cartouche de combustible et la vanne de la cartouche de combustible au-dessus d'un papier réactif, de telle façon que la vanne soit dirigée vers le bas, en direction du papier réactif et rechercher des signes de fuite. Si une fuite de liquide accessible est détectée, l'essai échoue.

NOTE Les combustibles à borohydrure de classe 8 (corrosif) réagissent chimiquement avec l'eau et, donc, il convient de ne pas utiliser l'eau ou des substances contenant de l'eau comme milieu d'essai fluide. Les combustibles à borohydrure de classe 8 (corrosifs) peuvent réagir avec des substances autres que l'eau et il convient donc d'utiliser la réactivité chimique et la stabilité du combustible à borohydrure de classe 8 (corrosif) particulier soumis à l'essai comme guide à la sélection d'un milieu d'essai fluide adapté.

E.7.3.1.3 Essai de la cartouche de combustible à basse pression externe

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets de la pression interne élevée dans la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer cet essai conformément à la Figure E.16.

- 2) Enregistrer la masse initiale de l'échantillon d'essai M_0 et l'instant de départ t_0 . Placer l'échantillon dans une chambre à vide et réduire la pression dans la chambre à vide à 95 kPa en dessous de la pression atmosphérique normale.
 - 3) Maintenir le vide pendant 30 min.
 - 4) Retirer l'échantillon de la chambre à vide et Enregistrer la masse finale M_1 et le temps t_1 . Déterminer la perte de gaz hydrogène et vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme décrit en E.7.2.1.
 - 5) Connecter la cartouche de combustible neuve au bloc d'alimentation électrique de la micropile à combustible ou au système à micropile à combustible. Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme décrit en E.7.2.1. Voir Figure E.16.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte non admissible de gaz hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif) de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 pour la cartouche de combustible et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. La perte de gaz hydrogène doit satisfaire aux exigences de E.7.2.3 (inférieure à 0,0032 g/h) pour la cartouche de combustible et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement.

E.7.3.1.4 Essais de pression différentielle du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

E.7.3.1.4.1 Essai à basse pression externe à 68 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

Cet essai est exigé pour tous les systèmes à micropiles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe E.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer cet essai conformément à la Figure E.6.

- 2) Les échantillons d'essai doivent être stockés à basse pression externe à 68 kPa de pression absolue pendant 6 h à la température ambiante du laboratoire. La fuite doit être mesurée en se basant sur la procédure décrite à la Figure E.6.
- 3) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à E.7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte non admissible de gaz hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. La perte de gaz hydrogène doit être déterminée par la mesure de perte de masse représentée à la Figure E.6. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible/bloc d'alimentation électrique des micropiles à combustible. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de E.7.3.12, l'essai d'émission est acceptable.

E.7.3.1.4.2 Essai à basse pression externe à 11,6 kPa du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible

Cet essai est exigé pour tous les systèmes à micropiles à combustible et tous les blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe E.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux spécifications du fabricant ou système à pile à combustible.
- b) **Objet:** simuler les effets d'une pression interne élevée ou d'une basse pression externe et s'assurer de l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer cet essai conformément à la Figure E.7.
 - 2) Les échantillons d'essai doivent être stockés à basse pression externe à 11,6 kPa de pression absolue pendant 1 h à la température ambiante du laboratoire. La fuite doit être mesurée en se basant sur la procédure décrite à la Figure E.7.
 - 3) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à E.7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune perte non admissible de gaz hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. La perte de gaz hydrogène doit être déterminée par la mesure de perte de masse représentée à la Figure E.7. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de E.7.3.12, l'essai d'émission est acceptable.

E.7.3.2 Essai de vibrations

Le E.7.3.2 remplace le 7.3.2 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible usagée, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible utilisé en E.7.3.1.
- b) **Objet:** simuler les effets des vibrations au cours de conditions normales de transport, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure E.2 pour la cartouche de combustible et conformément à la Figure E.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) L'échantillon d'essai doit être fixé solidement à la plate-forme du générateur de vibrations, sans déformer l'échantillon, et de manière à émettre correctement les vibrations.
 - 3) Les vibrations doivent être de forme d'onde sinusoïdale avec un balayage logarithmique entre 7 Hz et 200 Hz et de nouveau à 7 Hz, traversé en 15 min.
 - 4) Ce cycle doit être répété 12 fois pendant 3 h au total pour chacune des trois positions de montage perpendiculaires des échantillons d'essai.
 - 5) Le balayage en fréquence logarithmique se déroule comme suit: à partir de 7 Hz, une accélération de crête de $1 g_n$ est maintenue jusqu'à ce que la valeur de 18 Hz soit atteinte. L'amplitude est ensuite maintenue à 0,8 mm (excursion totale de 1,6 mm) et la fréquence est augmentée jusqu'à ce qu'une accélération de crête de $8 g_n$ se produise (environ 50 Hz). Une accélération de crête de $8 g_n$ est ensuite maintenue jusqu'à ce que la fréquence soit portée à 200 Hz.
 - 6) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à E.7.3.12.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 pour la cartouche de combustible et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à

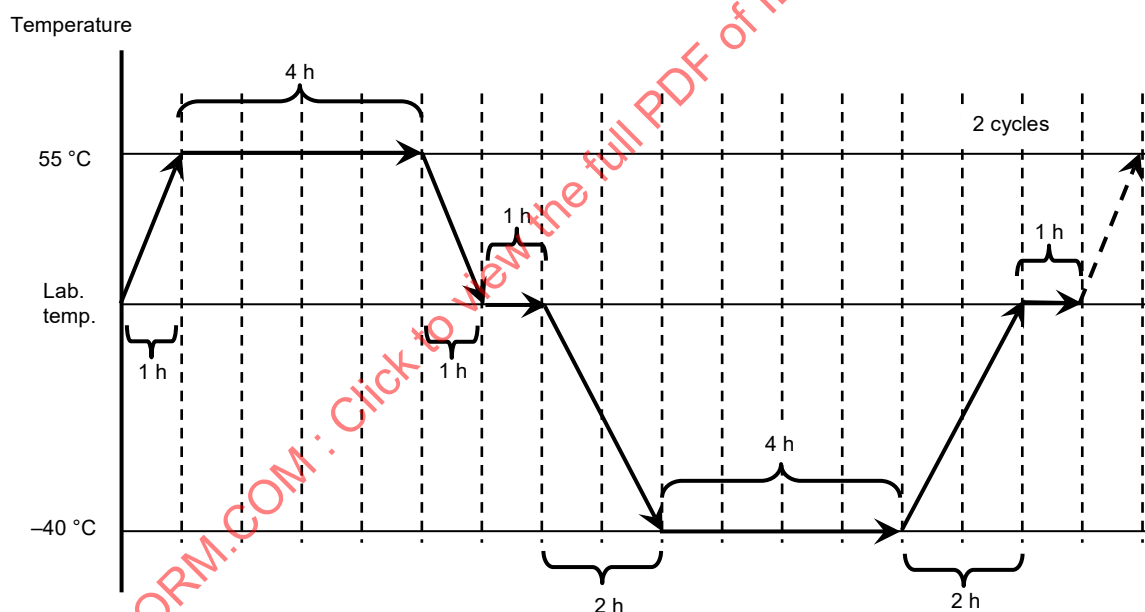
combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de E.7.3.12, l'essai d'émission est acceptable.

E.7.3.3 Essai de cycles de températures

Le E.7.3.3 remplace le 7.3.3 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E.

- a) **Échantillon d'essai:** cartouche de combustible utilisée en E.7.3.2, cartouche de combustible usagée en E.7.3.2, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant utilisé en E.7.3.2, ou système à micropile à combustible utilisé en E.7.3.2.
- b) **Objet:** simuler les effets d'une exposition à basse température et à température élevée et les effets de variations extrêmes de températures et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure E.3 pour la cartouche de combustible et conformément à la Figure E.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) Pour une cartouche de combustible, deux orientations de cartouches de combustible doivent être soumises à l'essai – vanne vers le haut et vanne vers le bas. Pour un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible, il n'est pas nécessaire de vérifier par essai plus d'une orientation.
 - 3) Voir Figure E.8 pour le profil de température à utiliser.
 - 4) Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, et augmenter la température de l'enceinte de la température de laboratoire à $55\text{ °C} \pm 2\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$, et la maintenir à $55\text{ °C} \pm 2\text{ °C}$ pendant au moins 4 h.
 - 5) Diminuer la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $1\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$, puis diminuer la température de l'enceinte à $-40\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$, et la maintenir à $-40\text{ °C} \pm 5\text{ °C}$ pendant au moins 4 h.
 - 6) Augmenter la température de l'enceinte à $22\text{ °C} \pm 5\text{ °C}$ en $2\text{ h} \pm 5\text{ min}$ et la maintenir à $22\text{ °C} \pm 5\text{ °C}$ pendant $1\text{ h} \pm 5\text{ min}$.
 - 7) Le processus ci-dessus doit être réalisé deux fois.
 - 8) Après 1 h à $22\text{ °C} \pm 5\text{ °C}$, la fuite et la perte de vapeur de combustible doivent être mesurées d'après la procédure décrite à la Figure E.3 (pour la cartouche de combustible) et d'après la procédure décrite à la Figure E.4 (pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible).
 - 9) Pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à E.7.3.12.
 - 10) Pour la cartouche de combustible, connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou au système à micropile à combustible. Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2 Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme décrit en E.7.2.1.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 pour la cartouche de combustible et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite

d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de E.7.3.12, l'essai d'émission est acceptable.



Anglais	Français
Temperature	Température
Lab. temp.	Température du laboratoire

Figure E.8 – Cycles de températures – Remplace la Figure 8

E.7.3.4 Essai d'exposition à température élevée

Le E.7.3.4 remplace le 7.3.4 pour les cartouches de combustible traitées par la présente Annexe E.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.

