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Pre-Standard

First edition
2006-02

Fuel cell technologies –

Part 6-1: Micro fuel cell power systems – Safety

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FUEL CELL TECHNOLOGIES –

Part 6-1: Micro fuel cell power systems – Safety

FOREWORD

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IEC-PAS 62282-6-1 has been processed by IEC technical committee 105: Fuel cell technologies.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
105/96/PAS	105/104/RVD

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard. Its structure will then be adapted to the IEC rules.

This PAS shall remain valid for an initial maximum period of three years starting from 2006-02. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

The contents of the corrigendum of April 2007 have been included in this copy.

FUEL CELL TECHNOLOGIES –

Part 6-1: Micro fuel cell power systems – Safety

1 Scope

1.1 System boundary

1.1.1 This consumer safety PAS covers fuel cell power systems, 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. As such, the externally accessible circuitry is considered as circuits that are "SELV" as defined in IEC 60950-1, and as limited power circuits if further compliance with IEC 60950-1, 2.5 is demonstrated. Systems that have internal systems exceeding 60 V d.c. or 240 VA should be appropriately evaluated in accordance with the separate criteria of IEC 60950-1.

1.1.2 This consumer safety PAS covers all fuel cell power systems, units and cartridges. This PAS establishes requirements for all fuel cell power systems, units and cartridges to ensure a reasonable degree of safety for normal use, reasonably foreseeable misuse, and consumer transportation of such items. The cartridges covered by this PAS are not intended to be refilled by the consumer. Cartridges refilled by the manufacturer or by trained technicians should meet all the requirements of this PAS as unused cartridges.

1.1.3 This PAS also covers compatible and separately transported fuel storage fuel cartridges for supplying fuel to the fuel cell power unit.

1.1.4 Fuel cell power systems that provide output levels that exceed electrical limits specified in 1.1.1 are covered by IEC 62282-5.

1.1.5 These products are not intended for use in hazardous areas.

1.1.6 Fuels and technologies covered

1.1.6.1 This PAS includes methanol or methanol and water solutions as fuels.

1.1.6.2 This PAS includes equipment designs that include proton exchange membrane (PEM) fuel cell stacks and direct methanol fuel cell stacks (DMFC).

1.1.6.3 This PAS includes requirements for other fuels and the associated systems in the annexes, formatted as deviations or additional requirements to the main body of this PAS.

1.1.6.4 It is understood that all fuel cartridges, power units and fuel cell systems should comply with applicable country and local requirements including transportation, child-resistance, and storage, where required.

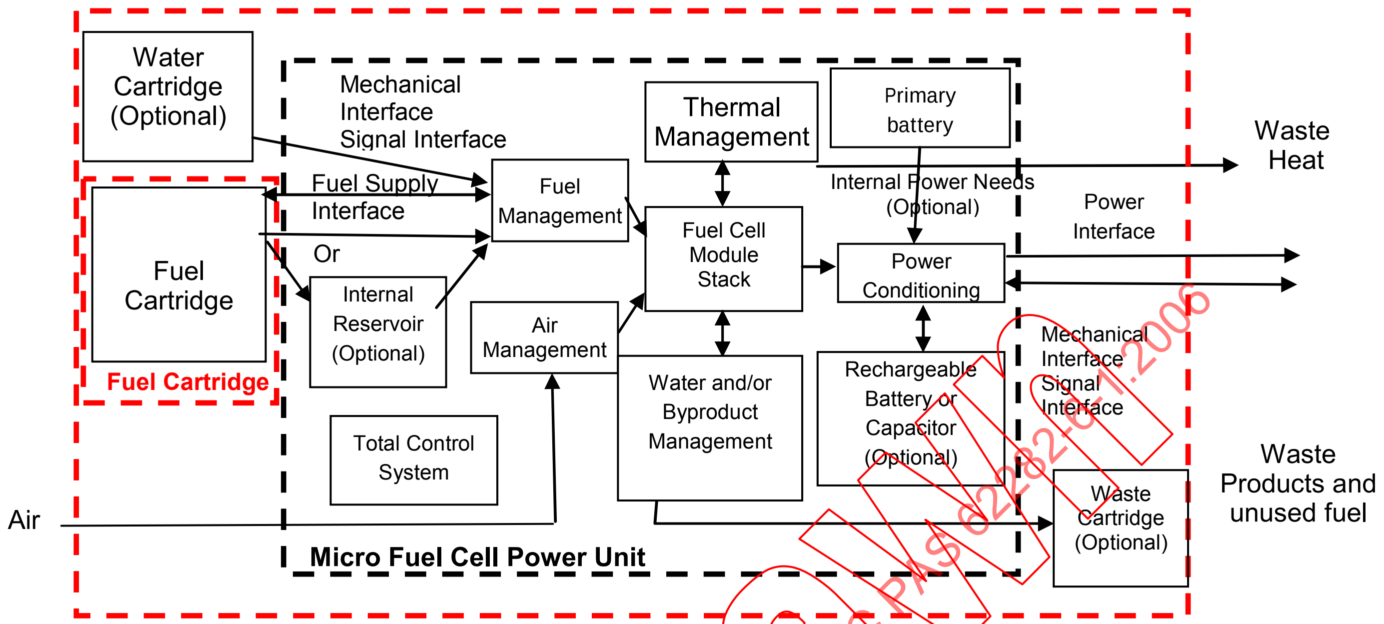


Figure 1 – Micro fuel cell power system

1.2 Equivalent Level of Safety

The requirements of this PAS are not intended to constrain innovation. The manufacturer may consider fuels, materials, designs or constructions not specifically dealt with in this PAS. These alternatives should be evaluated as to their ability to yield levels of safety equivalent to those prescribed by this PAS.

2 Normative references

The following referenced documents are indispensable for the application of this PAS. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60086-4:2000, *Primary batteries – Part 4: Safety of lithium batteries*

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 60695-2-20, *Fire hazard testing – Part 2-20: Glowing/hot-wire based test methods – Hot-wire coil ignitability – Apparatus, test method and guidance*

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

IEC 60730-1, *Automatic electrical controls for household and similar use – Part 1: General requirements*

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

IEC 61025, *Fault tree analysis*

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

IEC 61960, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*

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*

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*

ANSI/ASME B.31.3, *Process piping*

3 Terms and definitions

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

3.1
enclosure
parts of the micro fuel cell intended to be a barrier to protect, shield, and control access to the internal components or material

3.2
fire enclosure
part of the fuel cell power unit that is intended to minimize the spread of fire or flames from within

3.3
fuel
one of the following substances:

a) Methanol or methanol/water solution regardless of the concentration that is used to produce electricity in the fuel cell unit
b) Formic acid
c) Hydrogen
d) Methanol clathrate compound
e) Borohydride compounds
f) Butane

NOTE The methanol or methanol/water solution, is covered by the main body of the PAS. Annexes A through F cover the other fuels.

3.4
fuel cartridge
removable article that contains and supplies fuel to the fuel cell power unit or internal reservoir, not to be refilled by the user

3.5
insert cartridge
fuel cartridge, which has its own enclosure and is installed within the enclosure of the device powered by the fuel cell power system

3.6
exterior cartridge
fuel cartridge, which has its own enclosure that forms a portion of the enclosure of the device powered by the fuel cell power system

3.7
attached cartridge
fuel cartridge, which has its own enclosure that connects to the device powered by the fuel cell power system

3.8
satellite cartridge
fuel cartridge that is intended to be connected to and removed from the fuel cell power unit to transfer fuel to the internal reservoir inside the micro fuel cell power unit

3.9
fuel cell power unit
fuel cell power unit intended for use in a product in which service and replacement of the fuel cell power unit will be done only by the user or by a person who has been trained to service and repair the product

3.10
fuel supply unit, non-pressurized
cartridge in which the normal working pressure does not exceed a gauge pressure of 50 kPa at 22 °C

3.11
fuel supply unit, pressurized
cartridge in which the normal working pressure exceeds a gauge pressure of 50 kPa at 22 °C

3.12
hazardous liquid fuel
any liquid fuel amount over 5 ml or a concentration of methanol greater than, or equal to, 4 % by weight in water. Other hazardous fuel definitions are given in Annexes A through F

3.13
internal reservoir
structure in a fuel cell power unit that stores fuel and cannot be removed

3.14
leakage
accessible hazardous liquid fuel outside the system or cartridge

3.15
limited power sources
circuits supplied by a limited power source are not considered to be a potential fire hazard due to the limits on available power to the circuits. A limited power source is either inherently or non-inherently limited

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.

3.16
material, toxic
any material having a toxic hazard rating of 2, moderate, in Sax's "Dangerous Properties of Industrial Materials" or related reference guide

3.17
mechanical enclosure
parts of the micro fuel cell intended to be a barrier to protect, shield, and control access to the internal components or material

3.18
micro fuel cell
fuel cell power system and fuel cartridge 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

3.19
no accessible liquid
consumer cannot come into physical contact with hazardous liquid fuel

3.20
no-fuel vapour loss
fuel vapour escaping from the cartridge or system of less than 0,33 g/h

3.21
no leakage
no accessible hazardous liquid fuel outside the system or cartridge

3.22
room
constructed closed environment having a 2,1 m to 2,4 m (7 ft to 8 ft) high ceiling and having a total volume based on the intended portable fuel cell power unit application

3.23
valve, refill
component of the non-user-refillable fuel cartridge that allows refilling the cartridge only by trained technicians

3.24
valve, shut-off
component of a fuel cartridge that controls the release of fuel

3.25
waste cartridge
cartridge that stores waste and by-products from the power unit

3.26
water cartridge
cartridge that is filled with water (no additives) to adjust fuel concentration

4 Materials and construction of fuel cartridge, micro fuel cell power unit and micro fuel cell power system for portable devices

4.1 General

4.1.1 The fuel cell power unit when coupled to the fuel cartridge shall be designed and constructed to avoid any credible risk of fire or explosion posed by the fuel cell power system itself or gases, vapours, liquids or other substances produced or used by the fuel cell power system.

4.1.2 To prevent a fire or explosion hazard within the fuel cell power system, the manufacturer shall eliminate potential ignition source(s) within areas where fuel is present (or can be potentially released).

4.1.3 Flammable, toxic and corrosive fluids shall be kept within a closed containment system such as within fuel piping, in a reservoir, a cartridge or similar enclosure to avoid leakage.

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 cartridges, if anticipated by the manufacturer or trained technicians, shall be considered.

4.2.2 Guidance can be found in IEC 61025.

4.3 Fuel Input

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

4.3.2 The fuel cell power units shall specify the fuel cartridge(s) that it is intended for. This information shall be provided as part of the documentation provided with the fuel cell power unit or fuel cell power system.

4.4 General materials

The materials and coating shall be resistant to corrosion under the normal transportation and normal usage conditions over the lifespan of the product.

4.5 Selection of materials

4.5.1 Non-metallic materials such as rubber and plastics shall be selected so as to be resistant to deterioration under their normal usage conditions over the lifespan of the product.

4.5.2 Materials employed in the fuel cell system and cartridge shall be resistant to the affects of temperature and exposure to fuels and the effects of weather as outlined in 4.7.

4.5.3 Metallic and non-metallic materials used to construct internal or external parts of the fuel cell power system, in particular those exposed directly or indirectly to moisture, fuel and/or by-products 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 within the scheduled lifetime of the equipment and for all test conditions; in particular,

- they shall retain their mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) under normal usage;
- 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 expected lifetime of the equipment;
- 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.

4.5.4 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 ISO 188 and ISO 1817.

4.5.5 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.

4.6 Vacant

4.7 General construction

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

4.7.2 Connection mechanisms, including the connection between a detachable fuel cartridge and the fuel cell system, and the electrical connection between the fuel cell module and device, shall be designed in such a way that they cannot be attached at a wrong location or in an incomplete state so that leakage occurs.

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

4.8 Vacant

4.9 Piping and fittings

4.9.1 Where piping systems are designed for internal pressures over 50 kPa they shall be designed, constructed, and tested in accordance with ISO 15649 and ANSI/ASME B31.3.

4.9.2 Piping designed for operation below 50 kPa or, in accordance with the applicable regional or national pressure equipment codes and standards not qualifying as pressure piping, 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.

4.9.3 The piping shall comply dimensionally with the technical requirements given above, and the materials shall be compatible with the intended fluids and process parameters.

4.9.4 Threaded portions shall only be allowed in cases where a leakage does not create a hazard; e.g. air supply, cooling circuits. All other joints shall be glued, welded, brazed, or sealed, or at least have fitting connections with a defined sealing area as specified by the manufacturer.

4.9.5 Unions, when used in fuel gas or oxygen lines, shall be of the ground-joint type or the flanged-joint type or sealed using an O-ring resistant to the fluid transported or of the compression-joint type having packing resistant to the action of the fluid transported.

4.9.6 O-Rings shall be compatible with both the fluid transported and the ambient conditions of use.

4.9.7 The design and construction of both rigid and flexible pipes and fittings shall consider the following aspects.

4.10 Fuel containing parts and piping systems

4.10.1 Fuel-containing parts and their connections shall have adequate strength to withstand the pressures to which they are exposed. Compliance is determined by the pressure differential tests of 7.3.1 and the internal pressure tests of 7.3.11.

4.10.2 Connections within the piping and fuel handling parts of the system and cartridge shall be sufficiently leaktight to prevent leakage during normal use, reasonably foreseeable misuse, and consumer transportation. Compliance is determined by type tests 7.3.1 and 7.3.11.

4.10.3 Fuel valves

4.10.3.1 Applies to all shut-off valves, filling valves, relief valves, commercial refilling valves, including all cartridge types.

4.10.3.2 Operating and pressure-containing parts of the shutoff valve and relief valve assemblies shall last the life of the cartridge under normal conditions.

4.10.3.3 The fuel cartridge shall be packaged to prevent the valve from being damaged during shipping.

4.10.3.4 The valves must have a means to prevent leakage of fuel through normal use and storage of the cartridge.

4.10.3.5 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.

4.10.3.6 There shall be no leakage of fuel during storage, connection, disconnection or transferring of fuel from the cartridge to the power unit.

4.11 Materials and construction – System

The fuel cell power unit when coupled to the fuel cartridge shall be designed and constructed to avoid any credible risk of fire or explosion posed by the fuel cell power system itself or gases, vapours, liquids or other substances produced or used by the fuel cell power system.

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

4.11.2 The fuel cell power system shall be protected by means (e.g. ventilation, controlled oxidation, operating temperatures higher than the auto-ignition temperature, etc.) in such a way that leaking fuel from or inside the fuel cell power system cannot form explosive concentrations. The design criteria for such means (e.g. required ventilation rate) shall be provided by the fuel cell power system manufacturer. The means shall be provided either by the fuel cell power system manufacturer or by the manufacturer of the device powered by the fuel cell power system.

4.11.3 Components and materials inside the fuel cell power system 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.

4.11.4 Exemptions

4.11.4.1 Membranes, or other materials within the fuel cell stack volume which comprise less than 10 % of the total fuel cell stack mass, are considered to be of limited quantity and are permissible without flame-spread ratings.

4.11.4.2 If the actual temperature in any location of the fuel cell power system, where a flammable mixture may occur, is higher than the auto-ignition temperature, leakage of fuel into the oxidant or vice versa results in immediate oxidation of the flammable fuel. Thus, it is obvious that no major concentrations of explosive gases can accumulate. Whenever this temperature of such high-temperature fuel cells is lower than the auto-ignition temperature, the fuel cell power system shall be transferred into a safe state.