- b) **Objet:** simuler les effets d'une cartouche de combustible laissée dans des environnements à température élevée et garantir l'absence de fuite
- c) **Procédure d'essai:**
- 1) Effectuer ces essais conformément à la Figure E.3 pour la cartouche de combustible.
 - 2) Deux orientations doivent être soumises à l'essai -- vanne vers le haut et vanne vers le bas.
 - 3) Placer l'échantillon d'essai dans une enceinte d'essai à température contrôlée, à une température de $70\text{ °C} \pm 2\text{ °C}$, et laisser la température de l'enceinte revenir à $70\text{ °C} \pm 2\text{ °C}$, et maintenir cette température pendant au moins 4 h avec l'échantillon dans l'enceinte.
 - 4) Retirer l'échantillon d'essai à la température de laboratoire. Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte et de composants de combustibles liquides par un examen visuel avec l'essai à l'indicateur de pH comme décrit en E.7.2.1.
 - 5) Connecter la cartouche de combustible à un bloc d'alimentation électrique de la micropile à combustible ou un système à micropile à combustible. Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel avec l'essai à l'indicateur de pH comme décrit en E.7.2.1. Voir Figure E.3.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

E.7.3.5 Essai de chute

Le E.7.3.5 remplace le 7.3.5 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, cartouche de combustible usagée, bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets d'une chute involontaire, et garantir l'absence de fuite.

c) Procédure d'essai:

- 1) Effectuer ces essais conformément à la Figure E.2 pour la cartouche de combustible et conformément à la Figure E.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
- 2) L'échantillon d'essai doit chuter sur une surface horizontale se composant de bois dur d'au moins 13 mm d'épaisseur monté sur deux couches de contreplaqué, chacune d'une épaisseur de 18 mm à 20 mm, le tout sur un sol en béton ou en matériau équivalent non élastique, à partir d'une hauteur prédéterminée.
- 3) La hauteur de chute doit être de:
 - i) 1 200 mm $\pm$ 10 mm: dans le cas d'un bloc d'alimentation électrique de la micropile à combustible et/ou d'un système à micropile à combustible.
 - ii) 1 500 mm $\pm$ 10 mm: dans le cas d'une cartouche de combustible contenant plus de 200 ml.
 - iii) 1 800 mm $\pm$ 10 mm: dans le cas d'une cartouche de combustible contenant jusqu'à 200 g de combustible solide ou jusqu'à 200 ml de composant de combustible liquide.
- 4) Pour les essais de la cartouche de combustible, l'essai de chute doit être effectué dans quatre orientations de chute avec le même échantillon.
- 5) Pour le bloc d'alimentation électrique de la micropile à combustible ou le système à micropile à combustible, un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible peut être utilisé pour chacune des quatre orientations de chute, ou plusieurs systèmes à micropiles à combustible ou blocs d'alimentation électrique de micropiles à combustible peuvent être utilisés pour les chutes suivantes, à l'initiative du fabricant.
- 6) Pour tous les essais, les orientations de chute doivent être les suivantes:
 - i) vanne vers le haut;
 - ii) vanne vers le bas;
 - iii) deux autres orientations perpendiculaires.
- 7) Pour la cartouche de combustible, vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel avec l'essai à l'indicateur de pH comme décrit en E.7.2.1.
- 8) Connecter la cartouche de combustible neuve au bloc d'alimentation électrique de la micropile à combustible ou au système à micropile à combustible. Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme décrit en E.7.2.1. Voir Figure E.2.
- 9) Pour les essais du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible, effectuer l'essai d'émission conformément à E.7.3.12.

- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée

dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de E.7.3.12, l'essai d'émission est acceptable. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible est toujours en état de fonctionnement, les circuits de protection spécifiés par l'AMDE en tant que parties des systèmes de sécurité doivent toujours être pleinement fonctionnels. Il ne doit pas y avoir d'exposition des parties dangereuses.

E.7.3.6 Essai de charge de compression

Le E.7.3.6 remplace le 7.3.6 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E.

E.7.3.6.1 Système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur le bloc d'alimentation électrique de la micropile à combustible, ou le système à micropile à combustible.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure E.4 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) L'échantillon d'essai du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer sur l'échantillon une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$.
 - 3) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).
 - 4) Une force de compression de $245 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 5) L'essai doit en général être effectué dans trois orientations perpendiculaires. Si l'échantillon n'est pas stable de lui-même, il n'est pas nécessaire qu'il soit soumis à l'essai dans cette orientation.
 - 6) Effectuer l'essai d'émission conformément à E.7.3.12, après l'essai de charge de compression.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la

procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, mais les émissions ne dépassent pas les limites de E.7.3.12, l'essai d'émission est acceptable.

E.7.3.6.2 Cartouche de combustible

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets des forces raisonnablement rencontrées à cause d'une charge exercée par quelque chose de lourd placé sur la cartouche de combustible et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure E.2 pour la cartouche de combustible.
 - 2) L'échantillon d'essai de la cartouche de combustible doit être placé entre deux blocs plats en bois dur d'environ 254 mm (10 pouces) de long, 101,6 mm (4 pouces) de large et 12,7 mm (1/2 pouce) d'épaisseur équipés d'un ou de dispositifs qui permettent d'appliquer à l'échantillon une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$.
 - 3) Une force de compression doit être appliquée sur l'échantillon de manière progressive, à une vitesse inférieure ou égale à 12,7 mm/min (1/2 pouce/min).
 - 4) Une force de compression de $981 \text{ N} \pm 9,8 \text{ N}$ doit être appliquée sur l'échantillon fixe pendant 5 s.
 - 5) Les orientations de la cartouche de combustible doivent être choisies d'après les positions de repos en principe stables lors de chutes accidentelles (par exemple, les orientations ayant les centres de gravité les plus bas par rapport à la surface de repos). Il est acceptable de soumettre aux essais une seule surface d'une cartouche de combustible prismatique qui soit suffisamment cubique et la surface incurvée d'une cartouche de combustible cylindrique avec une longueur d'axe longitudinal supérieure à deux fois le diamètre. Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme décrit en E.7.2.1.
 - 6) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou au système à micropile à combustible. Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) comme décrit en E.7.2.2. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme décrit en E.7.2.1. Voir Figure E.2.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides

doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.

E.7.3.7 Essai de court-circuit externe

Le E.7.3.7 remplace le 7.3.7 pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique de micropiles à combustible traités par la présente Annexe E.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** simuler les effets d'un court-circuit externe.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure E.5 pour le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible.
 - 2) L'essai de court-circuit externe doit être effectué séparément et respectivement à la fois sur les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible en fonctionnement [DISPOSITIF EN POSITION «ON»] et sur les systèmes à micropile à combustible ou les blocs d'alimentation électrique des micropiles à combustible en état de non-fonctionnement [DISPOSITIF EN POSITION «OFF»].
 - 3) Chaque échantillon d'essai doit être court-circuité en reliant les bornes positive et négative du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible avec des conducteurs ayant une charge de résistance maximale de 0,1 Ω pendant au moins 5 min.
 - 4) À la suite de l'essai de court-circuit, évaluer la performance et effectuer les essais d'émissions conformément à la Figure E.5.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement, pour confirmer l'absence de perturbation du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.

Les surfaces externes ne doivent pas dépasser les températures du Tableau 2, pendant ou après les essais de court-circuit.

Les émissions doivent satisfaire aux critères de réussite de E.7.3.12. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible

ne fonctionne pas, mais les émissions ne dépassent pas les limites de E.7.3.12, l'essai d'émission est acceptable.

NOTE L'essai de court-circuit externe peut être effectué de manière séquentielle avec l'essai de température de surface, de composant et de gaz d'échappement, en utilisant le même échantillon.

E.7.3.9 Essai de stockage de longue durée

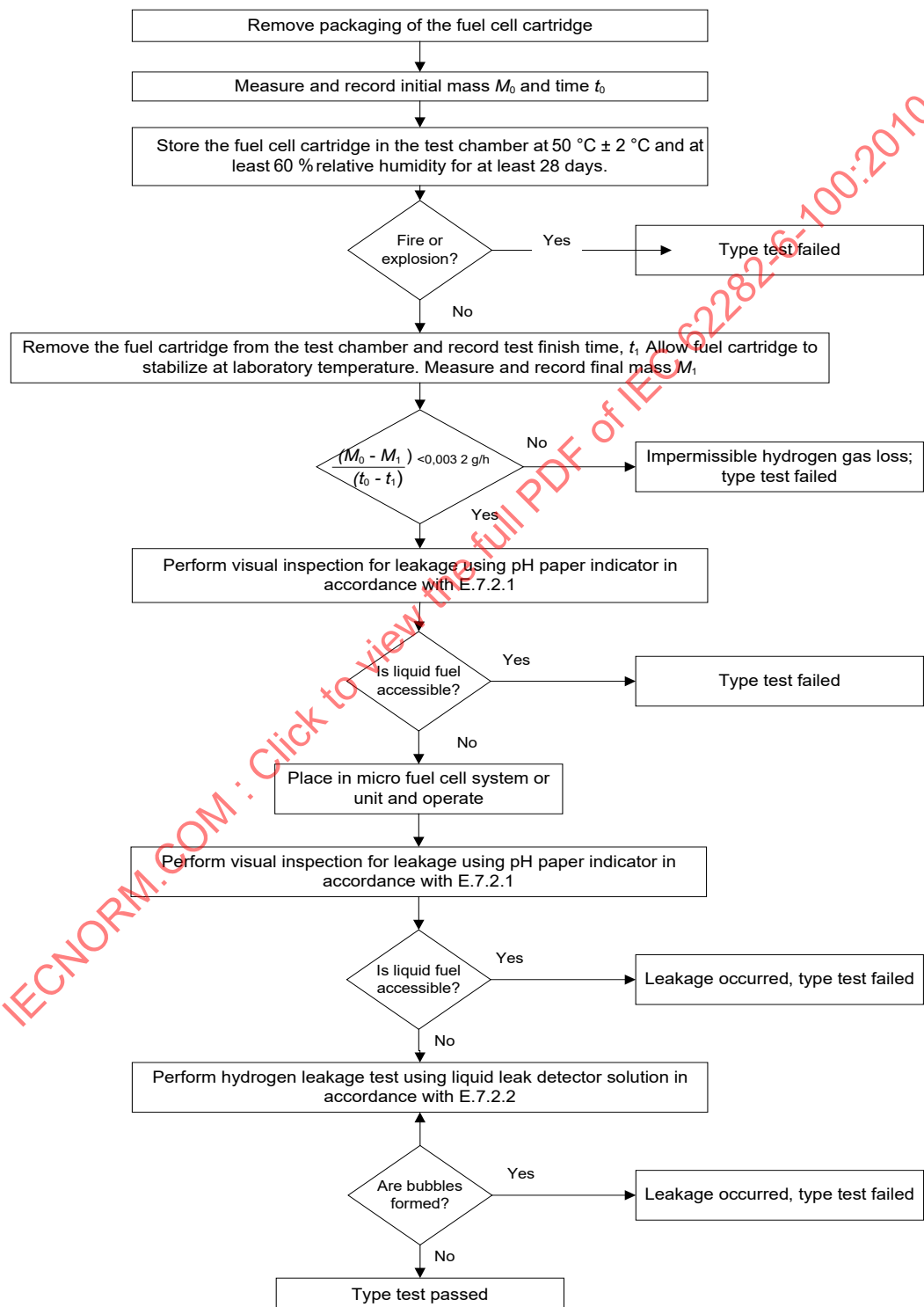
Le E.7.3.9 remplace le 7.3.9 pour les cartouches de combustible traitées par la présente Annexe E.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée ou cartouche de combustible usagée.
- b) **Objet:** simuler les effets du stockage de longue durée à température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Effectuer ces essais conformément à la Figure E.9 pour les cartouches de combustible.
 - 2) Enregistrer la masse initiale M_0 et le temps t_0 puis placer l'échantillon dans l'enceinte de température à $50\text{ °C} \pm 2\text{ °C}$ avec une humidité relative dans l'enceinte d'au moins 60 %.
 - 3) L'enceinte de température doit être équipée d'une ventilation et d'appareils de mesure capables de mesurer précisément la concentration d'hydrogène dans l'enceinte, selon la même configuration que celle de la Figure E.10.
 - 4) Le débit de la ventilation et la concentration d'hydrogène concernée dans l'enceinte doivent être surveillés de façon continue et enregistrés. Voir Tableau E.7. À aucun moment au cours de l'essai, la concentration d'hydrogène dans l'enceinte ne doit dépasser 25 % de la LII.
 - 5) L'échantillon doit rester dans l'enceinte à $50\text{ °C} \pm 2\text{ °C}$ avec une humidité relative dans l'enceinte d'au moins 60 % pendant au moins 28 jours.
 - 6) À la fin des 28 jours, retirer la cartouche de combustible de l'enceinte d'essai et consigner l'heure à laquelle la cartouche de combustible a été retirée de l'enceinte d'essai, t_1 . Laisser la cartouche de combustible se stabiliser à la température du laboratoire et consigner la masse finale, M_1 . La perte de gaz hydrogène est calculée comme suit et ne doit pas dépasser 0,0032 g/h:

$$\frac{M_0 - M_1}{t_1 - t_0} < 0,0032 \text{ g/h}$$

- 7) Effectuer les essais de fuite de combustible, de sous-produits combustibles, d'électrolyte et de composants de combustibles liquides conformément à E.7.2.1 pour la cartouche de combustible. Connecter la cartouche de combustible neuve au bloc d'alimentation électrique de la micropile à combustible ou au système à micropile à combustible. Vérifier s'il y a des fuites de combustible, de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel avec l'essai à l'indicateur de pH comme décrit en E.7.2.1. Voir Figure E.9.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les pertes de gaz hydrogène doivent satisfaire aux exigences de E.7.2.3 (moins de 0,0032 g/h). La concentration d'hydrogène dans l'enceinte d'essai de température ne doit pas dépasser 25 % de la LII à aucun moment au cours de l'essai. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc

d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. La survenue d'explosion doit être vérifiée visuellement.