4.12 Ignition sources

To prevent a fire or explosion hazard within the fuel cell power system, the manufacturer shall eliminate potential ignition source(s) within areas where fuel is present (or can be potentially released) by ensuring that

- the surface temperatures shall not exceed 80 % of the auto-ignition temperature, expressed in °C, of the flammable gas or vapour;
- equipment containing materials 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, if subject to contact with fuel, is suitable for the area in which it is installed.

4.13 Enclosures and acceptance strategies

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

4.13.1 Parts requiring a fire enclosure

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

4.13.1.2 Components in circuits supplied by limited power sources as specified in 2.5 of IEC 60950-1, but not mounted on material of flammability class V-1.

4.13.1.3 Components within a power supply unit or assembly having a limited power output as specified in 2.5 of IEC 60950-1, including non-arcing overcurrent protective devices, limiting impedances, regulating networks and wiring, up to the point where the limited power source output criteria are met.

4.13.2 Parts not requiring a fire enclosure

The following parts do not require a fire enclosure.

- Motors.
- Electromechanical components complying with 5.3.5 of IEC 60950-1.
- Wiring and cables insulated with PVC, TFE, PTFE, FEP, neoprene or polyamide;
- Components, including connectors, meeting the requirements of 4.7.3.2 of IEC 60950-1, which fill an opening in a fire enclosure.
- Connectors in circuits supplied by limited power sources complying with 2.5 of IEC 60950-1.
- Other components in circuits supplied by limited power sources complying with 2.5 of IEC 60950-1 and mounted on materials of flammability class V-1.
- Other components complying with Method 2 of 4.7.1 of IEC 60950-1.
- 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.
- Compliance with 4.7.2.1 and 4.7.2.2 of IEC 60950-1 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.
- Fuel cartridges without electrical circuitry that under fault conditions could be sufficient for ignition do not require a fire enclosure.

Table 1 – Summary of material flammability requirements

Parts requiring a fire enclosure	Parts not requiring a fire enclosure
Components in limited power circuits not mounted on Class V-1 minimum rated materials	Motors (complying with 7.2 of IEC 60950-1) and other electromechanical components (complying with 7.3 of IEC 60950-1)
Non-limited power circuits	Wires, cables insulated with PVC, TFE, PTFE, FEP, neoprene or polyamide
Areas that contain or process a flammable fluid	Components in limited power circuits mounted on Class V-1 minimum materials
Components with un-enclosed arcing parts such as relay contacts, commutators and open switches	Connectors in limited power circuits
Insulated wiring (not employing PVC or other insulation)	Plugs and connectors forming part of an interconnecting cable

Table 2 – Summary of material flammability requirements

Part		Requirements
Fire enclosure	Enclosure	V-1 (IEC 60695-11-10), or Test A2 of IEC 60950-1, or Hot wire test of IEC 60695-2-20 (if < 13 mm air from sources of ignition)
	Parts which fill an opening	V-1 (IEC 60695-11-10), or Test A2 of IEC 60950-1, or Component standard
Outside the fire enclosure	Components and parts including mechanical and electrical enclosures	HB40 (IEC 60695-11-10) for thickness > 3 mm, or HB75 (IEC 60965-11-10) for thickness < 3mm, or HBF (foamed) (ISO 9772), or 550 °C Glow wire test of IEC 60695-2-11, or See 4.7.3.3 of IEC 60950-1 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, or Components standard, or See 4.7.3.4 of IEC 60950-1 for exceptions
Any location	Air filter assemblies	V-2 (IEC 60695-11-10), or HF-2 (foamed) (ISO 9772), or Test A2 of IEC 60950-1, or See 4.7.3.4 of IEC 60950-1 for exceptions

4.13.3 Materials for components and other parts outside fire enclosures

4.13.3.1 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 F flammability class HB40 if the thinnest significant thickness of this material is > 3 mm, or Flammability

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

4.13.3.2 Requirements for materials in air filter assemblies are in 4.7.3.5 of IEC 60950-1 and for materials in high-voltage components in 4.7.3.6 of IEC 60950-1.

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; or

c) comply with the flammability requirements of the relevant IEC component standard; or

d) be mounted on material of flammability class V-1 and be of a small size.

4.13.3.3 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.

4.13.3.3.1 Electrical components that do not present a fire hazard under abnormal operating conditions when tested according to 5.3.6 of IEC 60950-1.

4.13.3.3.2 Materials and components within an enclosure of 0,06 m^3 or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas.

4.13.3.3.3 Components meeting the flammability requirements of a relevant IEC component standard which includes such requirements.

4.13.3.3.4 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.

4.13.3.3.5 Wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP, neoprene or polyamide.

4.13.3.3.6 Individual clamps (not including helical wraps or other continuous forms), lacing tape, twine and cable ties used with wiring harnesses.

4.13.3.3.7 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.

4.13.3.3.8 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.

4.13.4 Materials for components and other parts inside fire enclosures

4.13.4.1 Requirements for materials in air filter assemblies are in 4.7.3.5 of IEC 60950-1 and requirements for materials in high-voltage components in 4.7.3.6 of IEC 60950-1.

4.13.4.2 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:

- be of flammability class V-2, or flammability class HF-2; or
- pass the flammability test described in Clause A.2; or
- meet the flammability requirements of a relevant IEC component standard that includes such requirements.

4.13.4.3 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 5.3.6 of IEC 60950-1;
- materials and components within an enclosure of 0,06 m^3 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 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;
- wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP, neoprene or polyamide;
- 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-1or FT-1or 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;
- 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.

4.13.4.4 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.

4.13.5 Mechanical enclosures

4.13.5.1 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.

4.13.5.2 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, as applicable.

4.13.5.3 After the tests of 4.2.2 to 4.2.7 of IEC 60950-1, the sample shall continue to comply with the requirements of 2.1.1, 2.6.1, 2.10, 3.2.6 and 4.4.1 of IEC 60950-1. It shall show no signs of interference with the operation of safety features such as thermal cut-outs, overcurrent protection devices or interlocks.

4.13.5.4 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.

4.14 Protection against fire, explosion, corrosivity and toxicity hazard

4.14.1 Flammable, toxic and corrosive fluids shall be kept within a closed containment system such as within fuel piping, in a reservoir, a cartridge or similar enclosure. Emissions testing in accordance with 7.3.14 verifies this requirement.

4.14.2 One of the means of meeting requirements of emission limits is via detection of the emission and ensuring system shutdown prior to emissions reaching dangerous levels.

4.14.3 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.

4.15 Protection against electrical hazards

The voltages within the fuel cell power source shall be safety extra low voltage in accordance with the SELV limits. Determinations shall be made in accordance with IEC 60950-1, 2.1. If internal voltages exceed 60 V d.c. the micro fuel cell power unit is to be further investigated in accordance with IEC 60950-1.

4.16 Fuel cell stack

4.16.1 The fuel cell stack shall have a construction sufficient to withstand the stress generated by the expected levels of vibration and heat, etc.

4.16.2 The fuel cell stack shall not create a hazardous condition when dropped or otherwise subject to a mechanical shock during its intended use.

4.17 Fuel supply construction

4.17.1 Fuel cartridge construction

Fuel cartridges must conform to the following.

4.17.1.1 There shall be no leakage from the cartridge in the temperature range of –40 °C to +70 °C. See 7.3.3 and 7.3.4.

4.17.1.2 There shall be no leakage from the cartridge at an internal pressure of 95 kPa internal gage pressure plus normal working pressure at 22 °C or two times the pressure of the cartridge at 55 °C, whichever is greater.

4.17.1.3 Maximum methanol fuel volume shall not exceed 1 litre.

4.17.1.4 For normal use, reasonably foreseeable misuse, and consumer transportation of a fuel cartridge with a fuel cell by a consumer, means to prevent fuel leakage prior to, during, and after connection or transfer of fuel to the fuel cell shall be provided. Compliance is checked by 7.3.12.

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

4.17.1.6 For the installation of a fuel cartridge on the fuel cell, means to prevent the mis-connection shall be provided so as not to cause leakage.

4.17.1.7 Fuel supply connectors provided on the fuel cartridge shall have a construction that prevents the leakage of fuel when not attached to a fuel cell during normal usage, reasonably foreseeable misuse, and consumer transportation.

4.17.1.8 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 must pass all type tests with no leakage.

4.17.1.9 The structure at the connection to the fuel cartridge must not allow fuel to leak.

4.17.1.10 A fuel cartridge, including the fuel cartridge interface to the fuel cell device, 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, 7.3.4;
- drop test, 7.3.5;
- compressive loading test, 7.3.6;
- long-term storage test, 7.3.7;
- fuel cell power unit internal pressure test, 7.3.8;
- connection cycling test, 7.3.9.

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

4.17.1.12 The fuel cartridge design shall reasonably prevent the entry of debris during the transportation of the fuel cartridge.

4.17.2 Fuel cartridge fill requirement

The fuel cartridge design and fuel fill amount must allow fuel expansion *without leakage* to a cartridge temperature of 70 °C with either the cartridge alone or constrained by the system.

4.18 Protection against mechanical hazards

4.18.1 Tubing other than fuel tubing lines

Requirements are listed below for the construction of tubing lines other than fuel tubing lines inside the fuel cell system.

4.18.1.1 The line construction will 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 7.3.10.

4.18.1.2 The construction shall have been 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.

4.18.2 Exterior surface and component temperature limits

Fuel cell power units shall not attain excessive temperatures during normal operation. Compliance shall be checked by determining the temperature of the various parts under the following conditions. The fuel cell power unit is operated at full load until thermal equilibrium is reached or fuel supply is totally exhausted. During the test, thermal cutouts and overload devices shall not operate. The temperature shall not exceed the values shown in Table 3.

4.18.2.1 Exterior surfaces

To eliminate any risk of burn injury caused by contact with the fuel cell power system, the temperature of the external enclosure shall not exceed the value shown in Table 3.

4.18.2.2 Handles, knobs, grips and similar parts.

The user is intended to touch handles, knobs, grips and similar parts in order to operate the unit. The temperature of handles, knobs, grips and similar parts intended to be touched shall not exceed the values shown in Table 3.

4.18.2.3 Components

4.18.2.3.1 Table 3 shows the maximum normal temperature for various exterior components. The temperature of such components shall not exceed the values shown in Table 3.

4.18.2.3.2 For components and electrical wiring equipped in the fuel cell system that are not shown in Table 3, their temperatures shall not exceed those for which the components are rated.

Table 3 – 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 methanol and methanol vapour Exception – Areas that are separately evaluated for reforming fuel that utilize a high-temperature process.	*
* 80 % of the auto-ignition temperature of the potential flammable vapour.	

4.18.3 Motors

4.18.3.1 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.

4.18.3.2 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.

4.18.3.3 If a connector is used in the circuitry, it shall be considered normally non-arcing if disconnection is not required during operational maintenance and if it is mechanically prevented from separating or secured so that a separating force of at least 15 N (3,4 poundsforce) is required for loosening. If accessible during operational maintenance, the connector shall be marked in accordance with the following: "Warning – Do not disconnect while circuit is alive unless area is known to be non-hazardous." This warning shall be on or adjacent to the connector.

4.18.3.4 Impedance protected motors and motors equipped with thermal cut-offs are methods in which protection against over-temperature can be achieved.

4.19 Wiring material, including printed wiring

4.19.1 With the fuel cell power system 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.

4.19.2 In the event of the fuel cell power system 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.

4.20 Miscellaneous electrical equipment

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.

4.21 Construction of electric device components

4.21.1 Limited power sources

Limited power sources must meet one of the following.

a) The output is inherently limited in compliance with Table 4.

b) An impedance limits the output in compliance with Table 5. If a positive temperature coefficient device is used, it shall pass the tests specified in IEC 60730-1, Clauses 15, 17, J.15 and J17.

c) A non-arcing over-current protective device is used and the output is limited in compliance with Table 5.

d) A regulating network limits the output in compliance with Table 5, both under normal operating conditions and after any single fault (see IEC 60950-1, 1.4.14) in the regulating network (open circuit or short circuit).

e) A regulating network limits the output in compliance with Table 5 under normal operating conditions, and a non-arcing over-current protective device limits the output in compliance with Table 5 after any single fault (see 1.4.14) in the regulating network (open circuit or short circuit).

f) 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 4 and 5.

Table 4 – 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	≤ 8,0	≤ 5 x V_{oc}
20 < V_{oc} ≤ 30	≤ 8,0	≤ 100
30 < V_{oc} ≤ 60	≤ 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 (VA): Maximum output VA with any non-capacitive load measured 60 s after the application of the load.

Table 5 – 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	≤ 1000 / V_{oc}	≤ 250	≤ 5,0
20 < V_{oc} ≤ 30			≤ 100 / V_{oc}
30 < V_{oc} ≤ 60			≤ 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 5.

4.21.2 Devices that use electronic controllers

4.21.2.1 Control systems

System software and electronic circuitry relied upon as the primary safety means as determined from the analysis according to clause 4.2 in accordance with Annex H of IEC 60730-1.

Fuel cell system using electronic controllers shall conform to the following.

a) During the course of normal usage, in case of controller malfunction, safety shall not be compromised, namely the fuel system shall not be heated abnormally, and fuel shall not leak.

b) During the course of normal usage, safety shall not be compromised in cases where a portion of the control circuit becomes short-circuited or disconnected, namely the fuel system shall not be heated abnormally, and fuel shall not leak.

4.21.3 Electrical conductors/wiring

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

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

4.21.3.3 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.

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

4.21.3.5 Except in the following cases, exposed lead wires or terminals that connect to the exterior of the fuel cell system 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 fuel cell system operation.

4.21.3.6 Wireways shall be smooth and free from sharp edges.

4.21.3.7 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.

4.21.3.8 Holes in metal through which insulated wires pass shall be provided with bushings or shall have smooth well-rounded edges.

4.21.3.9 Compliance is checked by inspection. A radius of 1,5 mm (0,059 in) is considered to be well rounded.

4.21.3.10 Internal wiring and electrical connections between different parts of the fuel cell power unit shall be adequately protected or enclosed.

Compliance is checked by inspection.

4.21.4 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 is below a specific voltage is inherently limited in compliance with Table 4; or an impedance limits the output in compliance with Table 5.

4.21.5 Electric components and attachments

4.21.5.1 Electric components and attachments shall have sufficient electrical ratings for use within the fuel cell power system.

4.21.5.2 Lithium-ion batteries used in the fuel cell power system shall comply with IEC 60086-4 and IEC 61960.

4.22 Protection

4.22.1 Objective of protection devices

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

4.22.2 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.

4.22.3 Protection from electrical overloading

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

5 Abnormal operation requirements and tests

5.1 Abnormal operations and fault conditions

5.1.1 General

5.1.1.1 Equipment shall be designed so that the risk of fire due to mechanical or electrical overload or failure, or due to abnormal operation or careless use, is limited as far as practicable.

5.1.1.2 After abnormal operation or a single fault, the equipment shall still be in full working order.

5.1.1.3 It is permitted to use fusible links, thermal cutouts, overcurrent protection devices and the like to provide adequate protection if investigated and found not to become an ignition source.