Anglais	Français
Remove packaging of the fuel cell cartridge	Retirer l'emballage de la cartouche de pile à

	combustible
Measure and record initial mass M_0 and time t_0	Mesurer la masse initiale M_0 et le temps t_0 .
Store the fuel cell cartridge in the test chamber at $50 \pm 2 \text{ }^\circ\text{C}$ and at least 60% relative humidity for at least 28 days	Stocker la cartouche de pile à combustible dans l'enceinte d'essai à $(50 \pm 2) \text{ }^\circ\text{C}$ à une humidité relative d'au moins 60 % pendant au moins 28 jours.
Fire or explosion ?	Feu ou explosion?
Yes	Oui
Type test failed	Échec de l'essai de type
Remove the fuel cartridge from the test chamber and record test finish time t_1 . Allow fuel cartridge to stabilize at laboratory temperature. Measure and record final mass M_1	Retirer la cartouche de combustible de l'enceinte d'essai et enregistrer le temps de fin d'essai; t_1 . Laisser la cartouche de combustible se stabiliser à la température du laboratoire. Mesurer et enregistrer la masse M_1
No	Non
Impermissible hydrogen gas loss; type test failed	Perte non admissible de gaz hydrogène; échec de l'essai de type
Perform visual inspection for leakage using pH paper indicator in accordance with E.7.2.1	Effectuer un examen visuel pour rechercher des fuites à l'aide d'un papier indicateur pH conformément à E.7.2.1.
Is liquid fuel accessible?	Combustible liquide accessible?
Place in micro fuel cell system or unit and operate	Placer dans le système à micropile à combustible ou dans le bloc d'alimentation de la micropile à combustible puis faire fonctionner
Leakage occurred	Fuite
Perform hydrogen leakage test using liquid leak detector solution in accordance with E.7.2.2	Effectuer l'essai de fuite d'hydrogène à l'aide d'une solution de détecteur de fuite liquide conformément à E.7.2.2
Are bubbles formed?	Formation de bulles?
Type test passed	Réussite de l'essai de type

Figure E.9 – Diagramme d'essai de fuite d'hydrogène et de perte de masse de la cartouche de combustible pour l'essai de stockage de longue durée – Remplace la Figure 9

E.7.3.10 Essai de connexion à température élevée

Le E.7.3.10 remplace le 7.3.10 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E.

- a) **Échantillon d'essai:** cartouche de combustible inutilisée, ou cartouche de combustible usagée et bloc d'alimentation électrique de la micropile à combustible, ou une installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible, la cartouche de combustible étant à une température élevée, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 8) Effectuer ces essais conformément à la Figure E.2 pour les cartouches de combustible.
 - 9) Placer l'échantillon d'essai de la cartouche de combustible dans une enceinte d'essai à température contrôlée, c'est-à-dire à une température de $50 \text{ }^\circ\text{C} \pm 2 \text{ }^\circ\text{C}$ pendant au moins 4 h.

- 10) Le bloc d'alimentation électrique de la micropile à combustible ou l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible sont maintenus à la température ambiante du laboratoire.
 - 11) Retirer l'échantillon d'essai de l'enceinte et connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à l'installation d'essai fixe avec la vanne du bloc d'alimentation électrique de la micropile à combustible, dans les 5 min qui suivent le retrait de l'enceinte.
 - 12) Vérifier s'il y a des fuites à la connexion et à la déconnexion provenant de la cartouche de combustible et du système à micropile à combustible ou du bloc d'alimentation électrique des micropiles à combustible et réaliser la mesure des fuites et des fuites d'hydrogène conformément à E.7.2.1 et E.7.2.2.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées.

E.7.3.11 Essais de cycles de connexion

Le E.7.3.11 remplace le 7.3.11 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe E.

E.7.3.11.1 Cartouche de combustible

E.7.3.11.1.1 Cartouche insérable, cartouche externe ou cartouche fixée

- a) **Échantillon d'essai:** cartouche insérable inutilisée ou cartouche insérable usagée, cartouche externe ou cartouche fixée inutilisée ou usagée, et bloc d'alimentation électrique de la micropile à combustible alimenté conformément aux instructions du fabricant ou installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible et alimentée en combustible conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible et doit être apte à simuler le débit du combustible.
- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
 - 1) Connecter la cartouche de combustible neuve au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible. Vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène

doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides à la connexion par un examen visuel à l'aide d'un indicateur de pH comme décrit dans la procédure d'essai et de mesure des fuites spécifiée en E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte et de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite indiqués en E.7.2.1.

- 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 4) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite d'hydrogène tels que spécifiés dans la procédure d'essai et de mesure des fuites de E.7.2.1. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif) et de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite spécifiés dans la procédure d'essai et de mesure de fuites spécifiée de E.7.2.1.
- 5) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
- 6) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte et de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite indiqués en E.7.2.1.
- 7) Connecter et déconnecter la cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 8) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure d'essai et de mesure des fuites spécifiée en E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite d'hydrogène tels que spécifiés dans la procédure d'essai et de mesure des fuites de E.7.2.1. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme décrit dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite spécifiés dans la procédure d'essai et de mesure de fuites telle que spécifiée en E.7.2.1.
- 9) Connecter et déconnecter la cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
- 10) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite d'hydrogène dans la procédure d'essai et de mesure des fuites de E.7.2.1. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-

produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.

- 11) Connecter la cartouche de combustible et faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
 - 12) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
 - 13) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite d'hydrogène tels que spécifiés dans la procédure d'essai et de mesure des fuites de E.7.2.1. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides à la connexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
 - 14) Connecter la cartouche de combustible au système à micropile à combustible ou au bloc d'alimentation électrique de la micropile à combustible et effectuer les essais d'émission conformément à E.7.3.12 à la suite de l'essai de cycles de connexion.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. Les pertes de gaz hydrogène doivent satisfaire aux exigences de E.7.2.3. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12 pour les systèmes opérationnels et les systèmes en non-fonctionnement.

E.7.3.11.1.2 Cartouche satellite

- a) **Échantillon d'essai:** cartouche de combustible satellite inutilisée, et bloc d'alimentation électrique de la micropile à combustible ou installation d'essai fixe appropriée comportant une vanne de bloc d'alimentation électrique de la micropile à combustible alimentée en combustible, conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie du bloc d'alimentation électrique de la micropile à combustible et doit être apte à simuler le débit du combustible.

- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite.
- c) **Procédure d'essai:**
- 1) Connecter la cartouche de combustible neuve au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible. Vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides à la connexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1. Amorcer ou simuler le débit de combustible.
 - 2) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
 - 3) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
 - 4) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
 - 5) Connecter et déconnecter la première cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
 - 6) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
 - 7) Connecter et déconnecter la cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.

- 8) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
 - 9) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible et amorcer ou simuler le débit de combustible.
 - 10) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détection de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
 - 11) Répéter les étapes 1 à 10 quatre autres fois pour un total de 55 cycles, en attendant 1 h entre chaque série de 11 cycles.
 - 12) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible et effectuer les essais d'émissions tels que spécifiés en E.7.3.12 à la suite de l'essai de cycles.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12 pour les systèmes opérationnels et les systèmes en non-fonctionnement.

E.7.3.11.2 Bloc d'alimentation électrique de la micropile à combustible

- a) **Échantillon d'essai:** au moins deux cartouches de combustible inutilisées et 98 autres cartouches de combustible ou installations d'essai fixes comportant des vannes de cartouches de combustible supplémentaires et un bloc d'alimentation électrique de la

micropile à combustible alimenté en combustible, conformément aux instructions du fabricant. L'installation d'essai fixe doit avoir une configuration représentative de la géométrie et du matériau de la vanne de la cartouche de combustible et doit être apte à simuler le débit du combustible.

- b) **Objet:** simuler les effets de l'accouplement et du désaccouplement de la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible, et garantir l'absence de fuite, à la fois lors de l'utilisation initiale et après un vieillissement adapté de la connexion du bloc d'alimentation électrique de la micropile à combustible.

La première cartouche de combustible (#1) et la dernière cartouche de combustible (#100) sont examinées; les 980 cycles restants sont uniquement destinés à faire vieillir le bloc d'alimentation électrique de la micropile à combustible.

Dans le cas d'un bloc d'alimentation électrique de la micropile à combustible qui utilise une cartouche satellite, il doit être soumis à l'essai conformément à la procédure ci-dessous en simulant le débit de combustible entre la cartouche satellite et le bloc d'alimentation électrique de la micropile à combustible.

c) **Procédure d'essai:**

- 1) Connecter la première cartouche de combustible au bloc d'alimentation électrique des micropiles à combustible ou à la vanne du bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides à la connexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 2) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 3) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 4) Déconnecter la première cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides à la déconnexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 5) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
- 6) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des

fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.

- 7) Connecter et déconnecter la première cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 8) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 9) Connecter et déconnecter la première cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
- 10) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 11) Connecter la cartouche de combustible au bloc d'alimentation électrique des micropiles à combustible ou à la vanne du bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides à la connexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 12) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 13) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.

- 14) Déconnecter la première cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 15) Pour un vieillissement de la connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible, suivre les étapes suivantes:
- i) En utilisant soit des cartouches de combustible soit une installation d'essai fixe comportant des vannes de cartouche de combustible, lancer des cycles de connexion de la cartouche de combustible du bloc d'alimentation électrique de la micropile à combustible pour un total de 980 cycles de connexions et déconnexions.
 - ii) Simuler le débit de combustible après chaque série de 50 cycles de connexion/déconnexion.
 - iii) Le renversement du bloc d'alimentation électrique de la micropile à combustible du système à micropile à combustible ou des cartouches de combustible n'est pas nécessaire, mais si une fuite est détectée, l'essai échoue.
 - iv) Après ce vieillissement, une dernière cartouche de combustible inutilisée est soumise à l'essai.
- 16) Connecter la dernière cartouche de combustible inutilisée au bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 17) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.
- 18) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 19) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif) et de composants de combustibles liquides à la déconnexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.