5.1.1.4 Compliance is checked by inspection and by the tests of 5.1.2.

5.1.2 Compliance testing

5.1.2.1 Before the start of each test, the equipment should be operating normally.

5.1.2.2 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.

5.1.2.3 Equipment is tested by applying abnormal and fault conditions that may occur in normal use and foreseeable misuse. Hazard analysis (clause 4.2) shall be used for guidance in identifying key faults to test. In addition, equipment that is provided with a protective covering is tested with the covering in place under normal idling conditions until steady conditions are established.

5.1.2.4 The equipment, circuit diagrams, FMEA, hazard analysis, and component specifications are to be examined to determine those fault conditions that might occur. Examples include

a) short circuits and open circuits of semiconductor devices and capacitors;
b) faults causing continuous dissipation in resistors designed for intermittent dissipation;
c) internal faults in integrated circuits causing excessive dissipation.

5.1.3 Acceptance criteria

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

a) the equipment shall not emit molten metal.
b) 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;
c) enclosures shall not deform in such a way as to cause access to hazardous parts;
d) the temperatures of insulating materials other than thermoplastic materials 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;
e) 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;
f) 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.

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

5.1.4.1 Where it is required to apply simulated faults or abnormal operating conditions, these shall be applied in turn and one at a time.

5.1.4.2 Faults, which 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.

5.1.4.3 When applying simulated faults or abnormal operating conditions, accessories, supplies, consumable materials, shall be in place if they are likely to have an effect on the outcome of the test.

5.1.4.4 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.

5.1.4.5 Consideration shall also be given to arcing parts in the end-product if the application of the micro fuel cell may emit potentially flammable vapours during normal or abnormal operation.

5.1.4.6 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.

5.1.5 Abnormal operation – Electromechanical components

5.1.5.1 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.

5.1.5.2 The duration of each test shall be in accordance with the following.

a) For equipment or 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.

b) For other equipment and 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).

5.1.6 Abnormal operation – Batteries

A fully charged rechargeable battery provided with, or recommended by, the manufacturer for use with the fuel cell power unit shall be used for each of the following tests.

5.1.6.1 For evaluating the overcharging of a rechargeable battery, a battery is charged for a period of 7 h in accordance with each of the following conditions.

a) With the battery-charging circuit adjusted for its maximum charging rate (if such an adjustment exists); followed by

b) Any single component failure that is likely to occur in the charging circuit and which would result in overcharging of the battery.

c) The battery is charged for 7 h with any single component failure that is likely to occur and which would result in reversed charging of the battery; and

d) The battery is 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.

5.1.6.2 These battery abnormal tests shall not result in any of the following.

a) Chemical or fuel leaks of the battery, micro fuel cell, or fuel cartridge caused by cracking, rupturing or bursting of a jacket.

b) Explosion of the battery or micro fuel cell, if such explosion could result in injury to a user.

c) Emission of flame or expulsion of molten metal to the outside of the equipment.

d) Ignition of the fuel cell power system or cartridge or fuel contained therein.

e) After completion of the tests, the equipment is subjected to dielectric testing.

5.1.7 Abnormal operation – Simulation of faults based on hazard analysis

The following faults shall be simulated.

5.1.7.1 Any abnormal conditions deemed necessary, based on Clause 4 to evaluate the protection parameters provided for the system, e.g. over-temperature protection, short circuit, stack voltage.

5.1.7.2 Short circuit, disconnection or overloading of all relevant components and parts unless they comply with 4.2.6, 4.4.6, 4.7.2.1, and 4.7.3.4.

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

5.1.7.3 Temperatures in excess of the over-temperature protection circuitry to ensure the safety of the system.

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

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

6.1 Minimum markings required on the 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 HEAT OR FLAME ABOVE 50 °C.
e) FOLLOW USAGE INSTRUCTIONS.
f) IN THE CASE OF INGESTION OF FUEL OR CONTACT WITH THE EYES, SEEK MEDICAL ATTENTION.
g) MANUFACTURER NAME, MODEL DESIGNATION AND SERIAL NUMBER.
h) COMPOSITION AND AMOUNT OF FUEL.
i) TEXT OR MARKING THAT INDICATES THAT THE CARTRIDGE COMPLIES WITH IEC 62282-6-1.

6.2 Additional information required either on the cartridge or on accompanying written information or on the system or power unit

Usage instructions to include:

a) safety instructions and warnings;
b) text or markings on the system indicating that the system complies with IEC 62282-6-1;
c) all micro fuel cell power units and micro fuel cell power systems shall identify the fuel supply cartridge(s) which are acceptable for use with the units and systems;
d) all micro fuel cell power units and systems shall provide manuals providing for the following:
e) instructional information that educates the end-user in the proper use, function and disposal of the cartridge, unit and/or system;
f) information that identifies the manufacturer of the unit and/or system, including company name, address, telephone number, and web site;
g) all warnings and instructions affixed to the unit and/or device and to the 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;
h) instructions that the system shall be used in a well-ventilated area.

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

7 Type tests for a fuel cartridge, a micro fuel cell power unit, and a micro fuel cell power system

The type tests for micro fuel cell systems, fuel cell power units and fuel cartridges provide that these systems are safe for normal use.

7.1 Test conditions

7.1.1 Laboratory conditions

Unless otherwise explicitly prescribed in this chapter, 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 °C ± 5 °C)
Room atmosphere for fuel cell system only	The room atmosphere contains not more than 0,2 % carbon dioxide and not more than 0,002 % carbon monoxide. The room atmosphere contains at least 18 % oxygen but not more than 21 % oxygen.

The fuel cell power unit and cartridge shall be conditioned at a standard laboratory temperature of 22 °C ± 5 °C for a minimum of 3 h prior to the test being performed.

7.1.2 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 5 respectively. Exceptions will be noted in the various subclauses.

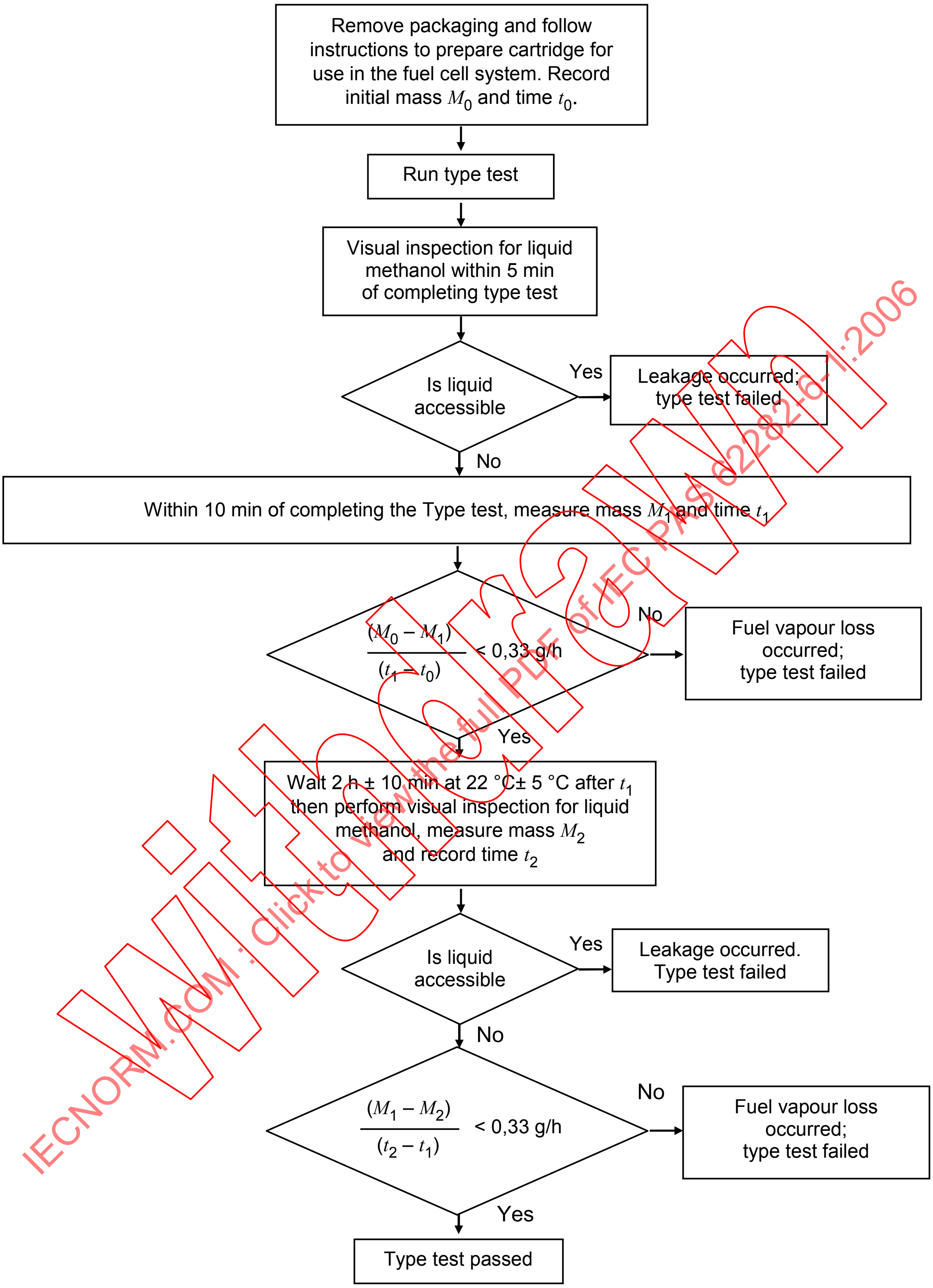


Figure 2 – Cartridge leakage and mass loss test flow chart for low external pressure, vibration, drop, and compressive loading tests

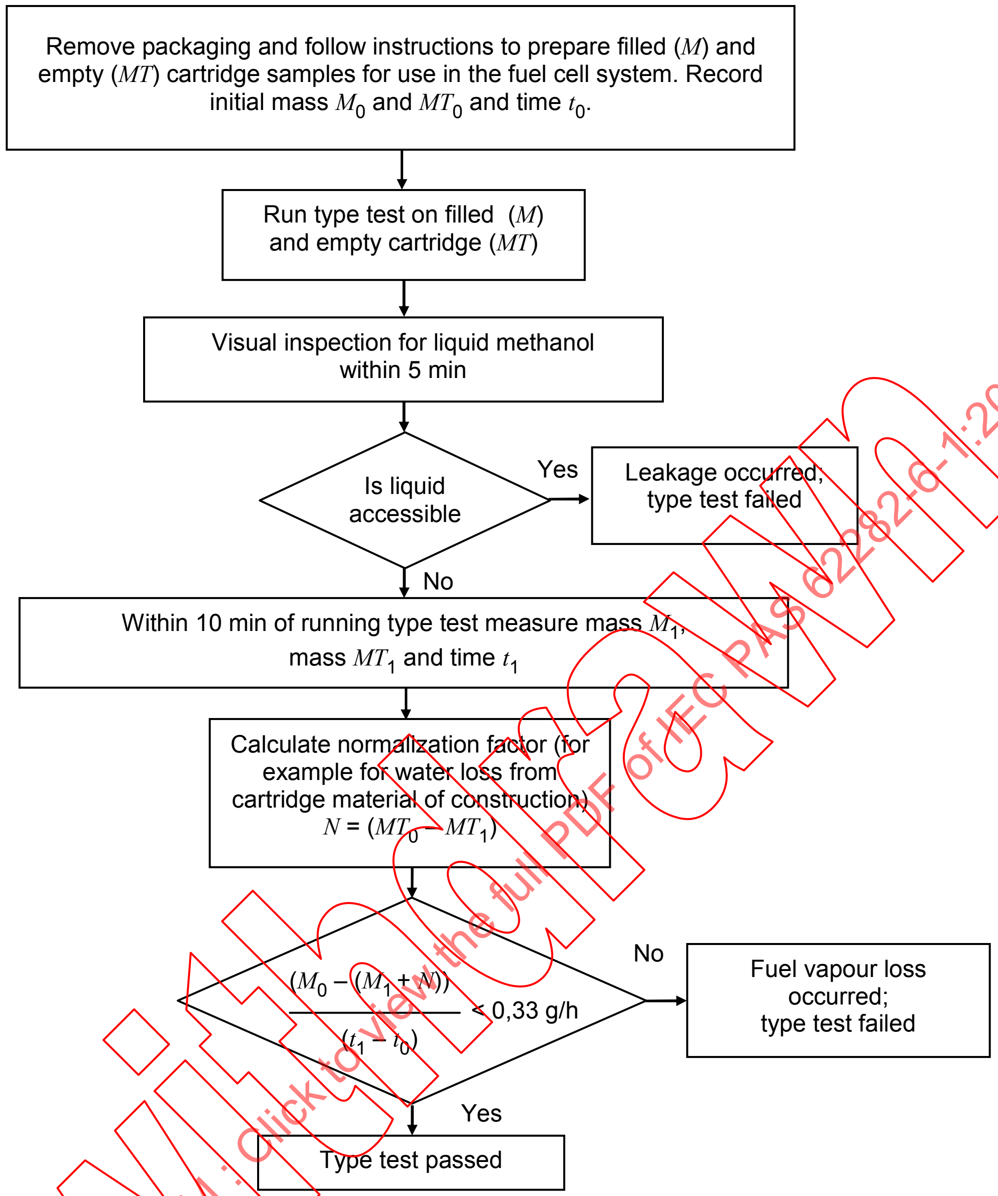


Figure 3 – Cartridge leakage and mass-loss test flow chart for temperature cycling type test and high-temperature exposure test