- 20) Répéter cette opération deux autres fois pour un total de trois connexions et déconnexions.
- 21) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif) et de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 22) Connecter et déconnecter la dernière cartouche de combustible quatre autres fois pour un total de sept connexions et déconnexions.
- 23) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif) et de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 24) Connecter et déconnecter la dernière cartouche de combustible trois autres fois pour un total de dix connexions et déconnexions.
- 25) Vérifier s'il y a des fuites d'hydrogène à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 26) Connecter la cartouche de combustible au bloc d'alimentation électrique des micropiles à combustible et vérifier s'il y a des fuites d'hydrogène à la connexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides à la connexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 27) Faire fonctionner le bloc d'alimentation électrique de la micropile à combustible, ou bien simuler un débit de combustible pendant au moins 1 min.

- 28) Arrêter le bloc d'alimentation électrique de la micropile à combustible, ou arrêter le débit de combustible simulé.
- 29) Déconnecter la cartouche de combustible et vérifier s'il y a des fuites d'hydrogène à la déconnexion à l'aide d'une solution de détecteur de fuite liquide (formation de bulles) conformément à la procédure de mesure des fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible et le réservoir interne du système de gestion du combustible, si applicable. Les fuites d'hydrogène doivent satisfaire aux critères d'absence de fuite indiqués dans la procédure de mesure des fuites d'hydrogène de E.7.2.2. Vérifier s'il y a des fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits de combustibles, d'électrolyte ou de composants de combustibles liquides à la déconnexion par un examen visuel à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent satisfaire aux critères d'absence de fuite dans la procédure d'essai et de mesure de fuites de E.7.2.1.
- 30) Connecter la cartouche de combustible au bloc d'alimentation électrique de la micropile à combustible ou à la vanne du bloc d'alimentation électrique de la micropile à combustible et effectuer les essais d'émissions tels que spécifiés en E.7.3.12 à la suite de l'essai de cycles.
- d) **Critères de réussite:** Aucun feu ni aucune flamme à aucun moment. Aucune explosion à aucun moment. Aucune fuite d'hydrogène. Aucune fuite de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH comme spécifié dans la procédure d'essai et de mesure de fuites de E.7.2.1. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 pour la cartouche de combustible. Les fuites de combustible à borohydrure de classe 8 (corrosif), de sous-produits combustibles, d'électrolyte ou de composants de combustibles liquides doivent être déterminées visuellement à l'aide d'un indicateur de pH spécifié dans la procédure d'essai et de mesure des fuites de E.7.2.1 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou dans un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Les fuites d'hydrogène doivent satisfaire aux exigences d'absence de fuite d'hydrogène (aucune bulle formée) de la procédure de mesure de fuites d'hydrogène de E.7.2.2 après que la cartouche de combustible a été installée dans un système à micropile à combustible ou un bloc d'alimentation électrique de la micropile à combustible et mise en fonctionnement. Le feu et la flamme doivent être vérifiés à l'aide d'une étamine, d'une caméra infrarouge, ou autres méthodes adaptées. Les émissions doivent satisfaire aux critères de réussite de E.7.3.12 pour les systèmes opérationnels et les systèmes en non-fonctionnement.

E.7.3.12 Essai d'émissions

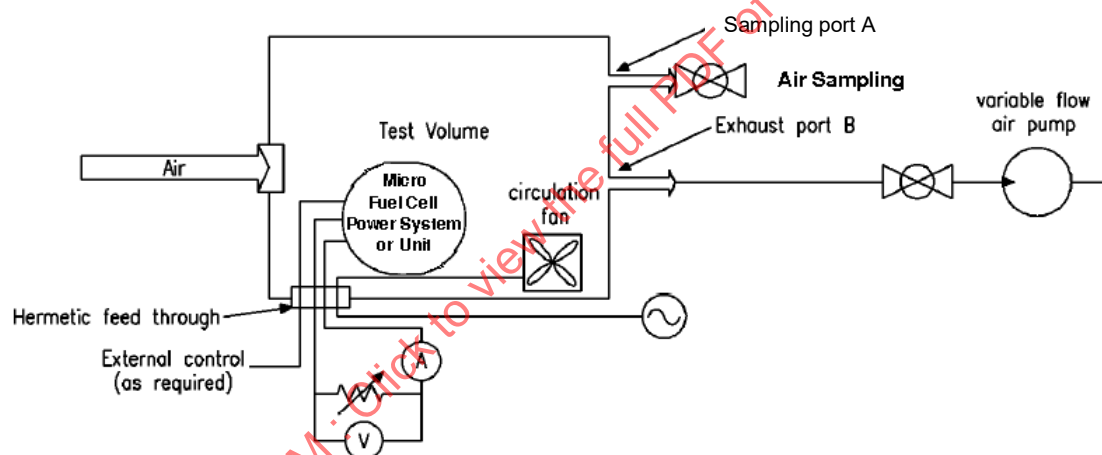
Ce paragraphe E.7.3.12 doit remplacer le 7.3.12 pour les systèmes à micropiles à combustible à borohydrure de classe 8 (corrosif) ou les blocs d'alimentation électrique des micropiles à combustible à borohydrure de classe 8 (corrosif) soumis à l'essai conformément à l'Annexe E. Le Tableau E.7, Limites d'émissions, inclus remplace le Tableau 7 de 7.3.12. La Figure E.10 remplace la Figure 10 et lui est identique. Les émissions d'hydrogène sont évaluées séparément. La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure E.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe E.

- a) **Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- b) **Objet:** Dans des conditions normales de fonctionnement, un système à micropile à combustible alimenté par borohydrure indirect peut présenter des émissions. Les émissions peuvent se composer d'eau ou d'hydrogène, ces deux éléments étant connus comme non toxiques. Les systèmes à micropiles à combustible à borohydrure indirect

n'émettent pas en principe de CO, de CO₂, de formaldéhyde ou d'autres composés organiques volatils. Cependant, il existe une faible possibilité que les systèmes à micropiles à combustible à borohydrure indirect utilisant des combustibles ou des composants de combustibles liquides contenant des additifs organiques puissent émettre du CO, du CO₂, du formaldéhyde ou d'autres composés organiques volatils dans des circonstances anormales. Puisque cette possibilité existe, les limites d'émission pour le CO, le CO₂, le formaldéhyde et les composés organiques volatils pour les systèmes à micropiles à combustible utilisant des combustibles ou des composants de combustibles liquides contenant des composés organiques, sont imposées par la présente annexe et sont données au Tableau E.7.

La possibilité d'émissions d'hydrogène existe pour les systèmes à micropiles à combustible à borohydrure indirect en non-fonctionnement. Par conséquent, des essais d'émissions d'hydrogène doivent être effectués avec le système à micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») comme essai supplémentaire. Les émissions d'hydrogène doivent être inférieures à la limite admissible 0,0032 g/h avec dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») donnée pour éviter les expositions dangereuses.

Les systèmes à micropiles à combustible émettent de la vapeur d'eau et, dans certaines conditions, cette vapeur d'eau peut se condenser. Cette condensation n'est pas considérée comme une émission ou une fuite si le pH du condensat est compris entre 3,5 et 10,5.



Anglais	Français
Air	Air
Sampling port	Orifice d'échantillonnage
Test volume	Volume d'essai
Micro fuel cell power system or unit	Système à micropile à combustible ou bloc d'alimentation électrique de la micropile à combustible
Circulation fan	Ventilateur de brassage
Hermetic feed through	Passage hermétique
External control (as required)	Commande extérieure (si exigée)
Exhaust port	Orifice d'évacuation
Air sampling	Échantillonnage de l'air
Variable flow air pump	Pompe à air à débit variable

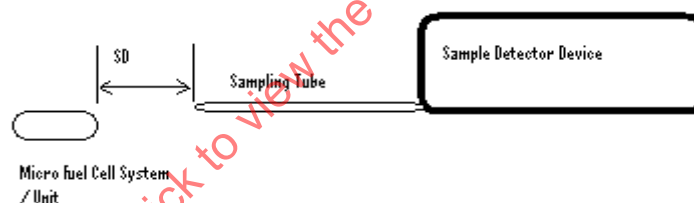
Figure E.10 – Appareillage d'essai du taux d'émission opérationnel – Remplace la Figure 10

- c) **Appareillage d'essai:** Un exemple d'appareillage d'essai d'émission opérationnel est représenté à la Figure E.10. La configuration représentée à la Figure E.10 sert aux essais de taux d'émission de tous les systèmes à micropiles à combustible ou blocs

d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe E. Les essais de taux d'émission conformément à E.7.3.12 d) 1) sont exigés pour tous les types de systèmes à micropiles à combustible et de blocs d'alimentation électrique des micropiles à combustible soumis à l'essai conformément à la présente Annexe E.

Pour l'analyse des émissions d'hydrogène, un spectromètre de masse, un chromatographe en phase gazeuse ou un autre instrument approprié étalonné pour mesurer la concentration d'hydrogène doit être utilisé et connecté à l'orifice d'échantillonnage A de la Figure E.10. Toutefois, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus.

Pour les systèmes à micropiles à combustible ou blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur (tels que les systèmes à micropiles à combustible ou les blocs d'alimentation électrique des micropiles à combustible utilisés pour alimenter des téléphones cellulaires, des jeux tenus à la main, etc.), des essais complémentaires conformes à E.7.3.12 d) 3) et E.7.3.12 d) 4) sont exigés pour vérifier que les concentrations des émissions dans le voisinage de la bouche ou du nez d'un utilisateur sont maintenues dans des limites appropriées. Ces essais de concentrations d'émissions doivent être réalisés dans une grande salle ouverte en utilisant un appareillage d'essai de concentration d'émission différent. Un exemple d'appareillage d'essai de la concentration d'émission opérationnel est représenté à la Figure E.11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé) pour les essais de la limite de concentration des émissions.



EN	FR
Sampling tube	Tube d'échantillonnage
Sample detector device	Dispositif de détection d'échantillon
Micro fuel cell system/unit	Système à micropile à combustible / bloc d'alimentation de la micropile à combustible

**Figure E.11 – Appareillage d'essai de concentration d'émission opérationnel
– Remplace la Figure 11**

Les gaz d'émission peuvent être composés de matières organiques toxiques, telles que le dioxyde de carbone, le monoxyde de carbone et le formaldéhyde, qui peuvent être évacuées d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible.

Pour analyser ces matières organiques, un chromatographe en phase gazeuse avec un détecteur à ionisation de flamme (GC/FID – *gas chromatograph/flame ionization detector*) ou avec un spectromètre de masse (GC/MS – *gas chromatograph/mass spectrometer*) doivent être utilisés en absorbant les gaz d'émission sur le tube à adsorption fixé sur l'orifice d'échantillonnage A de l'enceinte d'essai, ou directement sur un analyseur à travers l'orifice d'échantillonnage A de la Figure E.10. Toutefois, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus.

Un détecteur d'hydrogène étalonné pour la plage de concentration massique d'hydrogène de 0 % à 1 %, peut être utilisé pour mesurer la concentration d'hydrogène.

La concentration de CO et de CO₂ peut être mesurée par un analyseur à absorption infrarouge non dispersif. Ces appareils de mesure analytiques doivent être conformes à l'ISO 16000-3, à l'ISO 16000-6 et à l'ISO 16017-1. Cependant, l'utilisation d'autres appareils est autorisée, à condition que les performances soient équivalentes à celles des appareils mentionnés ci-dessus, en utilisant les normes mentionnées ci-dessus.

d) **Procédure d'essai:**

Les émissions d'hydrogène sont évaluées séparément. *La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure E.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe E.*

Les essais d'échantillonnage de taux d'émissions doivent être effectués avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit.