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

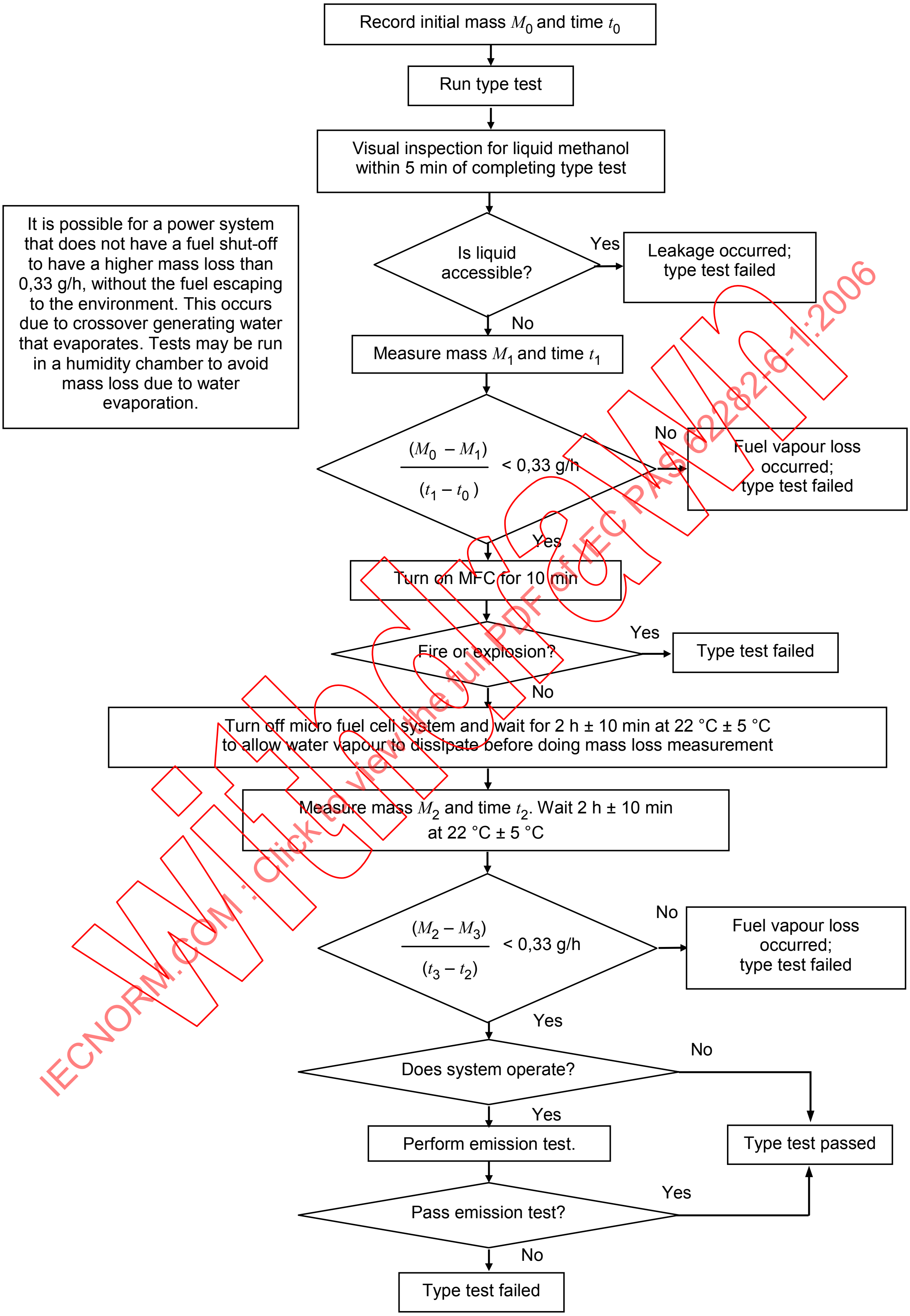


Figure 4 – Micro fuel cell system/unit leakage and mass-loss flow chart for vibration, drop, pressure differential and compressive loading tests

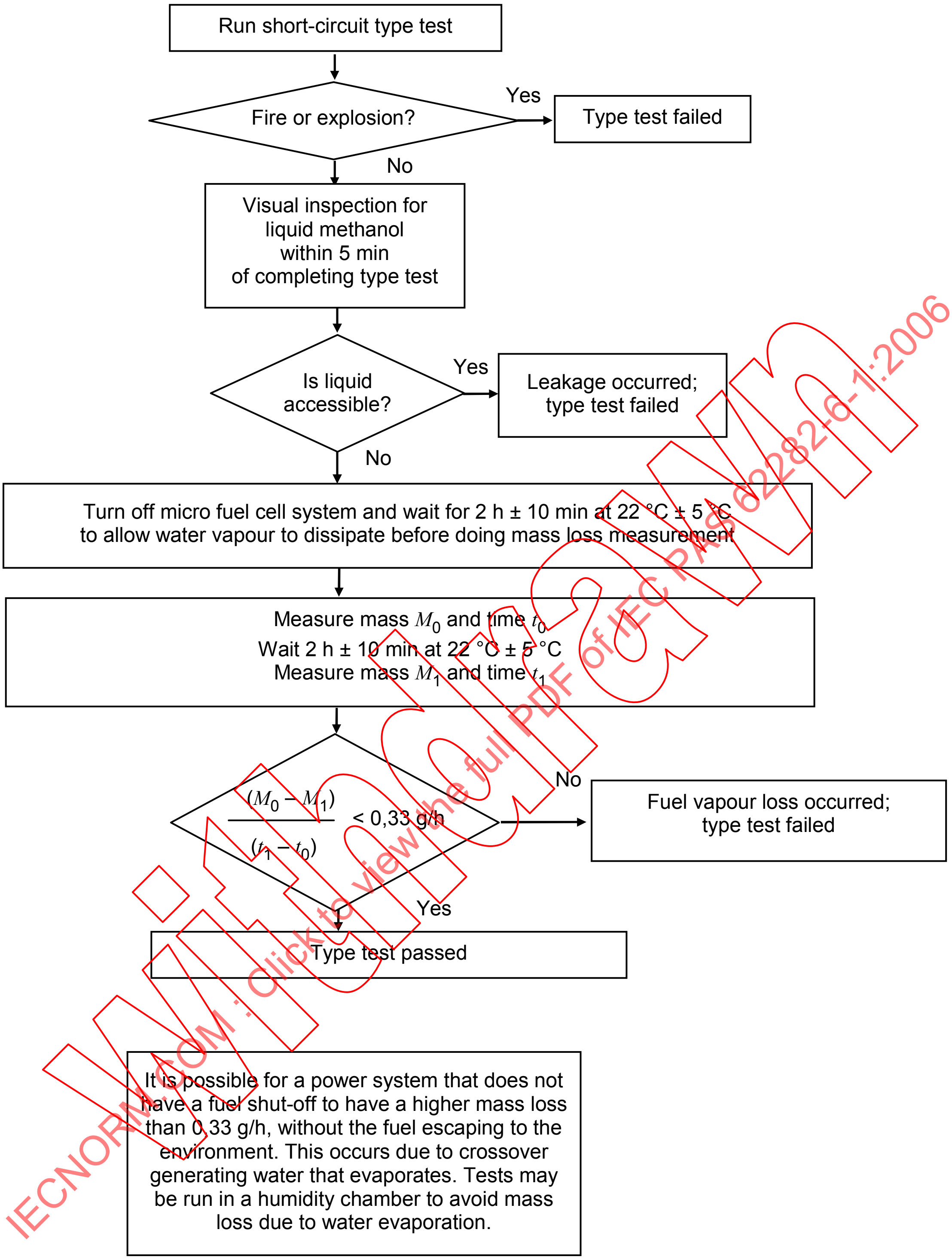


Figure 5 – Micro fuel cell system/unit leakage and mass-loss flow chart for short-circuit type test

7.2.1 Test sample quantity

The quantity of the samples shall be five cartridges and/or two power units/systems for all type tests. Tests 7.3.2 and 7.3.3 shall be carried out sequentially for testing of the cartridge. Tests 7.3.1, 7.3.2, and 7.3.3 shall be carried out sequentially for testing of the fuel cell power unit and/or power system.

7.3 Type tests

Type test items shall be as follows:

Table 7 – Type tests

	Test item	Test sample
7.3.1	Pressure differential tests*	Fuel cartridge Micro FC power unit and/or power system
7.3.2	Vibration test*	Fuel cartridge Micro FC power unit and/or power system
7.3.3	Temperature cycling test*	Fuel cartridge Micro FC power unit and/or power system
7.3.4	High temperature exposure	Fuel cartridge
7.3.5	Drop test	Fuel cartridge Micro FC power unit and/or power system
7.3.6	Compressive loading test	Fuel cartridge Partially filled cartridge Micro FC power unit and/or power system
7.3.7	External short-circuit test	Micro FC power unit or power system
7.3.8	Surface and exhaust gas temperature test	Micro FC power unit or power system
7.3.9	Long-term storage test	Fuel cartridge
7.3.10	High-temperature connection test	Fuel cartridge and micro FC power unit
7.3.11	Fuel cell power unit Internal pressure test	Micro FC power unit with a pressurized empty fuel cartridge
7.3.12	Connection cycling test	Fuel cartridge and micro FC power unit
7.3.14	Emission test	Micro FC power unit or power system

* The following tests must be done in sequence, using the same system hardware:
Pressure differential test → Vibration test → Temperature cycling test

7.3.1 Pressure Differential Tests

Purpose: To simulate the effects of high internal pressure or low external pressure and ensure no leakage.

7.3.1.1 Cartridge

Test procedure: Use 7.3.1.1, test A or test B.

Test A: For the internal pressurization test, the cartridge and the valve shall be tested separately.

Both test a) and test b) are required.

a) Cartridge body only:

   i) Using a suitable fluid medium such as water, pressurize the sample to an internal pressure that is the greater of a 95 kPa gauge pressure plus normal working pressure at 22 °C or twice the vapour pressure of the fuel at 55 °C.

   ii) The pressure rise not to exceed a rate of 60 kPa/s. Maintain the maximum pressure for 30 min at room temperature.

   iii) Passing Criteria: No accessible liquid test medium leakage and no sudden drop of pressure during the course of the test.

b) Cartridge valve

   i) Using a suitable fluid medium such as water, pressurize the closed valve to a pressure that is the greater of 95 kPa gauge pressure plus normal working pressure at 22 °C or twice the vapour pressure of the fuel at 55 °C.

   ii) The pressure rise not to exceed a rate of 60 kPa/s. Maintain the maximum pressure for 30 min at room temperature.

   iii) Passing Criteria: No accessible liquid test medium leakage and no sudden drop of pressure during the course of the test.

Test B Low external pressure

i) 95 kPa differential applied by external vacuum test where the lower pressure is applied externally to an unused cartridge. This method is generally not suitable for non-rigid cartridges because the required pressure differential is not attained. For non-rigid cartridges precise pressure differential measurement shall be used.

ii) Maintain the vacuum for 30 min.

iii) Passing Criteria: No fire at any time, no explosion at any time, no leakage. See Figure 2.

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

Both pressure differential Test A and Test B shall be carried out.

Test A: Power unit fuelled in accordance with manufacturer's specifications and/or system with unused fuel cartridge. Test samples in unused condition shall be stored at a pressure of 68 kPa for 6 h at ambient temperature (22 °C ± 5 °C). Methanol leakage shall be measured on the basis of the procedure described in Figure 4.

Test B: Power unit fuelled in accordance with manufacturer's specifications and/or system with unused fuel cartridge. Test samples in unused condition shall be stored at a low external pressure of 95 kPa differential pressure. External vacuum shall be applied for 30 min at ambient temperature (22 °C ± 5 °C). Methanol leakage shall be measured on the basis of the procedure described in Figure 4 with the acceptance criteria changed to “vapour loss less than 20 g/h” on the basis of not exceeding 25 % of the LFL.

7.3.2 Vibration test

Test sample: an unused fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system used in 7.3.1.

Purpose: To simulate the effects of normal transportation vibration and ensure no leakage.

Test procedure

i) Test sample of subject in unused condition firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.

ii) 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.

iii) 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.

iv) 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.

v) Perform emissions testing in accordance with 7.3.14.

Passing Criteria: No fire at any time, no explosion at any time, no leakage. Methanol leakage shall be measured on the basis of the procedure described in Figures 2 and 4. Emissions shall meet the acceptance criteria in 7.3.14. If the unit does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

7.3.3 Temperature cycling test

Test sample: an unused fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system used in 7.3.2.

Purpose: To simulate the effects of low-temperature and high-temperature exposure and the effects of extreme temperature change.

Test procedure (See Figure 6)

i) Place the test sample in a temperature-controlled test chamber and increase the chamber temperature from room temperature (22 °C ± 5 °C) to 55 °C ± 2 °C within 1 h and keep it at 55 °C ± 2 °C for a minimum of 4 h.

ii) Decrease the chamber temperature to 22 °C ± 5 °C within 1 h and keep it at 22 °C ± 5 °C for 1 h ± 5 min, then decrease the chamber temperature to –40 °C ± 5 °C within 2 h and keep it at –40 ± 5 °C for a minimum of 4 h.

iii) Increase the chamber temperature to 22 °C ± 5 °C within 2 h and keep it at 22 °C ± 5 °C for 1 h ± 5 min.

iv) The above process is to be done twice.

v) Perform emissions testing in accordance with 7.3.14.

Passing Criteria: No fire at any time, no explosion at any time, no leakage. After 2 h at 22 °C ± 5 °C, leakage shall be measured on the basis of the procedure described in Figure 3. Emissions shall meet acceptance criteria in 7.3.14. If the unit does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

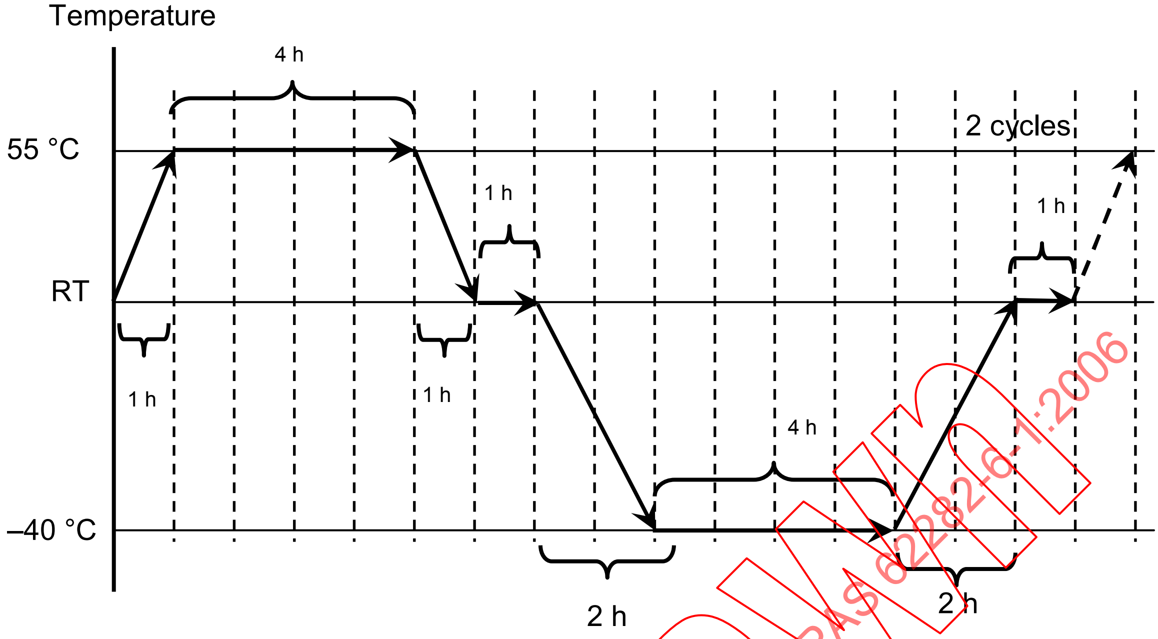


Figure 6 – Temperature cycling

7.3.4 High temperature exposure test

Test sample: an unused fuel cartridge

Purpose: To simulate the effects of a fuel cartridge left in high temperature environments

Test procedure:

i) Place the test sample in a temperature controlled test chamber that is at a temperature of 70 °C ± 2 °C and allow chamber temperature to recover to 70 °C ± 2 °C and maintain that temperature for at least 4 h with the sample in the chamber.

ii) Remove the test sample to a room temperature of 22 °C ± 5 °C.

iii) Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured on the basis of the procedure described in Figure 3.

7.3.5 Drop test

Test sample: an unused 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.

Purpose: To simulate the effects of an inadvertent drop and ensure no leakage.

Test procedure

i) 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.

ii) The height of the drop shall be:

1) 1200 mm ± 10 mm: in the case of a micro fuel cell power unit and/or a micro fuel cell power system.

2) 1500 mm ± 10 mm: in the case of a fuel cartridge of more than 200 ml.