- 1) Pour tous les systèmes à micropiles à combustible et les blocs d'alimentation électrique de micropiles à combustible – aussi bien ceux destinés à être utilisés très près de la bouche ou du nez d'un consommateur que ceux qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur – l'essai suivant d'échantillonnage du taux d'émission doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit.
 - i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure E.10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
 - ii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
 - iii) Les émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air A représenté à la Figure E.10.
 - iv) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
 - v) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure E.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
 - vi) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau E.7.
 - vii) Calculer le taux d'émission des composés chimiques émis en multipliant la concentration stabilisée maximale de chaque constituant par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air de la pompe à débit d'air variable à la sortie en régime établi à travers le système au débit d'échantillon simultané. Voir ci-dessous:

$$ER = (F_P + F_S) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres par heure;

F_S est le débit d'échantillon en litres par heure;

C est la concentration en grammes par litre;

- viii) Comparer le taux d'émission [DISPOSITIF EN POSITION «ON»] mesuré maximal par rapport au Tableau E.7. Si le taux d'émission n'est pas inférieur à la limite de taux d'émission dans le Tableau E.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite E.7.3.12 e) 1) i) et E.7.3.12 e) 2) i).
- ix) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 2) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui sont destinés à être utilisés très près de la bouche ou du nez d'un consommateur, l'essai complémentaire suivant d'échantillonnage de concentration d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible en marche («DISPOSITIF EN POSITION «ON»») comme suit.
- i) Les essais de taux d'émission des systèmes à micropiles à combustible ou des blocs d'alimentation électrique des micropiles à combustible doivent être réalisés dans une grande salle ouverte. L'intention de cet essai est d'approcher et de mesurer la concentration d'émission attendue près de la bouche ou du nez d'une personne en air calme. Un mannequin ou autre simulateur peut être utilisé pour améliorer la précision de l'essai. L'air à l'intérieur de la salle doit être échantillonné avant les essais afin d'assurer la précision et éviter les résultats erronés non conformes. Veiller à s'assurer que les matières dans la salle ou dans le système d'échantillonnage n'apportent pas d'émissions (c'est-à-dire, de contaminants) à l'essai. Avant les essais, il est recommandé de rechercher les traces de contamination dans le système sans le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible, pour éviter les résultats erronés non conformes. Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
- ii) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible à la puissance assignée dans la grande salle ouverte lors de l'échantillonnage de concentrations d'émissions à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure E.11. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai de concentration d'émission doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible, et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
- iii) Les renouvellements d'air dans la salle doivent être maintenus à un minimum correspondant aux conceptions résidentielles ou commerciales normales (par exemple, moins d'un renouvellement d'air par heure). Veiller à ne pas perturber la zone d'échantillonnage avec des débits d'air parasites.
- iv) Les concentrations des émissions gazeuses du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doivent être

échantillonnées à l'aide de l'appareillage d'essai de concentration d'émission opérationnel représenté à la Figure E.11. Pour les essais de la concentration d'émission, le tube d'échantillonnage d'air doit se prolonger sur une distance de séparation (SD) du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile qui est représentative de la zone de respiration d'un consommateur (la distance du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible jusqu'à la bouche ou au nez lorsqu'il est utilisé).

- v) La vitesse d'échantillonnage pour les mesurages de concentration d'émission très près doit être de 5 l par minute, ce qui représente la vitesse de respiration d'un être humain adulte
 - vi) Laisser le débit d'échantillon se stabiliser.
 - vii) Échantillonner et enregistrer les émissions gazeuses du système à pile à combustible ou du bloc d'alimentation électrique de la pile à combustible qui se produisent à une distance représentative de la zone de respiration d'un consommateur.
 - viii) Enregistrer les concentrations des composés chimiques concernés. Voir Tableau E.7.
 - ix) Comparer les concentrations maximales mesurées avec le Tableau E.7. Si les concentrations d'émission ne sont pas inférieures aux limites de concentration d'émission dans le Tableau E.7, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai et aucun autre essai n'est exigé. Voir les critères de réussite E.7.3.12 e) 2) ii).
 - x) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 3) À l'issue des mesurages d'émissions avec «DISPOSITIF EN POSITION «ON»» et avec («DISPOSITIF EN POSITION «OFF» conformément au Tableau E.7, les émissions d'hydrogène en situation «DISPOSITIF EN POSITION «ON»» sont évaluées comme suit:
- i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure E.10. Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible n'est plus opérationnel en raison d'un essai de type, l'essai d'émissions doit être effectué avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible alimenté complètement en combustible et avec l'interrupteur d'alimentation électrique en position «ON» («DISPOSITIF EN POSITION «ON»»).
 - ii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
 - iii) Les émissions de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure E.10.
 - iv) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.

- v) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure E.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
- vi) Enregistrer la concentration d'hydrogène.
- vii) Calculer le taux d'émission de l'hydrogène émis en multipliant la concentration stabilisée maximale d'hydrogène par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air de la pompe à débit d'air variable à la sortie en régime établi à travers le système au débit d'échantillon simultané. Voir ci-dessous:

$$ER = (F_P + F_S) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres par heure;

F_S est le débit d'échantillon en litres par heure;

C est la concentration en grammes par litre.

- viii) Comparer le taux d'émission d'hydrogène [DISPOSITIF EN POSITION «ON»] mesuré maximal par rapport au Tableau E.7.

NOTE Il s'agit d'un mesurage de concentration stabilisée.

- ix) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 4) À l'issue des mesurages des émissions d'hydrogène avec «DISPOSITIF EN POSITION «ON»», les émissions d'hydrogène avec («DISPOSITIF EN POSITION «OFF»») sont évaluées comme suit.
- i) Faire fonctionner le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à la puissance assignée à l'intérieur de la petite enceinte d'essai représentée sur la Figure E.10 pendant une durée de 10 min ou pendant la durée jusqu'à l'instant où 10 % de la pleine capacité en combustible d'une cartouche de combustible pleine ont été consommés, en prenant la plus courte des deux durées.
 - ii) Mettre le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») et mesurer les taux d'émission avec le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à l'arrêt («DISPOSITIF EN POSITION «OFF»») à l'intérieur de la petite enceinte d'essai représentée à la Figure E.10.
 - iii) La petite enceinte d'essai doit être alimentée en air propre. Il convient que l'alimentation en air dans l'enceinte d'essai provienne d'une source de pureté connue. Si de l'air en bouteille n'est pas utilisé, il convient que l'utilisation d'échantillons témoins pour déterminer les niveaux de concentration de fond soit prise en compte, pour éviter les résultats erronés non conformes.
 - iv) Les émissions de gaz hydrogène du système à micropile à combustible ou du bloc d'alimentation électrique de micropile à combustible doivent être échantillonnées à la sortie de la petite enceinte d'essai, à l'orifice d'échantillonnage d'air représenté à la Figure E.10.

- v) Laisser se stabiliser le débit d'air de la pompe à air à débit variable de l'enceinte d'essai, le débit du ventilateur de brassage et le débit d'échantillon.
- vi) Échantillonner et enregistrer le contenu gazeux de l'enceinte d'essai à travers l'orifice d'échantillonnage de l'air A représenté à la Figure E.10, tout en mesurant simultanément et enregistrant le débit de la pompe à air à débit variable et en mesurant et enregistrant le débit d'échantillon à travers l'orifice d'échantillonnage de l'air A.
- vii) Enregistrer la concentration d'hydrogène.
- viii) Calculer le taux d'émission de l'hydrogène émis en multipliant la concentration stabilisée maximale d'hydrogène par le débit d'air simultané total à travers le système. Le débit d'air total à travers le système est déterminé en ajoutant le débit d'air de la pompe à débit d'air variable à la sortie en régime établi à travers le système au débit d'échantillon simultané. Voir ci-dessous:

$$ER = (F_P + F_S) \times C$$

où

ER est le taux d'émission en grammes par heure;

F_P est le débit de la pompe à air à débit variable en litres par heure;

F_S est le débit d'échantillon en litres par heure;

C est la concentration en grammes par litre.

- ix) Comparer le taux d'émission d'hydrogène [DISPOSITIF EN POSITION «OFF»] mesuré maximal par rapport au Tableau E.7.

NOTE Il s'agit d'un mesurage de concentration stabilisée.

- x) Les mesurages d'émission doivent être moyennés sur une certaine durée qui est représentative du fonctionnement normal du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ainsi que du matériel qu'il alimente (c'est-à-dire une cartouche de combustible valable pour le fonctionnement). Il n'est pas nécessaire d'effectuer le contrôle en continu, à condition d'effectuer les mesurages au démarrage initial, à au moins 3 h de fonctionnement et à la fin de la cartouche de combustible. Si la cartouche de combustible ne dure pas 3 h, la durée complète de la cartouche de combustible doit être mesurée en continu.
- 5) Évaluer le taux d'émission d'hydrogène comme suit:
- i) Si le taux d'émission d'hydrogène mesuré est inférieur à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») et est inférieur à la valeur admissible 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible satisfait à l'essai et aucun essai supplémentaire n'est nécessaire.
 - ii) Si le taux d'émission d'hydrogène mesuré n'est pas inférieur à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») et n'est pas inférieur à la valeur admissible totale 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système ou le bloc échoue à l'essai et aucun essai supplémentaire n'est nécessaire.
 - iii) Si le taux d'émission d'hydrogène mesuré est inférieur à la valeur admissible 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»») et est inférieur à la valeur admissible totale 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), mais n'est pas inférieure à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), passer en A.7.3.13 Essai de détection de pertes localisées de gaz hydrogène pour vérifier qu'aucune source de perte de gaz hydrogène ne dépasse 0,016 g/h.

e) **Critères de réussite:**

- 1) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau E.7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau E.7 lorsqu'il est respectivement vérifié par essai conformément aux essais E.7.3.12 d) 1) pour le dispositif en marche («DISPOSITIF EN POSITION «ON»») et E.7.3.12 d) 2) pour le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
- 2) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible à utiliser très près de la bouche ou du nez d'un consommateur:
 - i) Le taux maximal d'émission pour chacun des constituants concernés dans le Tableau E.7 doit être inférieur à la valeur limite de taux d'émission indiquée dans le Tableau E.7 lorsqu'il est respectivement vérifié par essai conformément aux essais E.7.3.12 d) 1) pour le dispositif en marche («DISPOSITIF EN POSITION «ON»») et E.7.3.12 d) 2) pour le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
 - ii) Pour les systèmes à micropiles à combustible et les blocs d'alimentation électrique des micropiles à combustible qui ne sont pas destinés à être utilisés très près de la bouche ou du nez d'un consommateur: En plus de satisfaire à la limite du taux d'émission ci-dessus, la concentration maximale d'émission pour chacun des constituants concernés ne doit pas dépasser la limite de concentration d'émission indiquée dans le Tableau E.7 lorsqu'elle est respectivement vérifiée par essai conformément aux essais E.7.3.12 d) 3) pour le dispositif en marche («DISPOSITIF EN POSITION «ON»») et E.7.3.12 d) 4) pour le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»). Si le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne fonctionne pas, ou s'il s'arrête d'une manière sûre avant de dépasser une limite, l'essai est acceptable.
- 3) Les émissions d'hydrogène sont évaluées séparément. La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure E.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe E. À l'issue des mesurages d'émissions d'hydrogène avec («DISPOSITIF EN POSITION «ON»») et avec («DISPOSITIF EN POSITION «OFF»») conformément au Tableau E.7, les émissions d'hydrogène en situation «DISPOSITIF EN POSITION «ON»» sont évaluées comme suit:
 - i) **Critères de réussite pour systèmes en non-fonctionnement:** Le taux d'émission d'hydrogène doit être inférieur à 0,0032 g/h avec le dispositif à l'arrêt («DISPOSITIF EN POSITION «OFF»»).
 - ii) **Critères de réussite pour les systèmes opérationnels:** Si le taux total d'émission d'hydrogène est inférieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible satisfait à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux total d'émission d'hydrogène n'est pas inférieur à 0,8 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), le système à micropile à combustible ou le bloc d'alimentation électrique des micropiles à combustible échoue à l'essai d'émission et aucun essai supplémentaire n'est exigé. Si le taux d'émission d'hydrogène est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»), E.7.3.13, Essai de détection de pertes localisées de gaz hydrogène doit être effectué avec des résultats acceptables pour démontrer que les fuites d'hydrogène ne dépassent pas 0,016 g/h à partir d'une seule fuite localisée.

NOTE 1 Le niveau d'émission d'hydrogène inflammable admissible qui n'entretient pas de flammes est de 3 ml/min (Proceedings of the 2001 DOE Program Review; NREL/CP-570-30535; M.R. Swain et M.N. Swain, *Codes and Standards Analysis*, 2001 (USA)). La limite d'émission d'hydrogène non inflammable est fondée sur les critères selon lesquels l'émission d'hydrogène n'augmente pas de plus de 25 % de la LII dans le volume de référence.

NOTE 2 L'hydrogène est défini comme un asphyxiant simple, mais, pour que ce risque existe, les niveaux d'oxygène doivent descendre à moins de 18 % à la pression atmosphérique normale. Le risque d'inflammabilité lié à l'hydrogène se produit à des concentrations d'hydrogène dans l'air supérieures à 4 %, tandis que le risque d'asphyxie survient à des concentrations d'hydrogène dans l'air supérieures à 12 %. Par conséquent, les limites d'inflammabilité sont utilisées en définissant les limites pour les émissions d'hydrogène.

NOTE 3 Les limites des niveaux d'émissions de vapeurs de dioxyde de carbone et de monoxyde de carbone sont fondées sur les effets de la toxicité sur les humains, tandis que les limites des niveaux d'émissions d'hydrogène sont fondées sur le risque lié à la création d'une atmosphère inflammable dans des espaces confinés et sur le risque d'une flamme d'hydrogène qui peut être entretenue.

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Tableau E.7 – Limites d'émissions – Remplace le Tableau 7

Émissions	«DISPOSITIF EN POSITION «ON»» Limite de concentration ^a d'après les valeurs de TWA pour la condition d'essai de marche du dispositif («DISPOSITIF EN POSITION «ON»»)	«DISPOSITIF EN POSITION «ON»» Taux d'émission admissible dans le volume 10 m ³ ACH ^b
Eau	Illimitée pour un pH compris entre 3,5 et 10,5	Illimitée pour un pH compris entre 3,5 et 10,5
Hydrogène	0,8 g/m ³	0,8 g/h total 0,016 g/h à partir d'une seule fuite localisée
Formaldéhyde^d	0,000 1 g/m ³	0,000 6 g/h
CO	0,029 g/m ³	0,290 g/h
CO₂	9 g/m ³	60 g/h ^c
Composés organiques volatils	0,000 1 g/m ³	0,000 6 g/h
Le Tableau E.7 remplace le Tableau 7. ^a Les limites de concentrations pour CO et CO₂ de ce tableau sont l'équivalent en mg/m³ des limites d'exposition TWA et STEL. ^b La limite du taux d'émission «DISPOSITIF EN POSITION «ON»» était basée sur la valeur 10 m³ ACH, choisie comme le produit du volume de référence par les renouvellements d'air par heure (ACH), parce qu'elle couvre les environnements raisonnablement prévisibles dans lesquels les systèmes à micropiles à combustible sont utilisés. L'espace intérieur dans une petite voiture et le volume minimal par personne à bord d'un avion commercial sont fixés à 1 m³. L'ACH minimal utilisé à bord d'un avion de passagers est de 10 et le réglage de ventilation le plus faible dans les voitures est de 10 ACH. Les maisons et les bureaux peuvent présenter des niveaux d'ACH aussi bas que 0,5, mais le volume par personne est supérieur à 20 m³, et donc un produit de 10 est satisfaisant. ^c Un être humain adulte assis a un taux d'émission de CO₂ de 30 g/h. Les taux d'émission des piles à combustible, mais aussi des adultes sont limités, de telle sorte que la concentration de CO₂ n'atteigne pas la limite de concentration sur huit heures fixée par l'OMS de 9 g/m³. Dans un environnement avec 10 m³ ACH, ceci limite la contribution de la pile à combustible à 60 g/h. ^d La limite fixée par l'OMS est de 0,000 1 g/m³. Les niveaux de fond sont de 0,000 03 g/m³. La limite d'émission ne peut pas faire passer le niveau de fond au-dessus de la limite fixée.		

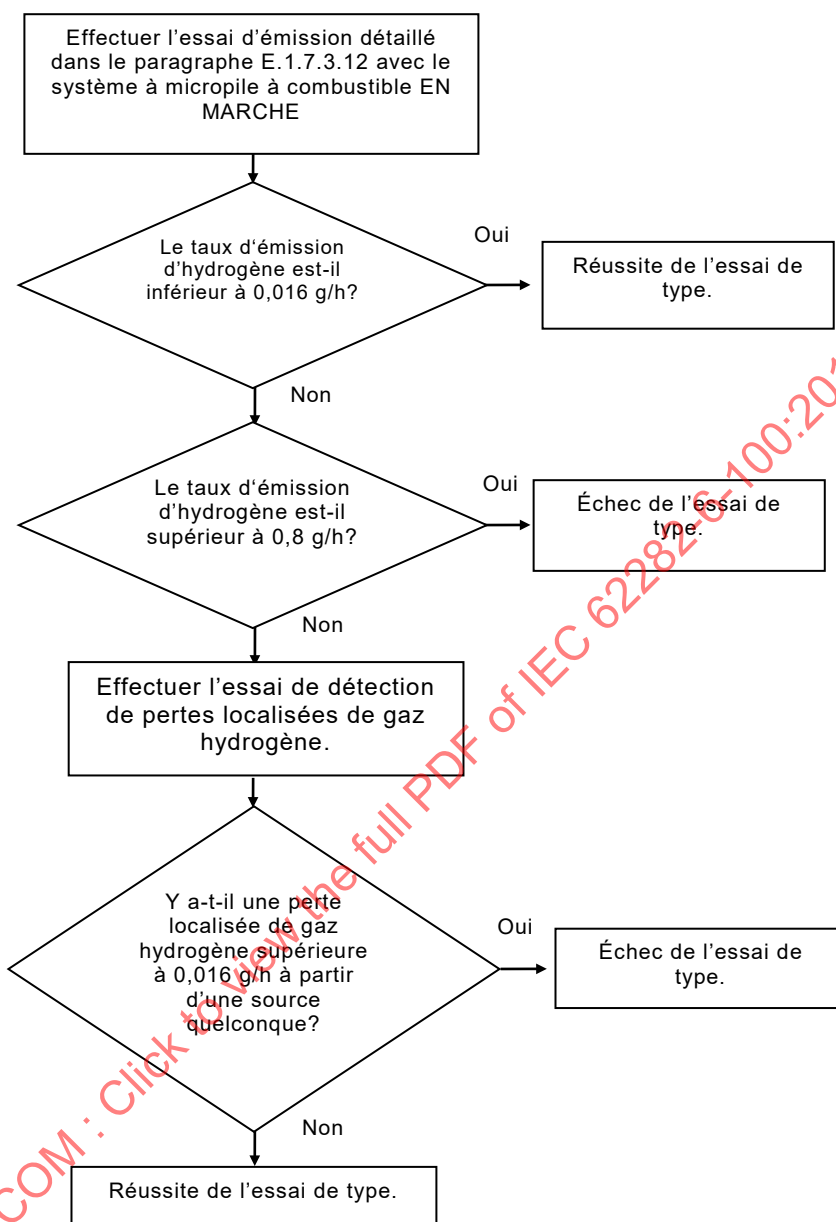


Figure E.12 – Procédure d'essai d'émissions d'hydrogène pour système à micropile à combustible en fonctionnement – Remplace la Figure 12

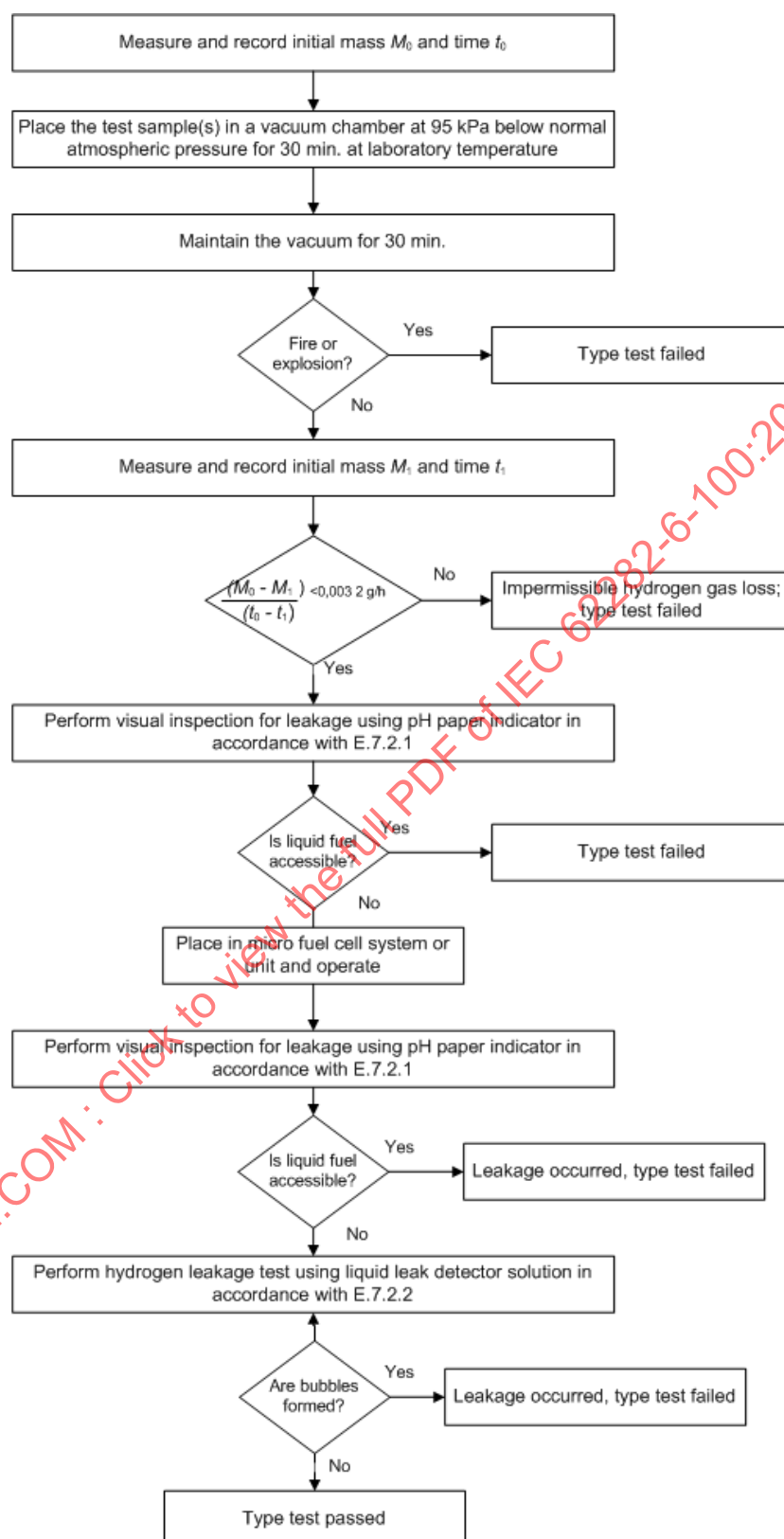


Figure E.16 – Fuel cartridge leakage test flow chart for low external pressure test