3) 1800 mm ± 10 mm: in the case of a fuel cartridge of up to 200 ml.

iii) For the cartridge tests, the drop test shall be carried out in four drop directions with the same sample. For the power unit or the power system, one device may be used for all four drop directions, or more than one device may be used in subsequent drops, at the discretion of the manufacturer.

iv) Drop directions

- Valve up
- Valve down
- Two other mutually perpendicular directions

v) For power system or power unit tests, perform emissions testing in accordance with 7.3.14.

Passing Criteria: No fire at any time, no explosion at any time, no leakage. Methanol leakage shall be measured based upon the procedure described in Figures 2 and 4. Emissions shall meet acceptance criteria in 7.3.14. If the unit or system does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

7.3.6 Compressive loading test

Test sample: an unused fuel cartridge, and a half-filled fuel cartridge (45 – 55 % full), 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: To simulate the effects of the forces reasonably encountered due to being stepped on, or something heavy being placed on the fuel cartridge, fuel cell power unit, or fuel cell power system.

Test procedure

Test A: Power unit or system

i) The power unit/system test sample shall be placed between two flat wooden blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick.

ii) A crushing force shall be applied to the exposed surfaces of the enclosure gradually at a rate of 12,7 mm/min (1/2 inch/min).

iii) Each force applicator shall exert 25 kg ± 1 kg on the sample for 5 s.

iv) The test shall be carried out in three different orientations as a rule. If the sample does not stand on its own, it does not need to be tested in that orientation.

v) For power system or power unit tests, perform emissions testing in accordance with 7.3.14 following the crush test.

Test B: Cartridge

vi) The cartridge test sample shall be placed between two flat wooden blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick.

vii) A crushing force shall be applied to the exposed surfaces of the enclosure gradually at a rate of 12,7 mm/min (1/2 inch/min).

viii) Each force applicator shall exert 100 kg ± 1 kg on the sample for 5 s.

ix) 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 cartridge that is sufficiently cubic and the curved surface of a cylindrical cartridge with a longitudinal axis length longer than twice the diameter.

Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured on the basis of the procedure described in Figures 2 and 4, respectively. Emissions from power units or power systems shall meet the acceptance criteria in 7.3.14. If the unit or system does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

7.3.7 External short-circuit test

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: To simulate the effects of an external short circuit.

Test procedure

i) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power unit with wire having a maximum resistance load of 0,1 Ω for at least 5 min.

ii) Tests shall be executed in operation and non-operation of fuel cells respectively.

iii) Perform emissions testing in accordance with Clause 7.3.14 during and after short circuit testing.

Passing Criteria: No fire at any time, no explosion at any time, no leakage. The leakage is measured by the procedure in Figure 5. Exterior surfaces shall not exceed temperatures in Table 3 during or after short circuit testing. Emissions shall meet the acceptance criteria in 7.3.14. If the unit or system does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

NOTE This test can be done sequentially with the surface and exhaust gas temperature test using the same sample.

7.3.8 Surface and exhaust gas temperature test

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: To eliminate any risk of burn injury caused by contact with the enclosure of fuel cell power system or blown exhaust gas from the vent.

Test procedure

i) Temperature of the bare surface of micro fuel cell power units or micro fuel cell power systems operating at rated output shall be measured.

ii) The temperature of exhaust gas shall be measured at 1 cm of the exhaust vent of micro fuel cell power units and/or micro fuel cell power systems operating at rated output.

iii) Requirements: The micro fuel cell power unit or micro fuel cell power system shall comply with the criteria unless the surface temperature of parts and the temperature of exhaust gas, where persons can touch easily, exceeds the specific value. The maximum temperature at the casing surface shall not exceed the value shown in Table 3 depending upon the material. The temperature at 1 cm of the exhaust vent of the operating micro fuel cell shall be less than 70 °C.

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

7.3.9 Long-term storage test

Test sample: an unused fuel cartridge.

Purpose: To simulate the effects of long-term storage at elevated temperature and ensure no leakage.

Test procedure:

Option 1 (preferred)

i) Use a load cell designed and calibrated for use at 50 °C.

ii) Place the load cell in a temperature chamber at 50 °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 cartridge, to ensure all the weight is applied to the load cell.

iii) 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 0,33 g/h with a sample time of 10 min or less.

iv) If the fuel cartridge still has liquid fuel in the test sample at the end of the test then calculate the fuel vapour loss by the number of hours that the test sample was in the oven (28 days × 24 h/day = 672 h). If the average mass loss does not exceed 0,33 g/h, then the test sample passes the test for fuel vapour loss.

v) If the cartridge is empty prior to the end of the test and the weight change could have exceeded the 0,33 g/h fuel vapour criteria within a mass loss of 0,33 g then a new test sample must be re-tested with increased monitoring to assure that the criteria of 0,33 g/h is not exceeded.

vi) If the cartridge did exceed the 0,33 g/h fuel vapour loss criteria then the test sample fails the test.

Option 2A

For a fuel cartridge containing 70 ml of fuel or more.

i) Weight measurements should be collected with a high degree of confidence to assure that the fuel vapour loss does not exceed 0,33 g/h with a minimum of once per week.

ii) The time in which the test samples are removed from the oven for measurement, shall not be included in the time the test sample is to be tested (28 days). Additional time should be added to the total test time to allow for re-heating the test sample after each removal from the oven. The test samples should only be stabilized at room temperature if the mass loss will be affected.

iii) If the fuel cartridge still has liquid fuel in the test sample at the end of the test then calculate the fuel vapour loss by the number of hours that the test sample was in the oven (28 days × 24 h/day = 672 h) and as long as the average mass loss does not exceed 0,33 g/h then the test sample passes the test for fuel vapour loss.

iv) If the cartridge is empty prior to the end of the test and the weight change could have exceeded the 0,33 g/h fuel vapour criteria within a mass loss of 0,33 g then a new test sample shall be re-tested with increased monitoring to assure that the criteria of 0,33 g/h was not exceeded.

v) If the cartridge did exceed the 0,33 g/h fuel vapour loss criteria, then the test sample fails the test.

Option 2B

For a fuel cartridge containing less than 70 ml of fuel (option 1 is preferred for test samples containing less than 70 ml of fuel).

i) Weight measurements should be collected with a high degree of confidence to assure that the fuel vapour loss does not exceed 0,33 g/h with a minimum of once every three days.

ii) The time the test samples are removed from the oven 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 °C) each time the test sample is removed from the oven. The test samples should only be stabilized at room temperature if the mass loss will be affected.

iii) If the fuel cartridge still has liquid fuel in the test sample at the end of the test, then calculate the fuel vapour loss by the number of hours that the sample was in the oven (28 days × 24 h/day = 672 h) and, as long as the average mass loss does not exceed 0,33 g/h, then the test sample passes the test for fuel vapour loss.

iv) If the cartridge is empty prior to the end of the test and the weight change could have exceeded the 0,33 g/h fuel vapour criteria within a mass loss of 0,33 g then a new test sample shall be re-tested with increased monitoring to assure that the criteria of 0,33 g/h was not exceeded.

v) If the cartridge did exceed the 0,33 g/h fuel vapour loss criteria, then the test sample fails the test.

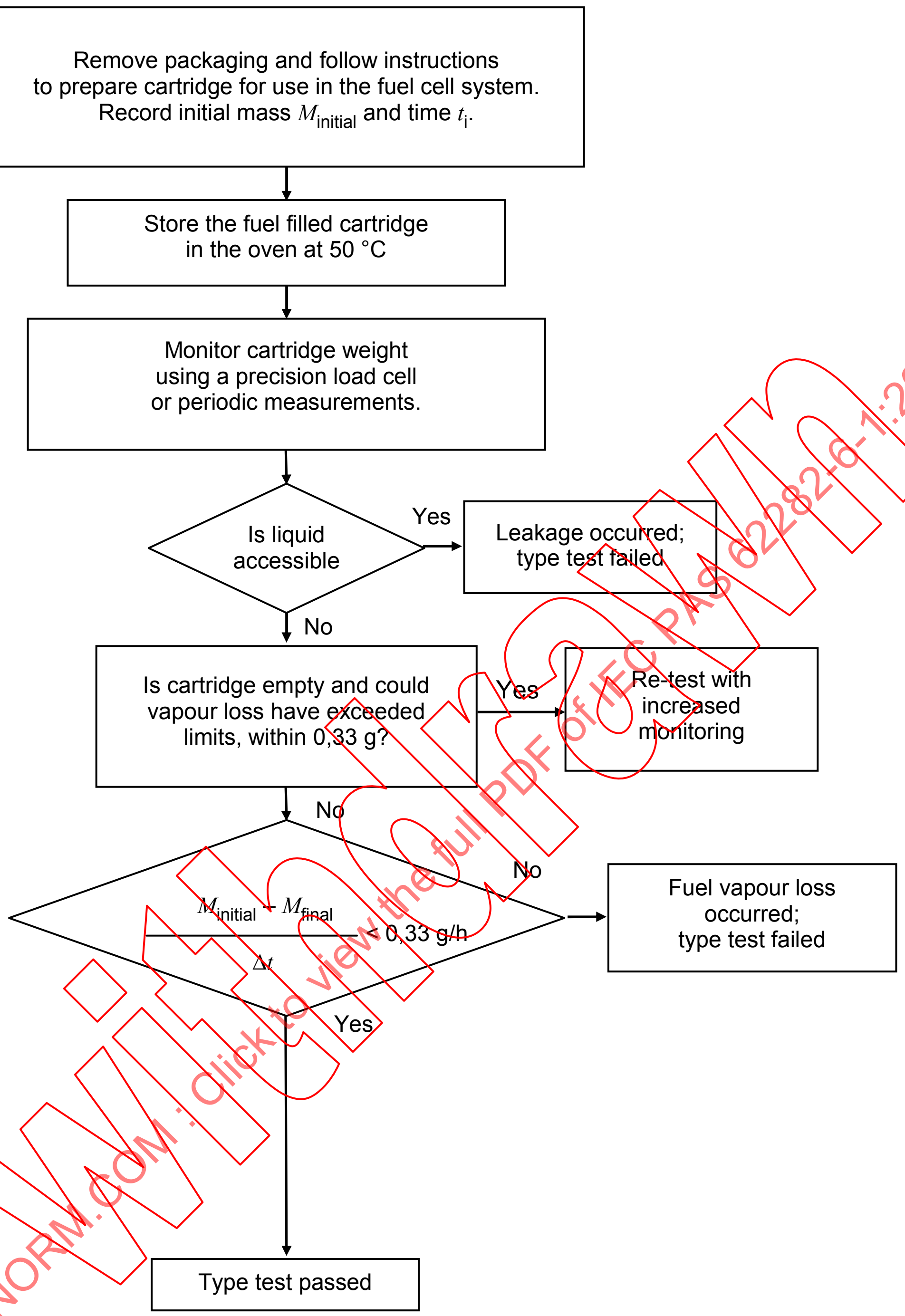


Figure 7 – Fuel cartridge leakage and mass-loss flow chart for long-term storage

7.3.10 High-temperature connection test

Test sample: an unused fuel cartridge and a micro fuel cell power unit or micro fuel cell power unit valve.

Purpose: To simulate the effects of mating and un-mating of the fuel cartridge to the 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.

Test procedure:

i) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of 50 °C ± 2 °C for at least 4 h.

ii) The micro fuel cell power unit or micro fuel cell power unit valve is kept at normal room temperature, 22 °C ± 5 °C.

iii) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve within 5 min of removal from the chamber.

iv) Check for leakage upon connection.

v) Disconnect the fuel cartridge and check for leakage.

vi) Acceptance criteria: No leakage, no fire, and no explosion. If, using normal force, the cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, this is acceptable.

vii) Leakage shall be checked visually. Invert the 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.

viii) Flame shall be checked using cheesecloth.

ix) Explosion shall be checked visually to verify no disturbance to the system or the test cell.

7.3.11 Fuel cell power unit internal pressure test

Purpose:

a) To test those parts of the fuel cell power system that maintain high fuel pressure during operation or storage such as the sections between the cartridge and the system including the regulator valve or fuel pump or whatever is subject to a high pressure.

b) To test that there is no leakage at the cartridge connection.

Approach: Pressurize with a liquid through a test fixture that has a valve to simulate the cartridge connection; or put a connection at the outboard end of a standard cartridge.

Test procedure

i) Connect a cartridge valve with a cartridge connection and having a special pressurizing fitting to a fuel cell power unit.

ii) Using a suitable liquid pressurizing medium such as water, pressurize the fuel cartridge connection and the downstream system to a pressure which is greater than 95 kPa plus normal working pressure or two times the fuel vapour pressure at 55 °C. The pressure rise shall not exceed 60 kPa per second.

iii) Maintain pressure for 30 min.

iv) Acceptance criteria: No accessible liquid test medium leakage. No sudden drop in pressure.

7.3.12 Connection cycling tests

7.3.12.1 Cartridge

7.3.12.1.1 Insert/exterior/or attached cartridge systems

Test sample: an unused fuel cartridge and a micro fuel cell power unit or micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions.

Purpose: To simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage.

Test procedure

i) Connect the first new fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection.

ii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

iii) Turn off the unit or stop simulated fuel flow.

iv) Disconnect the fuel cartridge and check for leakage.

v) Repeat this twice more for a total of three connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the first cartridge four more times for a total of seven connections and disconnections.

viii) The cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

ix) Connect and disconnect the first cartridge three more times for a total of ten connection and disconnections.

x) Invert the cartridge and the system over indicating paper such that the valve points downward toward the indicating paper and look for signs of leakage.

xi) Connect cartridge and operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

xii) Turn off the unit or stop simulated fuel flow

xiii) Disconnect the fuel cartridge and check for leakage.

xiv) Acceptance criteria: No leakage, no fire, and no explosion.

xv) Leakage shall be checked visually and if any accessible liquid leakage is found the test fails.

xvi) The flame shall be checked using cheesecloth.

xvii) Explosion shall be checked visually to verify that there is no disturbance to the system or the test cell.

7.3.12.1.2 Satellite cartridge

Test sample: an unused satellite fuel cartridge and a micro fuel cell power unit or micro fuel cell power unit valve fuelled in accordance with the manufacturer's instructions.

Purpose: To simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage.

Test procedure

i) Connect the first new fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection.

ii) Disconnect the fuel cartridge and check for leakage.

iii) Repeat this twice more for a total of three connections and disconnections.

iv) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

v) Connect and disconnect the first cartridge four more times for a total of seven connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the first cartridge three more times for a total of 10 connection and disconnections.

viii) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

ix) Repeat steps i) through viii) four more times for a total of 50 cycles, waiting 1 h between each set of 10 cycles.

x) Acceptance criteria: No leakage, no fire, and no explosion.

xi) Leakage shall be checked visually and, if any accessible liquid leakage is found, the test fails.

xii) The flame shall be checked using cheesecloth.

xiii) The explosion shall be checked visually to verify that there is no disturbance to the system or the test cell.

7.3.12.2 Micro fuel cell power unit

Test sample: a minimum of two unused cartridges and an additional 98 cartridges or cartridge valves and a micro fuel cell power unit fuelled in accordance with the manufacturer's instructions.

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.

Cartridge 1 and cartridge 100 are inspected, the other 980 cycles are only to age the system.