Anglais	Français
Measure and record initial mass M_0 and time t_0	Mesurer et enregistrer la masse M_0 et le temps t_0
Place the test sample(s) in a vacuum chamber at 95 kPa below normal atmospheric pressure for 30 min, at	Placer le ou les échantillons dans une chambre à vide à 95 kPa en dessous de la pression atmosphérique

Anglais	Français
laboratory temperature	pendant 30 min, à la température du laboratoire
Maintain the vacuum for 30 min	Maintenir le vide pendant 30 min
Fire or explosion?	Feu ou explosion?
Yes	Oui
Type test failed	Échec de l'essai de type
Measure and record initial mass M_1 and time t_1	Mesurer et enregistrer la masse M_1 et le temps t_1
Impermissible hydrogen gas loss	Perte non admissible de gaz hydrogène
Perform visual inspection for leakage using pH paper indicator in accordance with E.7.2.1	Effectuer un examen visuel pour rechercher des fuites à l'aide d'un papier indicateur pH conformément à E.7.2.1
Is liquid fuel accessible?	Combustible liquide accessible?
Place in micro fuel cell system or unit and operate	Placer dans le système à micropile à combustible ou dans le bloc d'alimentation de la micropile à combustible puis faire fonctionner.
Leakage occurred	Fuite
Perform hydrogen leakage test using liquid leak detector solution in accordance with E.7.2.2	Effectuer l'essai de fuite d'hydrogène à l'aide d'une solution de détecteur de fuite liquide conformément à E.7.2.2
Are bubbles formed?	Formation de bulles?
Type test passed	Réussite de l'essai de type

Figure E.16 – Diagramme d'essai de fuite de cartouche de combustible pour l'essai de pression externe

E.7.3.13 Essai de détection de pertes localisées de gaz hydrogène

La procédure pour les essais d'émission d'hydrogène est détaillée dans la Figure E.12, qui doit être utilisée comme figure supplémentaire lorsque les essais sont réalisés conformément à l'Annexe E. Ce paragraphe s'ajoute aux exigences de l'Article 7.

Ce paragraphe doit être utilisé si cela est exigé par le E.7.3.12 d) 5) iii) pour démontrer la conformité avec le Tableau F.7 pour les systèmes à micropiles à combustible à borohydrure de classe 8 (corrosif) et les blocs d'alimentation électrique des micropiles à combustible à borohydrure de classe 4.3 (hydorréactifs). Il est nécessaire d'exécuter ce paragraphe pour satisfaire aux critères de réussite de E.7.3.12 e) 3) ii) si le taux total d'émission d'hydrogène provenant d'un système à micropile à combustible à borohydrure de classe 8 (corrosif) opérationnel ou d'un bloc d'alimentation électrique de la micropile à combustible à borohydrure de classe 8 (corrosif) opérationnel est inférieur à 0,8 g/h, mais supérieur à 0,016 g/h avec le dispositif en marche («DISPOSITIF EN POSITION «ON»»).

- Échantillon d'essai:** bloc d'alimentation électrique de la micropile à combustible alimenté en combustible, conformément aux spécifications du fabricant ou système à micropile à combustible avec cartouche de combustible inutilisée.
- Objet:** Dans les conditions de fonctionnement (ou en essayant d'obtenir les conditions de fonctionnement) d'un système à micropile à combustible ou d'un bloc d'alimentation électrique de la micropile à combustible relevant du domaine d'application de la présente Annexe A, l'émission de l'hydrogène doit être maintenue à un niveau inférieur aux valeurs spécifiées dans le Tableau E.7. L'essai de détection de pertes localisées de gaz hydrogène doit être effectué pour déterminer qu'aucune source sur le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible ne peut entretenir une flamme dans tous les cas où une telle conformité ne peut être définitivement déterminée par l'essai d'émission. Le fait de maintenir ces limites assure qu'il n'y aura ni accumulation de la concentration inflammable dans le volume de référence ni pertes de gaz hydrogène provenant de l'éprouvette qui pourraient entretenir une flamme. Ce maintien garantit également qu'une alimentation adéquate en oxygène sera maintenue dans l'environnement de fonctionnement

- c) **Appareillage d'essai:** La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25 % de la LII. La réponse des détecteurs d'hydrogène susmentionnés est généralement lente, le temps de réponse étant de plusieurs secondes, et donc des vitesses de balayage élevées peuvent causer une sous-estimation de la concentration d'hydrogène. Un élément d'importance est que la vitesse de balayage doit être suffisamment lente pour mesurer précisément la concentration d'hydrogène.
- d) **Procédure d'essai:**
- 1) Le système à micropile à combustible ou bloc d'alimentation électrique des micropiles à combustible doit rester en marche («DISPOSITIF EN POSITION «ON»») pendant toute la durée de l'essai de détection de pertes localisées de gaz hydrogène.
 - 2) L'essai doit être réalisé dans un espace sans circulation d'air importante. La vitesse mesurée du vent à 10 cm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible ne doit pas dépasser 0,02 m/s. La concentration locale de la diffusion d'hydrogène mesurée dans cet essai est très sensible à l'effet du vent. Il est souhaitable que la vitesse du vent en n'importe quel endroit de l'espace d'essai soit aussi proche que possible de zéro. Les essais réalisés dans un espace clos, tel qu'une boîte à gants ou enceinte équivalente, constituent un moyen disponible de satisfaire à cette exigence.
 - 3) La surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être systématiquement balayée avec un détecteur d'hydrogène ponctuel. Ce détecteur d'hydrogène peut être un spectromètre de masse, un détecteur d'hydrogène portatif, ou tout autre appareil adapté à la mesure de faibles quantités d'hydrogène à partir d'une source localisée qui est au moins aussi précise, si ce n'est plus, que les appareils susmentionnés. Le détecteur d'hydrogène doit être accordé pour détecter un niveau d'hydrogène qui se situe à 25 % de la LII.
 - 4) Le capteur du détecteur d'hydrogène doit balayer le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible à une distance inférieure ou égale à 3 mm, perpendiculairement à la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Les balayages linéaires consécutifs ne doivent pas être éloignés de plus de 8 mm le long de la surface du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. La surface totale du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible doit être balayée de cette manière.
 - 5) Une méthode efficace pour réaliser ces balayages consisterait à fixer une cale sur le capteur, qui assure le maintien en toutes circonstances d'un espacement de 3 mm depuis le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible. Un stylo ou autre ustensile de marquage fixé sur la cale pourrait être utilisé pour identifier les zones balayées et pour garantir que la distance entre les balayages ne dépasse pas 8 mm.
 - 6) Il convient que le capteur soit toujours dirigé directement vers le bas, et que le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible soit déplacé sous ce dernier, de telle sorte que la surface juste en dessous du capteur soit toujours horizontale.
 - 7) Si aucun point n'est détecté lorsque la concentration d'hydrogène est supérieure à 25 % de la LII, l'essai est terminé et le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible doit être considéré comme ayant satisfait à l'essai.
 - 8) Lorsqu'un certain nombre de balayages de source ponctuelle présentent une vaste région de 25 % ou plus de la LII dans les balayages linéaires initiaux, le fait d'enregistrer les valeurs mesurées de la concentration permet de déterminer le point de départ des balayages en spirale secondaires. Les sources ponctuelles sont

censées se trouver aux endroits auxquels il existe des valeurs maximales locales dans la distribution des valeurs mesurées de la concentration.

- 9) S'il est détecté que des points ont une concentration d'hydrogène de 25 % de la LII ou plus, un deuxième essai doit être réalisé pour garantir que l'émission ne dépasse pas 0,016 g/h d'hydrogène pur depuis une source quelconque.
 - 10) Le deuxième essai doit être réalisé avec la hauteur du capteur réglée à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible.
 - 11) Un balayage en spirale doit alors être réalisé, depuis le point auquel a eu lieu la détection de 25 % de la LII ou plus de l'hydrogène, au cours du balayage linéaire initial. Le balayage en spirale doit présenter un espacement de 1 mm ou moins entre les balayages et doit former une spirale sur une distance radiale d'au moins 4 mm et suffisamment loin pour détecter le niveau maximal d'hydrogène à partir de la source d'hydrogène particulière.
 - 12) Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Si le balayage en spirale ne détecte pas de concentrations d'hydrogène supérieures ou égales à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible satisfait à l'essai.
- e) **Critères de réussite:** Aucune perte de gaz hydrogène provenant d'une source quelconque à plus de 0,016 g/h telle qu'indiquée par les essais de balayage. Aucune indication d'hydrogène qui soit à 25 % de la LII pendant les essais de balayage primaire ni aucune indication d'hydrogène à 25 % de la LII pendant les essais de balayage secondaire à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible. Si le balayage en spirale à 6,5 mm au-dessus du système à micropile à combustible ou du bloc d'alimentation électrique de la micropile à combustible détecte une concentration maximale d'hydrogène supérieure ou égale à 25 % de la LII, le système à micropile à combustible ou le bloc d'alimentation électrique de la micropile à combustible échoue à l'essai. Voir Tableau E.7.

Annexe F

(normative)

Systèmes à micropiles à combustible à borohydrure: Composés de classe 4.3 (hydroréactifs) dans les piles à combustible à borohydrure indirect

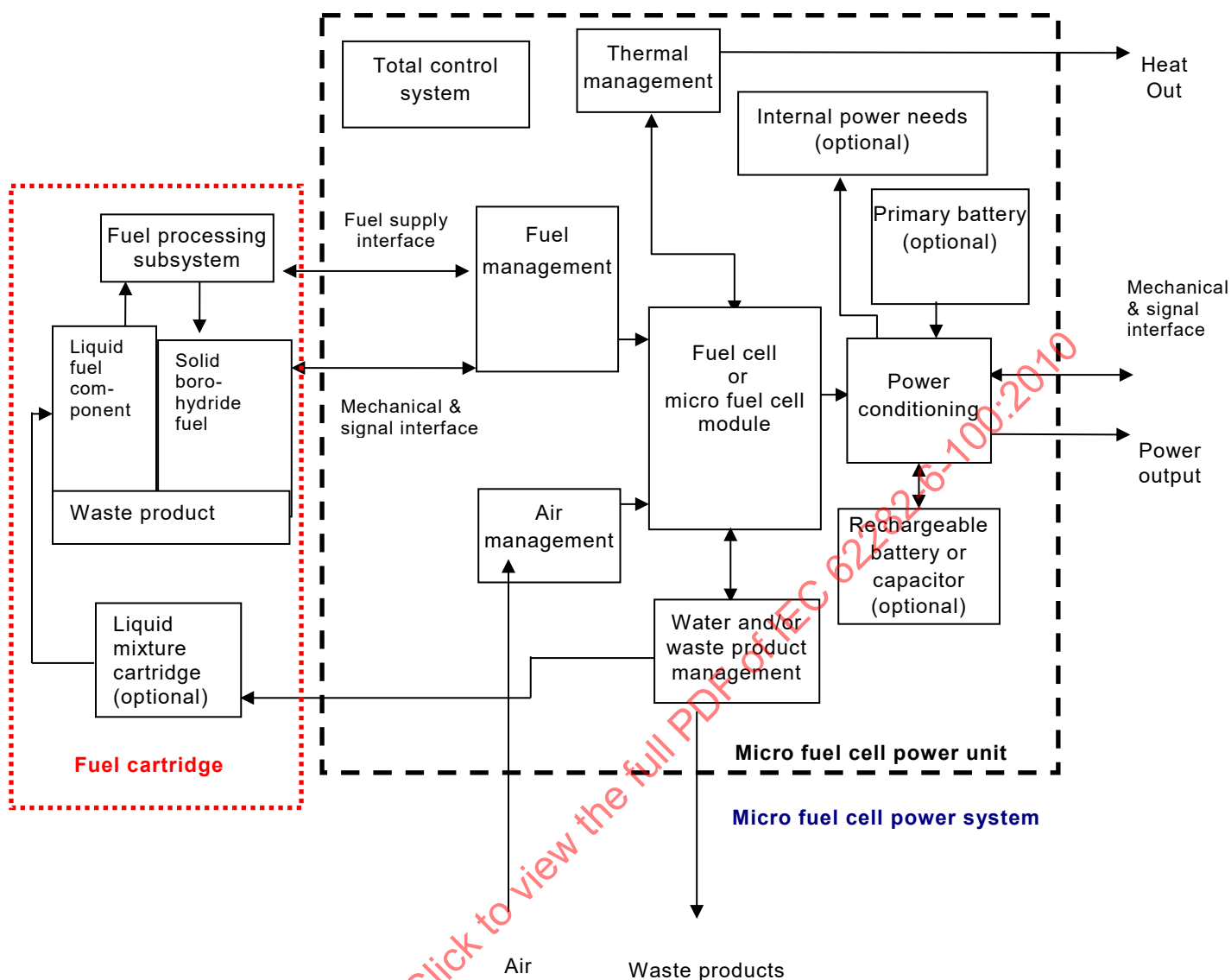
F.1 Domaine d'application

F.1.2 Combustibles et technologies traités par la présente annexe

L'Annexe F traite des systèmes à micropiles à combustible, des blocs d'alimentation des micropiles à combustible et des cartouches de combustible qui utilisent comme combustible l'hydrogène produit à partir de composés de borohydrure de classe 4.3 (hydroréactifs). Ces systèmes et blocs d'alimentation utilisent des technologies de piles à combustible à membrane à échange de protons. Les conceptions peuvent inclure des sous-systèmes de traitement de combustibles pour obtenir un gaz hydrogène à partir du combustible à base de composés à borohydrure.

La Figure F.1 remplace la Figure 1 tandis que la Figure F.12 est une figure supplémentaire pour la présente annexe présentant un schéma de principe du système à micropile à combustible à utiliser avec la présente annexe.

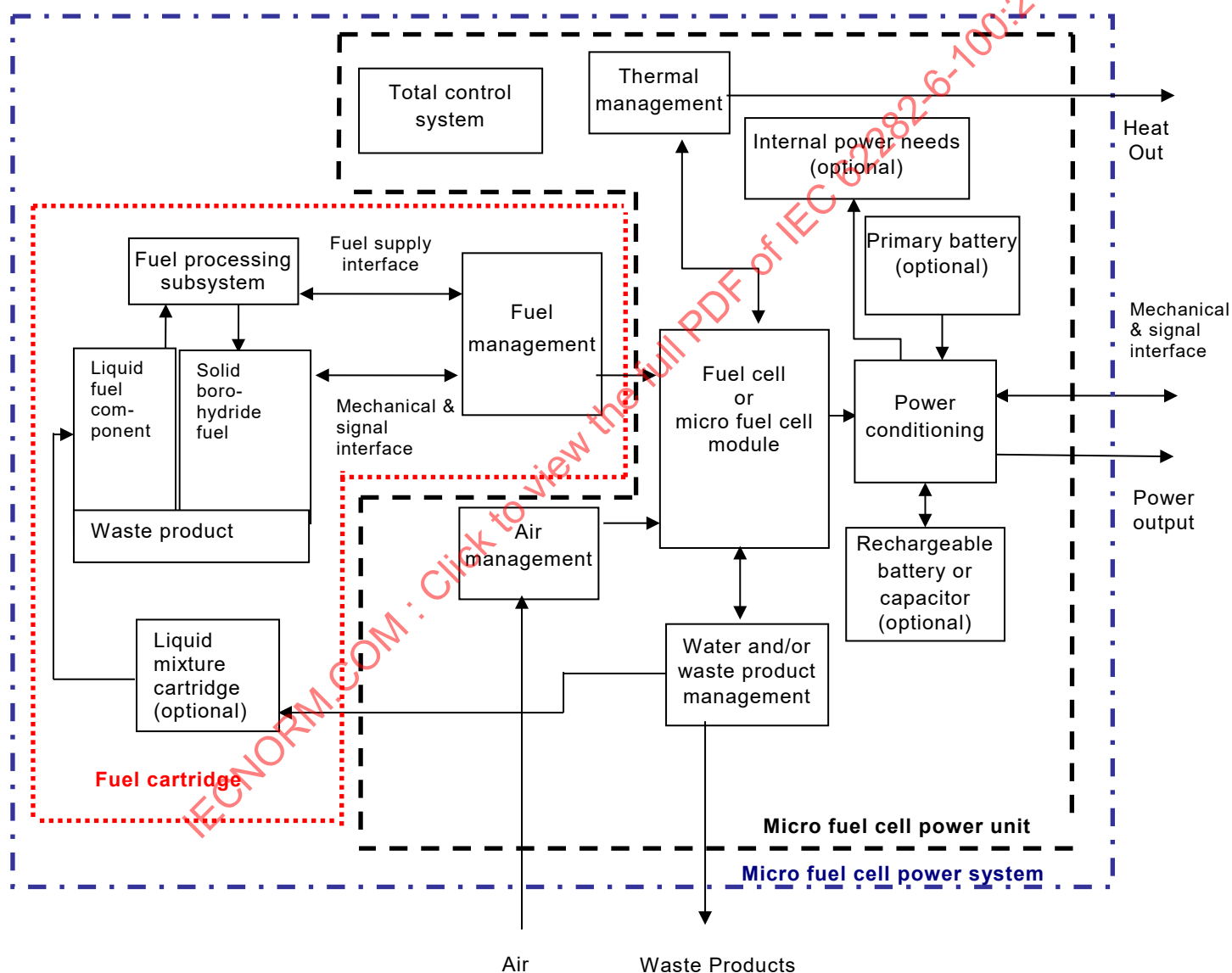
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Anglais	Français
Air	Air
Air management	Gestion de l'air
Fuel cartridge	Cartouche de combustible
Fuel management	Gestion du combustible
Fuel processing subsystem	Sous-système de traitement du combustible
Fuel supply interface	Interface alimentation en combustible
Heat out	Chaleur produite
Internal power needs (optional)	Besoins internes en énergie (facultatif)
Liquid Fuel Component	Composant de combustible liquide
Liquid mixture cartridge (optional)	Cartouche de mélange de combustibles (facultatif)
Mechanical & Signal interface	Interface mécanique et de signal
Micro fuel cell or micro fuel cell module	Micropile à combustible ou module de micropiles à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de la micropile à combustible
Power conditioning	Conditionnement de l'énergie
Power output	Puissance de sortie

Anglais	Français
Primary battery (optional)	Pile électrique (facultatif)
Rechargeable battery or capacitor (optional)	Batterie rechargeable ou condensateur (facultatif)
Solid borohydride fuel	Combustible à borohydrure solide
Total control system	Système global de commande
Waste products	Déchets
Water and/or waste product management	Gestion de l'eau et/ou des déchets

Figure F.1 – Schéma de principe du système à micropile à combustible à borohydrure pour un composé de classe 4.3 (hydroréactif) dans un système à pile à combustible à borohydrure indirect; gestion du combustible dans un bloc d'alimentation électrique de la micropile à combustible – Remplace la Figure 1



EN	FR
Air	Air
Air management	Gestion de l'air
Fuel cartridge	Cartouche de combustible
Fuel management	Gestion du combustible
Fuel processing subsystem	Sous-système de traitement du combustible

EN	FR
Fuel supply interface	Interface alimentation en combustible
Heat out	Chaleur produite
Internal power needs (optional)	Besoins internes en énergie (facultatif)
Liquid Fuel Component	Composant de combustible liquide
Liquid mixture cartridge (optional)	Cartouche de mélange de combustibles (facultatif)
Mechanical & Signal interface	Interface mécanique et de signal
Micro fuel cell or micro fuel cell module	Micropile à combustible ou module de micropiles à combustible
Micro fuel cell power system	Système à micropile à combustible
Micro fuel cell power unit	Bloc d'alimentation électrique de micropiles à combustible
Power conditioning	Conditionnement de l'énergie
Power output	Puissance de sortie
Primary battery (optional)	Pile électrique (facultatif)
Rechargeable battery or capacitor (optional)	Batterie rechargeable ou condensateur (facultatif)
Solid borohydride fuel	Combustible à borohydrure solide
Total control system	Système global de commande
Waste products	Déchets
Water and/or waste product management	Gestion de l'eau et/ou des déchets

Figure F.12 – Schéma de principe du système à micropile à combustible à borohydrure pour un composé de classe 4.3 (hydroréactif) dans un système à pile à combustible à borohydrure indirect; gestion du combustible dans la cartouche de combustible

F.2 Références normatives

En plus des références normatives spécifiées dans l'Article 2, les documents de référence suivants sont indispensables pour l'application du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

ISO 16111:2008, *Appareils de stockage de gaz transportables — Hydrogène absorbé dans un hydrure métallique réversible*

F.3 Termes et définitions

Les termes et définitions ci-dessous remplacent les termes et définitions correspondants de l'Article 3 pour les systèmes à micropiles à combustible, les blocs d'alimentation électrique des micropiles à combustible et les cartouches de combustible traités par la présente Annexe F. Tous les termes et définitions de l'Article 3 qui ne sont pas spécifiquement mentionnés ici s'appliquent également.

F.3.5 combustible

formulation de classe 4.3 (hydroréactive) des composés à borohydrure utilisés pour produire de l'électricité indirectement dans un système à micropile à combustible

F.3.8 composant de combustible liquide

solutions d'eau de classe 8 (corrosives), ou non dangereuses, contenant des acides ou des sels métalliques comme activateurs, ou des alcools comme supprimeurs du point de congélation