Test procedure

Cartridge 1

i) Connect the first unused fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

ii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

iii) Turn off the unit or stop simulated fuel flow.

iv) Disconnect the fuel cartridge and check for leakage.

v) Repeat this twice more for a total of three connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the first cartridge four more times for a total of seven connections and disconnections.

viii) Invert the cartridge and the system over indicating paper in such a way the the valve points downward toward the indicating paper and look for signs of leakage.

ix) Connect and disconnect the first cartridge three more times for a total of 10 connection and disconnections.

x) Invert the cartridge and the system over indicating paper in such a way the the valve points downward toward the indicating paper and look for signs of leakage.

xi) Connect the fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

xii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

xiii) Turn off the unit or stop simulated fuel flow.

xiv) Disconnect the fuel cartridge and check for leakage.

xv) Acceptance criteria: No leakage, no fire, and no explosion.

xvi) Leakage shall be checked visually and if any accessible liquid leakage is found the test fails.

xvii) The flame shall be checked using cheesecloth.

xviii) The explosion shall be checked visually to verify that there is no disturbance to the system or the test cell.

Power unit connection ageing

Using either cartridges or cartridge valves, cycle the micro fuel cell power system connection for a total of 980 connections and disconnections. Inversion of the system or the cartridges is not necessary, but, if leakage is found, the test fails. Following this ageing, a final unused cartridge will be tested.

Final cartridge

i) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

ii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

iii) Turn off the unit or stop simulated fuel flow.

iv) Disconnect the fuel cartridge and check for leakage.

v) Repeat this twice more for a total of three connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way the the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the final cartridge four more times for a total of seven connections and disconnections.

viii) Invert the cartridge and the system over indicating paper in such a way the the valve points downward toward the indicating paper and look for signs of leakage.

ix) Connect and disconnect the final cartridge three more times for a total of 10 connection and disconnections.

x) Invert the cartridge and the system over indicating paper in such a way the the valve points downward toward the indicating paper and look for signs of leakage.

xi) Connect the fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

xii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

xiii) Turn off the unit or stop simulated fuel flow.

xiv) Disconnect the fuel cartridge and check for leakage.

xv) Acceptance criteria: No leakage, no fire, and no explosion.

xvi) Leakage shall be checked visually and, if any accessible liquid leakage is found, the test fails.

xvii) The flame shall be checked using cheesecloth.

xviii) The explosion shall be checked visually to verify that there is no disturbance to the system or the test cell.

7.3.13 Vacant

7.3.14 Emission test

Test samples: 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 storing or operating conditions of micro fuel cell power unit or micro fuel cell power system, which is fuelled with methanol, emission of CO/CO2 gas and organic compounds such as methanol, formaldehyde, formic acid and methyl formate shall be maintained under the specific values.

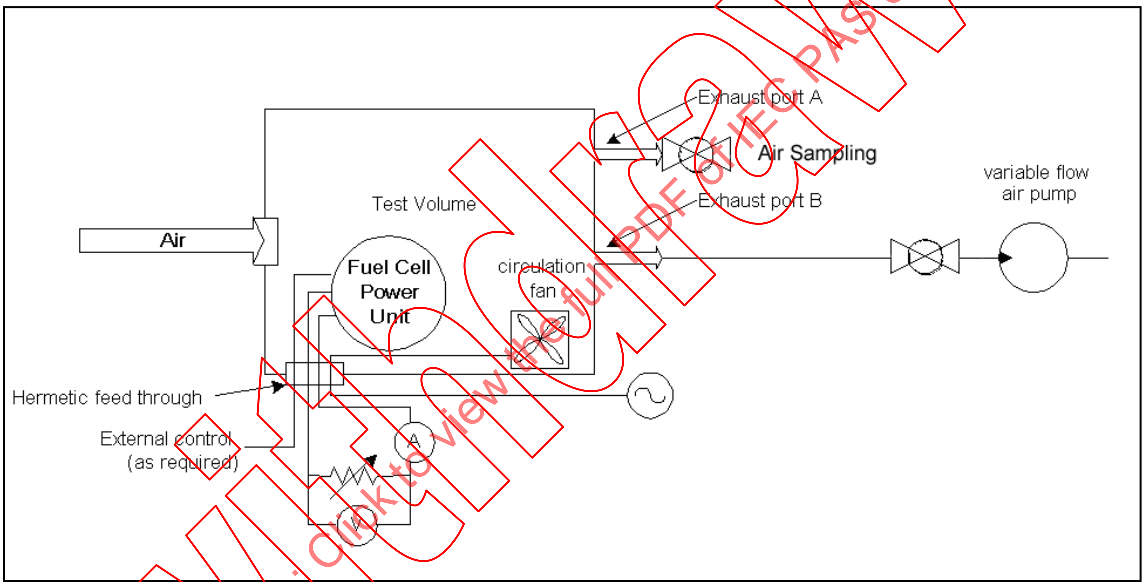


Figure 8 – Operational emission test apparatus

An example of the operational emission test apparatus is shown in Figure 8.

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

ii) To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) and a high-performance liquid chromatography (HPLC) shall be used by absorbing emission gas to the sorbent tube fixed to exhaust port A of the test chamber or directly to an analyzer through exhaust port A in Figure 8.

iii) The concentration of CO and CO2 gas can be measured by non-disperse 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, or better than, that of the above-mentioned standards.

Test procedure

i) Operate the micro fuel cell power unit or micro fuel cell power system at rated power inside the small test chamber shown in Figure 8. The small test chamber shall be supplied with clean air.

ii) Exhaust gas from micro fuel cell power unit or micro fuel cell power system shall be sampled at the outlet of the small test chamber.

iii) 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) Sample the gaseous contents of the test chamber through sampling Port A, while measuring and recording flow through the system.

v) Record the concentrations of chemical compounds of interest, see Table 8.

vi) Calculate the emission rate of chemical compounds being emitted by multiplying the concentration of each constituent by the flow rate of air through the system and compare the maximum measured emission rate to Table 8.

vii) Acceptance criteria: The maximum emission rate for each of the constituents of interest shall be less than the emission rate limit value in Table 8. If the fuel cell does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.

Table 8 – Emission limits

	Concentration limit	Emission rate limit*
Water	Unlimited	No limit
Methanol	260 mg/m^3	2600 mg/h
Formaldehyde	0,1 mg/m^3**	0,6 mg/h
CO	29 mg/m^3	290 mg/h
CO2	9 g/m^3	60 000 mg/h***
Formic acid	9 mg/m^3	90 mg/h
Methyl formate	245 mg/m^3	2450 mg/h

* The emission rate limit was based on 10 m^3 · ACH, selected as the product of the reference volume times the air changes per hour (ACH) volume because it covers the reasonably foreseeable environments where MFC systems will be used. The interior space in a small car and the minimum volume per person on commercial aircraft is at 1 m^3. 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 m^3, so a product of 10 is conservative.

** WHO guideline limit is 0,1 mg/m^3. Background levels are 0,03 mg/m^3. The emission limit cannot push the background level above the guideline limit.

*** A seated adult has a CO_2 emission rate of 30 000 mg/h. The fuel cell plus human emission rates are limited to 9 g/m^3, so the fuel cell emission rate is limited to 60 000 mg/h.

Annex A
(Normative)

formic acid fuel cell systems

This annex for formic acid fuel cell (FAFC) systems outlines the additional or modified requirements with respect to the requirements contained in the main body of this PAS, for certification of such fuel cell power systems and their respective fuel cartridges. Where possible, the numbering system of this annex corresponds to the numbering of clauses in the main body. Requirements from the main body of this PAS not specifically discussed in this annex apply to formic acid fuel cell systems as written. Modified clause numbers reflect their counterpart clause in the main body. Any additional clauses have been assigned new numbers. This Annex A establishes modifications and additions to the main body of the PAS for application to the fuel and technologies addressed by this annex.

A.1 Scope

A.1.1 System boundary

Except where specifically noted, 1.1 and 1.2 of IEC 62282-6-1 shall apply as written when used in conjunction with this annex.

A.1.1.1 Fuel and technology covered by this annex

A.1.1.1.1 This annex covers micro fuel cell power units that use less than 85 % formic acid by weight in water solution as a fuel.

A.1.1.1.2 This annex includes equipment designs that currently include direct formic acid fuel cell stacks (DFAFC).

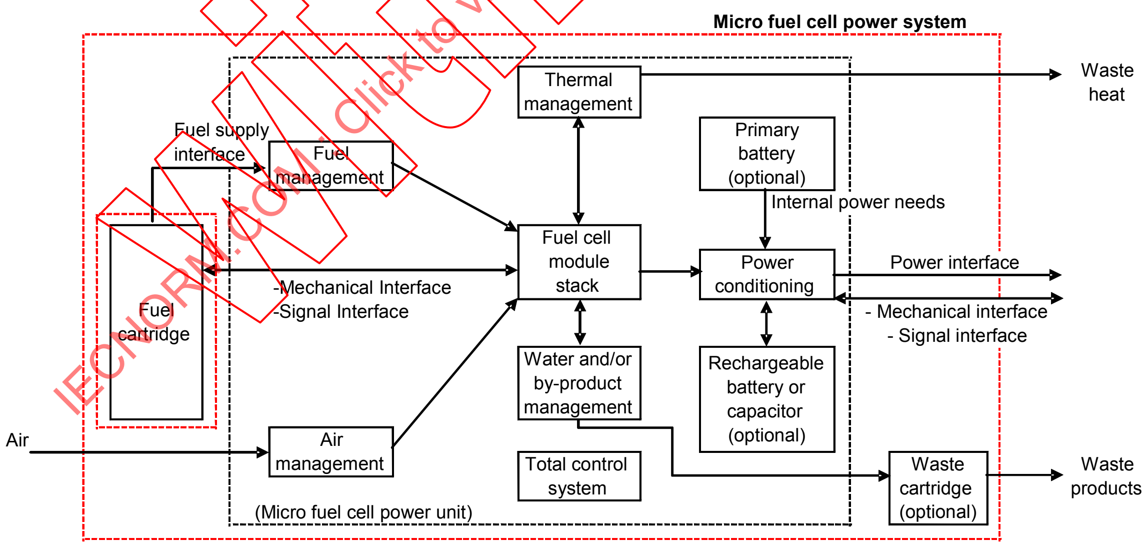


Figure A.1 – Formic acid fuel cell system diagram

A.1.2 Considerations

In addition to the "equivalent level of safety" statement in 1.2 of the main body of this PAS, the following considerations also apply to FAFC systems.

A.1.2.1 The following similarities, A.1.2.1.1 to A.1.2.1.3, between methanol and formic acid fuel cell systems is being mentioned to provide better understanding of why the formic acid requirements mimic methanol requirements with minimal changes.

A.1.2.1.1 The similarity in fuel cell system components (see figure 1 and figure A.1).

A.1.2.1.2 Both systems use liquid fuels and both systems have the "no-accessible liquid" criteria for no leakage (see definitions in Clause 3).

A.1.2.1.3 Both systems have similar emissions (differences highlighted in this annex) thus have similar criteria for measurement and analysis of the emissions and similar considerations for the emissions risk levels.

A.1.2.2 Any considerations/requirements contained within the main body of this PAS specifically pertaining to quantities of methanol or methanol vapour are only applicable to formic acid if similar quantities are stated for formic acid in this annex.

A.1.2.3 Formaldehyde and methyl formate emissions seen in methanol systems are not present in formic acid 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 (e.g., > 200 °C), pressures (e.g., >100 atmospheres), and in the presence of typical hydrogenation catalysts (e.g., transition metal oxides). These conditions are not expected to be seen in the formic acid fuel cell system; thus these three emission products do not have to be considered in formic acid fuel cell systems.

A.1.2.4 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. Formic acid fuel cell cartridges and power units are not expected to be subjected to such high temperatures. Properly functioning non-operating systems have fail-safe mechanisms to prevent fuel flow to the catalysts. Failure modes and effects analysis and related testing should ensure protection against such failure modes and ensure existence of relevant design mitigations.

A.1.2.5 Carbon monoxide and formic acid vapour are the only possible emissions from formic acid fuel cell cartridges or from non-operational (device-off) fuel cell systems.

A.1.2.6 Carbon dioxide, carbon monoxide, formic acid vapour, hydrogen and water vapour are all possible emissions from an operational (device-on) fuel cell system.

A.1.2.7 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 fuel cell system products.

A.2 Normative references

Clause 2 applies as written when used in conjunction with this annex.

A.3 Terms and definitions

Except as noted below the terms and definitions of Clause 3 shall apply when used in conjunction with this annex. The numeric index of the term and definitions below correspond to the term in Clause 3 with an alternative meaning when considering a device for testing under this annex.

A.3.3
fuel
formic acid fuel is formic acid / water solution less than 85 percent concentration by weight that is used to produce electricity in a fuel cell unit

A.3.12
hazardous (corrosive) liquid fuel
formic acid fuel that has a pH less than 2,5 (pH of 2,5 is approximately 0,5 % formic by weight in water)

A.3.14
leakage
accessible hazardous liquid fuel outside the system or cartridge or a positive pH indication of liquid formic acid (see A.3.12 and A.3.27)

A.3.20
no fuel vapour loss
fuel vapour escaping from the cartridge or system is less than 18 mg/h

A.3.27
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) wrapped around the device during the type test. Attention should be paid to not wrongly interpret the acidic nature of condensate (pH as low as 4,5), as an acid, in the temperature cycling and low temperature type tests

A.3.28
impermissible hydrogen emissions
release of hydrogen that results in one or a combination of the following situations that are deemed unsuitable:

a) hydrogen-in-air mixture in excess of 25 % of the lower flammability limit of hydrogen in the reference volume of 10 m^3 ACH (cubic meter air changes per hour) (see Table A.1).

or

b) leakage rate of hydrogen greater than 3 sccm (standard cubic centimeters per minute) from any single source

A.4 Materials and construction of fuel cartridge, micro fuel cell power unit, and micro fuel cell power system for portable device

A.4.1.1 General

Except where specifically noted, Clause 4 shall apply for the purposes of this annex. Where subclauses corresponding to those in Clause 4 of IEC 62282-6-1 are not included in this annex and do not contain specific mention of methanol, it shall be assumed that said clauses are to apply to this annex as written.

A.4.17.1.3 Maximum formic acid fuel volume shall not exceed 200 ml for products intended for carry-on and use in passenger aircraft. One litre is the limit for other applications.

A.5 Requirements of fuel cartridge, micro fuel cell power unit, and micro fuel cell power system

Except where specifically noted, Clause 5 of IEC 62282-6-1 shall apply for the purposes of this annex. Where subclauses corresponding to those in Clause 5 are not included in this annex and do not contain specific mention of methanol, it shall be assumed that said clauses are to apply to this annex as written.

A.6 Instructions and warnings for fuel supply cartridges, micro fuel cell power units, and micro fuel cell power systems using formic acid as a fuel

Except where specifically noted, Clause 6 shall apply for the purposes of this annex. Where subclauses corresponding to those in Clause 6 are not included in this annex and do not contain specific mention of methanol, it shall be assumed that said clauses are to apply to this annex as written.

A.6.1 Minimum markings required on the cartridge

A.6.1.1 Contents are corrosive, do not dissassemble

A.7 Type tests for a fuel cartridge, a micro fuel cell power unit, and a micro fuel cell power system

Except where specifically noted below, Clause 7 shall apply as written. For most of this clause (excluding 7.3.14), mention of the terms methanol and methanol limits for liquid leakage (no accessible liquid) and no fuel vapour loss (0,33 g/h) can be directly replaced with the terms formic acid and formic acid limits for liquid leak (no accessible liquid) and no fuel vapour loss (0,18 mg/h) in all type tests. Also, pH paper, wrapped around the device, may be used to aid in the visual check for liquid formic acid leaks (see A.3.27). For operational tests, reactant air passages into the system and exhaust ports should not be blocked with pH paper.

A.7.3.9 Long-term storage test

Option 1 and Option 2A are not preferred for formic acid cartridges due to the very low anticipated vapour loss.

Option 2B (preferred for formic acid cartridges) with the 0,33 g/h value for methanol vapour loss replaced with 18 mg/h for formic acid vapour loss and the sampling period set to a minimum of once every four days.

The positive indication of an acid on pH paper wrapped around the cartridge or a continuous vapour loss of greater than 18 mg/h would indicate a failure.

Due to the similarity in the boiling points of formic acid and water, the amount (percentage) of water vapour present in the total vapour lost from the cartridge, will be approximately the same percentage of water in the formic acid fuel (15 % for the 85 % formic acid fuel). Thus if the total vapour loss rate is greater than 18 mg/h, then consideration can be given to subtracting out the water content in the vapour according to its percentage in the fuel. Due to the extremely low formic acid to carbon monoxide decomposition rate at 50 °C and the human exposure limit to carbon monoxide (TWA = 25 ppmv and STEL = 200 ppmv) 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 after subtracting the water content from the total vapour loss, it does not pass the 18 mg/h limit, then a full emission test (7.3.14) can be performed for the device-off (or cartridge only) situation at 50 °C in the 1 $m^3 \cdot$ ACH volume and all emission components measured.

A.7.3.14 Emission test

Purpose: Under storing (considered device-off or cartridge only situations) or operating conditions (considered device-on and producing power situations), formic acid fuel cell system emissions of formic acid vapours, carbon-dioxide, carbon-monoxide, hydrogen, and water vapours shall be maintained at less than the specific values as stated in Table A.1.

Table A.1 – Allowable emissions limits and rates

Emissions	**Concentration limit**[a] based on TWA values for Device-On test condition	**Concentration limit**[a] based on STEL values for Device-Off 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	29 mg/m^3	232 mg/m^3	232 mg/h	290 mg/h
CO_2	9 000 mg/m^3	54 000 mg/m^3	Not applicable (see A.1.2.5)	60 000 mg/h[d]
Formic acid	9 mg/m^3	18 mg/m^3	18 mg/h	90 mg/h
Hydrogen	800 mg/m^3	800 mg/m^3	Not applicable (see A.1.2.5)	8 000 mg/h or 4 mg/h (flammable hydrogen)

a The concentration limit in this table is the mg/m^3 equivalent of the TWA and STEL Exposure Limits, quoted in ppmv, in Table A.2.

b The Device-On emission rate limit is based on 10 m^3 · ACH, selected as the product of the reference volume times the air changes per hour (ACH) volume because it covers the reasonably foreseeable environments where micro fuel cell systems will be used. The interior space in a small car and the minimum volume allocation per person on commercial aircraft is at 1 m^3. 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 m^3, so a product of 10 is conservative.

c The Device-Off emission rate is based on 1 m^3 · ACH because it covers the reasonably foreseeable environments where fuel cell 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 adult has a CO_2 emission rate of 30 000 mg/h. The fuel cell plus human emission rates are limited to the 9 000 mg/m^3, so the fuel cell emission rate is limited to 60 000 mg/h.

Table A.2 – Safe human exposure limits to fafc emission products

Exhaust component	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)
Carbon-dioxide	< 5 000 ppmv	<30 000 ppmv
Formic acid vapours (toxicity)	< 5 ppmv	<10 ppmv
Carbon-monoxide	< 25 ppmv	<200 ppmv
Hydrogen	< (25 % of LFL) = 1 % (10 000 ppmv) in sample collected from reference volume at stable operation or less than 3 ml/min flammable hydrogen emission rate at leak point.	< (25 % of LFL) = 1 % (10 000 ppmv) in sample collected from reference volume at stable operation or less than 3 ml/min flammable hydrogen emission rate at leak point.

Test apparatus

iv) In addition to the equipment described in 7.3.14, a hydrogen detector calibrated for the zero-to-one- percent (10 000 ppmv) hydrogen can be used to measure the hydrogen concentration.

Test Procedure (continued)

Upon completion of the emissions measurements described in 7.3.14, if the hydrogen measurement is below the allowable 10 000 ppmv but exceeds 180 ppmv then proceed with the following local flammable hydrogen concentration test.

viii) Local flammable hydrogen concentration test

The test for hydrogen emissions is done as part of the emissions test procedure. If the hydrogen emissions level is higher than 10 000 ppmv (25 % of LFL) then the device has failed. If the hydrogen emissions level is less than 180 ppmv (corresponding to a 3 ml/min leak) then the device has passed the emission test and no further checks are needed. If the hydrogen level is above 180 ppmv but less than 10 000 ppmv (25 % of LFL) then proceed to check the existence of local flammable concentrations of hydrogen (in the vicinity of the device). This test is as follows.

a) Using a fast response time hydrogen leak detector with a point source sampler that is calibrated to detect 25 % of LFL for hydrogen, scan/sweep the device surface, while it is operating, as close (less than 3 mm normal) to the surface as possible.

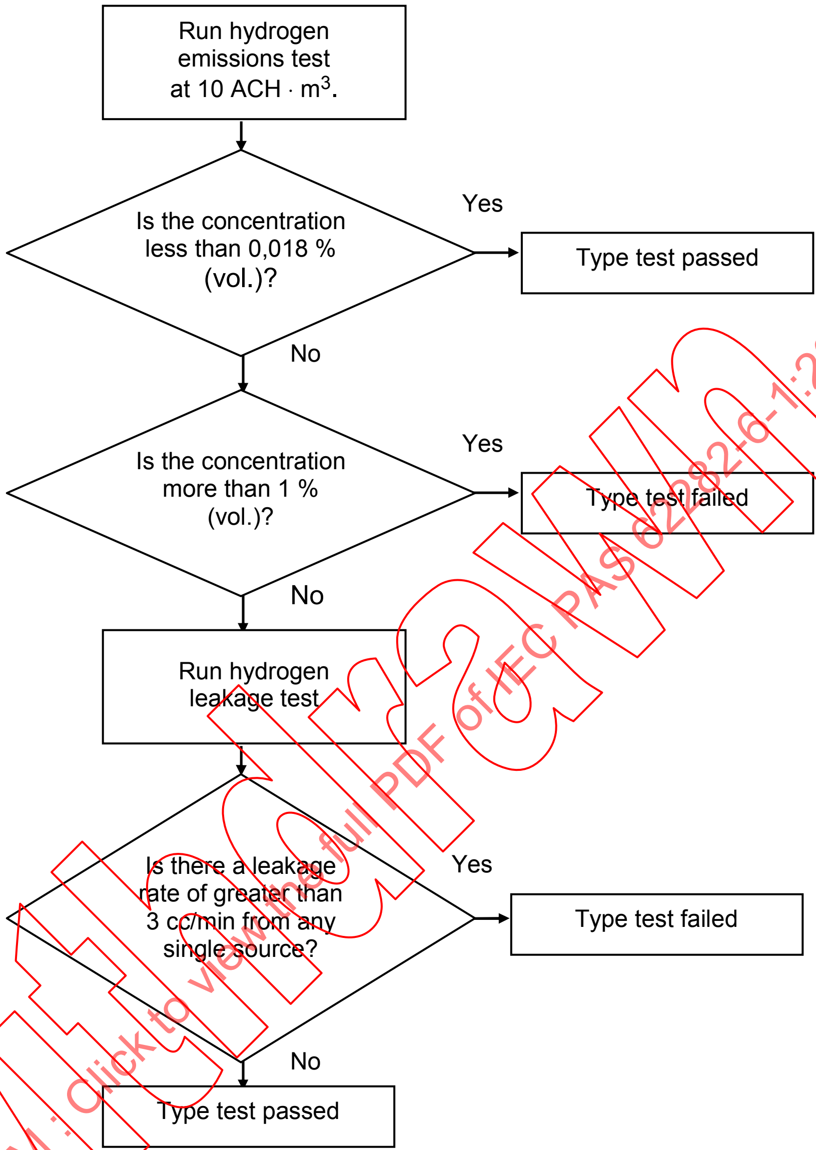
b) If not more than 25 % of LFL is not detected, then the device passes the test and no further investigation is needed. If it does not pass the test, then proceed to c).

c) If any points are detected to have a hydrogen concentration of 25 % LFL or greater, a second test must be conducted to ensure that the emission does not exceed 3 cc/min of pure hydrogen from any single source.

   1) The second test shall be performed using the following procedure: the sensor height shall be adjusted from 3 mm above the device to 6,5 mm above the device.

   2) 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 must have a spacing of 1 mm or less between sweeps and must spiral out to a radial distance of at least 4 mm.

   3) If the spiral sweep at 6,5 mm above the device detects a concentration of hydrogen that is 25 % of LFL or greater, then the device fails. If the spiral sweep detects hydrogen concentrations of not more than 25 % LFL, then the device passes.



NOTE 1 The allowable flammable hydrogen emission level that will not support a standing flame is 3 ml/min (Codes and Standards Analysis, Swain and Swain, 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 confined space.

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 for 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.2 – Hydrogen emissions measurement flow chart

Annex B
(normative)

Hydrogen stored in hydrogen absorbing metal alloy

This annex, for proton exchange membrane fuel cells powered by hydrogen gas stored in an hydrogen absorbing metal alloy, outline the additional or modified requirements with respect to the requirements contained in the main body of this PAS, for certification of such fuel cell power systems and their respective fuel cartridges. Where possible, the numbering system of this annex corresponds to the numbering of clauses in the main body. Requirements from the main body of this PAS not specifically discussed in this annex apply to hydrogen fuel cell systems as written. Modified clause numbers reflect their counterpart clause in the main body. Any additional clauses have been assigned new numbers. This annex establishes modifications and additions to the main body of the PAS for application to the fuel and technologies addressed by this annex.

B.1 Scope

B.1.1 System Boundary

Except where specifically noted, Subclause 1.1 shall apply as written when used in conjunction with this annex.

B.1.1.6 Fuel and technology covered by this annex

B.1.1.6.1 This annex shall apply fuel cells powered by hydrogen gas stored in a hydrogen absorbing metal alloy.

B.1.1.6.2 This annex includes equipment designs that include proton exchange membrane (PEM) fuel cell stacks.

B.1.1.6.3 This subclause applies as written.

B.1.1.6.4 This subclause applies as written.

B.1.2 This subclause applies as written.

B.1.3 Considerations

B.1.3.1 Hydrogen is not toxic; therefore, sentences concerning toxicity of fuel in the main body of IEC 62282-6-1 shall not apply in this annex. In addition, the by-products of a hydrogen powered PEM fuel cell (heat and water) are not toxic; therefore, clauses and subclauses concerning toxicity of emissions in the main body of this PAS shall not apply in this annex.

B.1.3.2 Any descriptions contained within the main body specifically pertaining to methanol are also not applicable.

B.1.3.3 The fuels covered by this annex are flammable. The requirements and tests specified by this annex are designed to mitigate this risk and ensure a reasonable degree of safety for normal use, reasonably foreseeable misuse, and consumer transportation.

B.2 Normative references

In addition to the normative references specified in Clause 2, the following normative document contains provisions that, through reference in this text, constitute provisions of this annex, as applicable.

ISO 16111, *Transportable gas storage devices – hydrogen absorbed in reversible metal hydride*[1)]

This reference shall apply in principle to the fuel cartridge of all devices tested under this annex. Devices with a fuel cartridge water capacity of less than 120 ml shall be exempt from specific sections of this reference, as outlined in this annex. In cases where exemptions have been outlined, the cartridge shall still be designed to an acceptable level of safety, and shall successfully pass all other required type tests.

B.3 Terms and definitions

Except as noted below, the terms and definitions of Clause 3 shall apply to this annex. The numeric index of definitions below correspond to the term in Clause 3 with an alternative meaning when considering a device for testing under this annex. Terms and definitions not included in this annex are to apply as defined in Clause 3.

B.3.4
fuel
For this annex, hydrogen gas, stored in a hydrogen-absorbing metal alloy

B.3.13
leakage
not applicable

B.3.18
leakage
hydrogen gas escaping from the cartridge or system that results in one or a combination of the following situations:

a) fuel vapour in air mixture in excess of 25 % of the lower flammability limit of hydrogen in the control volume;

b) leakage rate of hydrogen greater than 3 standard cc/min from any single source

B.3.23
no accessible liquid
not applicable

B.3.24
no fuel vapour loss
hydrogen gas escaping from the cartridge or system does not result in one or a combination of the following situations:

a) fuel vapour in air mixture in excess of 25 % of the lower flammability limit of hydrogen in the control volume;

b) leakage rate of hydrogen greater than 3 standard cc/min from any single source

1) To be published.

B.3.25
no leakage
hydrogen gas escaping from the cartridge or system does not result in one or a combination of the following situations:

a) fuel vapour in air mixture in excess of 25 % of the lower flammability limit of hydrogen in the control volume;

b) leakage rate of hydrogen greater than 3 standard cc/min from any single source

B.4 Materials and construction of fuel cartridge, micro fuel cell power unit, and micro fuel cell power system for portable devices

B.4.1 General

Except where specifically noted, Clause 4 shall apply for purposes of this annex. Where subclauses corresponding to those in Clause 4 are not included in this annex, it shall be assumed that said clauses are to apply to this annex as written. Due to the nature of the fuel considered for this annex, all subclauses of Clause 4 that refer to methanol or considerations for parts in contact with liquids shall not apply to devices tested under this annex. The material and construction of fuel cartridges having a volumetric capacity greater than 120 ml shall also comply with ISO/TS 16111.

B.4.4 General materials

B.4.4.1 Subclause 4.4 shall apply as written.

B.4.4.2 In addition, fuel cartridges with greater than 120 ml volumetric capacity shall comply with materials and construction requirements of ISO/TS 16111.

B.4.5 Selection of materials

Subclauses of IEC 62282-6-1 related to the selection of materials based on compatibility with liquid fuels are not applicable to systems tested under this annex due to the fact that these systems employ gaseous fuel (hydrogen). All other subclauses shall apply as written.

B.4.5.7 In addition, fuel cartridges with a volumetric capacity of greater than 120 ml shall comply with the general materials requirements of ISO/TS 16111.

B.4.5.8 Fuel containing parts, such as piping systems, shall employ materials suitable for exposure to hydrogen, as defined in ISO/TS 16111. In particular, Annex A of ISO/TS 16111 details material compatibility for hydrogen service.

B.4.7 General construction

Subclause 4.7 shall apply as written.

B.4.9 Piping and fittings

Subclause 4.9 shall apply as written when used in conjunction with this annex.

B.4.10 Fuel containing parts and piping system

Subclause 4.10 shall apply as written with the following additions.

B.4.10.4 Fuel-containing parts, such as piping systems, shall employ materials suitable for exposure to hydrogen, as defined in ISO 16111. In particular, Annex A of ISO/TS 16111 details material compatibility for hydrogen service.

B.4.11 Materials and construction – System

Except as specifically noted below, Subclause 4.11 shall apply as written.

B.4.11.1 The maximum quantity of hydrogen stored in the fuel cell power unit shall not be more than 25 g.

B.4.12 Ignition sources

Subclause 4.12 shall apply as written.

B.4.13 Enclosures and acceptance strategies

Subclause 4.13 shall apply as written.

B.4.14 Protection against fire, explosion, corrosivity, and toxicity hazards

Subclause 4.14 shall apply as written with the following modifications.

B.4.14.1 Flammable fluids, in particular, hydrogen gas, shall be kept within a closed containment system, such as within fuel piping, in a reservoir, a cartridge, or similar enclosure. Leak testing in accordance with B.7.2 verifies this requirement.

B.4.15 Protection against electrical hazards

Subclause 4.15 shall apply as written.

B.4.16 Fuel cell stack

Subclause 4.16 shall apply as written.

B.4.17 Fuel supply construction

Except where specifically noted, Subclause 4.17 shall apply as written when used in conjunction with this annex.

B.4.17.1.2 There must be no leakage from the cartridge at an internal pressure of 95 kPa internal gauge pressure plus normal working pressure at 22 °C or two times the working pressure of the cartridge at 55 °C, whichever is greater.

B.4.17.1.3 The maximum quantity of hydrogen gas permitted is 100 g.

B.4.17.1.10 This subclause shall apply as written, except where the type tests of 7.3 have been altered in B.7.3. Where type tests have been modified, the modified version shall be used to verify compliance with this subclause.

B.4.17.1.13 In addition to the above requirements, fuel cartridges with a volumetric capacity greater than 120 ml shall comply with ISO/TS 16111.

B.4.17.1.14 Fuel cartridges having a water capacity of less than 120 ml shall be subject to the requirements of ISO/TS 16111 with the following exceptions.

B.4.17.1.14.1 Subclause 5.1 of ISO/TS 16111 shall not apply. The shell of the fuel cartridge must still be designed to comply with all applicable type tests set out in ISO/TS 16111.

B.4.17.1.14.2 Section 5.4 of ISO/TS 16111 shall permit the use of vent features that are properly designed as an integral feature of the shell of the tank.

B.4.17.1.14.3 Section 6.1 of ISO/TS 16111 shall apply with modified acceptance criteria to accommodate shells with integral vent features.

B.4.17.1.15 The maximum volumetric capacity of the fuel cartridge shall not exceed 1 litre.

B.4.17.2 Fuel cartridge fill requirement

B.4.17.2.1 The fuel cartridge shall not be filled beyond its design capacity, as defined in ISO/TS 16111.

B.4.17.2.2 The maximum pressure of the fuel cartridge shall not exceed 5 MPa at 55 °C.

B.4.18 Protection against mechanical hazards

Except where specifically noted, subclause 4.18 shall apply as written.

B.4.18.1.1 This subclause shall apply as written, except that compliance with 4.18.1.1 shall be determined by B.7.3.1 and B.7.3.11, not 7.3.1 and 7.3.10 as stated in the main body of this PAS.

B.4.18.1.2 This clause shall apply as written, except that compliance with 4.18.1.2 shall be determined by B.7.3.3 and B.7.3.5 instead of 7.3.3 and 7.3.5, as stated in the main body of this PAS.

B.5 Abnormal operation requirements and tests

Clause 5 shall apply as written.

B.6 Instructions for fuel cartridge, micro fuel cell power unit, and micro fuel cell power system

Except where specifically noted below, Clause 6 of IEC 62282-6-1 shall apply as written.

B.6.1 Minimum markings required on the cartridge

All requirements of 6.1 shall apply with the following modification.

a) CONTENTS ARE FLAMMABLE, DO NOT DISASSEMBLE.

B.6.2 Additional information required either on the cartridge or on accompanying written information or on the system or power unit

Subclause 6.2 shall apply as written.

B.7 Type tests for a fuel cartridge, a micro fuel cell power unit, and a micro fuel cell power system

Except where specifically noted, the type tests described in Clause 7 shall be performed on the fuel cell power unit with and without the fuel cell cartridge as directed.

B.7.1 Test conditions and requirements

This subclause shall apply as written with the following additions.

B.7.1.3 In addition to the tests prescribed by Clause 7, if the volumetric capacity of the fuel cartridge is greater than 120 ml, the cartridge shall meet the acceptance criteria of the type tests set out in ISO/TS 16111.

B.7.1.4 In addition to the tests prescribed by Clause 7, if the volumetric capacity of the fuel cartridge is less than 120 ml, the cartridge shall meet the acceptance criteria of the type tests set out in ISO/TS 16111, with the exception of the fire test required by 6.1.4 of ISO/TS 16111, which shall be altered as set out in B.7.1.5 of this annex.

B.7.1.5 If the volumetric capacity of the fuel cartridge is less than 120 ml, the acceptance criteria for the fire test required by 6.1.4 of ISO/TS 16111 shall be modified to allow the use of a vent feature integral with the shell of the cartridge. It is to be understood that the purpose of the fire test in this case is not to test the integrity of the cartridge, but to ensure a safe failure mode when the small cartridge is exposed to a fire for a prolonged period of time.

B.7.1.6 If there is a pressure regulator between the fuel cell power unit and the internal fuel reservoir, the reservoir shall meet the acceptance criteria of the type tests set out in ISO/TS 16111, with the modified acceptance criteria for the fire test as laid out in B.7.1.5.

B.7.2 Leakage measurement of hydrogen

Tests and inspections related to measurement of leakage of methanol or other liquids or emissions are not applicable to devices tested under the scope of this annex. Compliance with the ‘no leakage’ requirement for all type tests specified in B.7.3 shall be determined by the hydrogen leak test of B.7.2.1 as outlined in Figure B.1.

B.7.2.1 Leakage measurement of hydrogen and measuring procedure

For hydrogen fuel cartridges, fuel cell power units, and fuel cell systems, leakage measurement of hydrogen shall be executed according to the following procedure, also illustrated in Figure B.1.

B.7.2.1.1 The cartridge shall be charged with hydrogen to its rated charging pressure.

B.7.2.1.2 After executing the type tests in accordance with the test procedure described in 7.3, the micro FC power unit, both with and without the fuel cartridge, shall be monitored for leakage using the procedure detailed in B.7.2.1.4.

B.7.2.1.3 This procedure shall apply to the examination of hydrogen leakage from the cartridge, unit and system after all applicable type tests of this PAS.

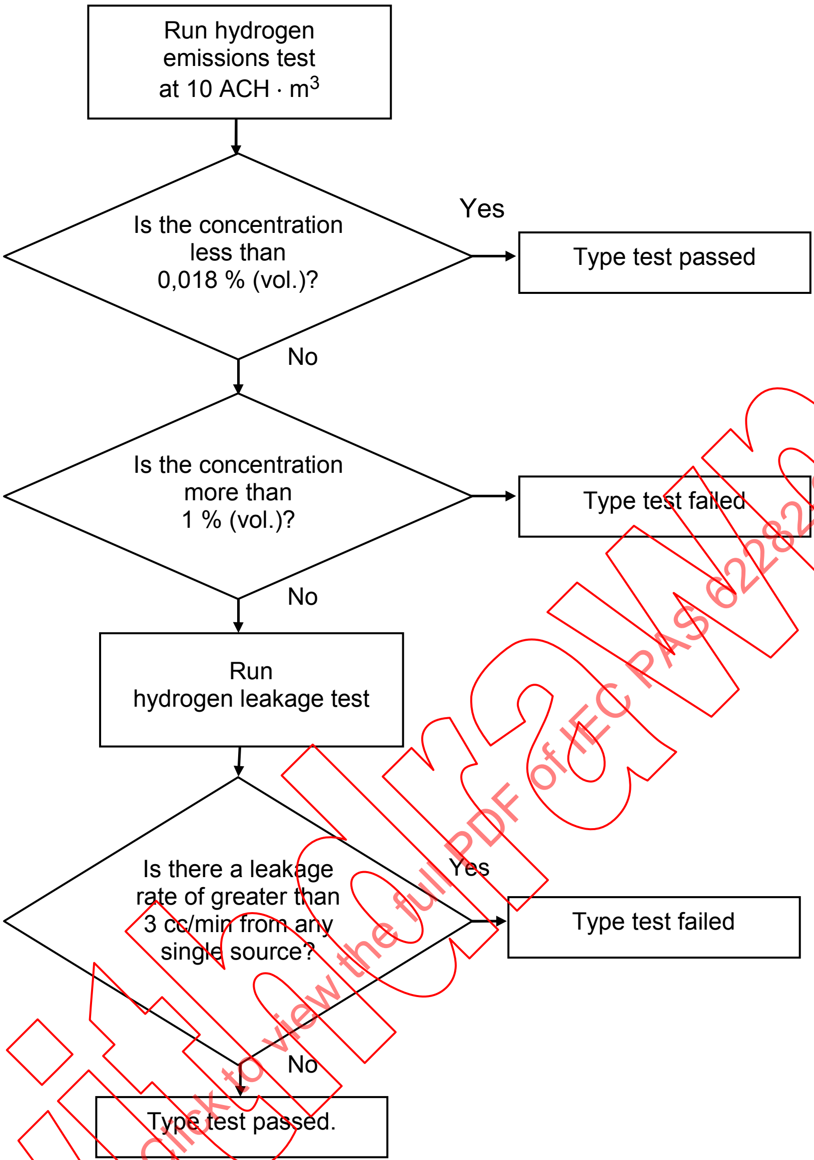


Figure B.1 – Hydrogen leak test procedure

B.7.2.1.4 Measurement procedure

B.7.2.1.4.1 Emission test

The emission test according to B.7.3.14, set up to detect hydrogen, shall be performed following each type test. Following this emission test, one of three results is possible:

a) Hydrogen concentration is less than 0,0162 mg/h (0,018 % vol.). This level would result from one single source venting pure hydrogen at 3 cc/min. If hydrogen concentration is less than 0,0162 mg/h (0,018% vol.), the device passes the leakage test; no further testing required.

b) Hydrogen concentration is greater than 25 % LFL. Device fails leakage test. No further testing required.

c) Hydrogen concentration is greater than 0,0162 mg/h (0,018 % vol.) but less than 25 % LFL. Proceed to leakage test of B.7.2.2.4.2 to determine that no single source emits pure hydrogen at greater than 3 cc/min.

B.7.2.1.4.2 Leakage test

The leakage test shall be performed to determine that no single source on the device can support a flame in all cases where such compliance cannot be definitively determined by the emission test.

a) The testing shall be conducted in a space with no substantial air movement. A measurement of wind speed 10 cm above the device shall not exceed 0,02 m/s.

b) The surface of the device shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen leak detector, or other device suitable for measuring small quantities of hydrogen leakage from a point source that is at least as accurate, if not more so, than the afore-mentioned devices. The hydrogen detector must be tuned to detect a level of hydrogen that is at 25 % of LFL.

c) The sensor of the hydrogen detector must sweep the device at a distance no more than 3 mm normal to the surface of the device. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the device. The entire surface of the device shall be swept in this manner.

d) 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 device 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.

e) The sensor should always face directly downward, and the device should be moved beneath it in such a way that the surface directly below the sensor is always horizontal.

f) If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the device shall be considered to have passed.

g) 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 3 cc/min of pure hydrogen from any single source.

h) The second test shall be performed using the following procedure: the sensor height shall be adjusted from 3 mm above the device to 6,5 mm above the device.

i) 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 must have a spacing of 1 mm or less between sweeps, and must spiral out to a radial distance of at least 4 mm.

j) If the spiral sweep at 6,5 mm above the device detects a concentration of hydrogen that is 25 % of LFL or greater, the device fails. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the device passes.

B.7.2.1.5 Passing criteria: no leakage of hydrogen as defined in B.3.25.

B.7.2.5 Test sample quantity

This subclause shall apply as written.

B.7.3 Type tests

For all type tests performed, the device must meet the requirements of B.7.2.1 for no leakage of hydrogen. Except as specifically noted below, all type tests shall apply as written.

B.7.3.1 Pressure differential tests

B.7.3.1.1 Cartridge

Test A Internal pressurization

Test A of 7.3.1.1 is not applicable to cartridges tested under this annex. Instead, cartridges shall B.7.3.1.1 Test B, below:

Test B Low external pressure

i) This test shall be performed on fuel cartridges certified by this annex.

ii) Subclause 7.3.1.1 Test B shall apply as written with the addition that the external vacuum shall be applied for a period of 30 min.

iii) Passing criteria: No fire at any time, no explosion at any time, no leakage. See Figure B.1.

B.7.3.1.2 Micro fuel cell power unit or micro fuel cell power system

Both Test A and Test B shall be completed.

Test A: Test A shall be executed as prescribed by 7.3.1.2, with the exception that the leakage shall be measured using the hydrogen leak test of B.7.2.1.

Test B: Test B shall be executed as prescribed by 7.3.1.2, with the exception that the leakage shall be measured using the hydrogen leak test of B.7.2.1.

B.7.3.2 Vibration test

This test shall apply as written in 7.3.2, with the following modifications.

v) Perform leakage testing in accordance with B.7.2.1.

Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured using the procedure in B.7.2.1 as specified by v). If the unit is not operational, but emissions do not violate the 'no leakage' criteria, the leakage test is acceptable.

B.7.3.3 Temperature cycling test

This test shall apply as written in 7.3.3, with the following modifications.

vi) Perform leakage testing in accordance with B.7.2.1.

Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured using the procedure in B.7.2.1 as specified by vi). If the unit is not operational, but emissions do not violate the 'no leakage' criteria, the leakage test is acceptable.

B.7.3.4 High-temperature exposure test

This test shall apply as written in 7.3.2, with the following modifications.

Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured using the procedure in B.7.2.1.

B.7.3.5 Drop test

B.7.3.5.1 If the drop test of 6.3 of ISO/TS 16111 is performed using the same cartridge for all four drop orientations, the cartridge drop test of 7.3.5 (2 or 3) is not required. The drop test of ISO/TS 16111 is seen to be more rigorous, and therefore more than sufficient to ensure adequate safety of the cartridge. If the drop test of ISO/TS 16111 is performed using a different cartridge for each drop orientation, the cartridge drop test of 7.3.5, with the modifications below, must be performed in addition to the drop test of ISO/TS 16111.

B.7.3.5.2 The micro fuel cell power unit drop test of 7.3.5 shall apply as written with the following modifications.

vi) Perform hydrogen leakage test in accordance with B.7.2.1.

Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured using the procedure in B.7.2.1 as specified by vi). If the unit is not operational, but emissions do not violate the 'no leakage' criteria, the leakage test is acceptable.

B.7.3.6 Compressive loading test

This subclause shall apply as written with the following modifications.

Test sample: an unused fuel cartridge, 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.

Power unit or system:

v) Perform leak test in accordance with B.7.2.1.

Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured using the procedure in B.7.2.1. If the unit is not operational, but emissions do not violate the 'no leakage' criteria, the leakage test is acceptable.

B.7.3.7 External short-circuit test

This subclause shall apply as written with the following modifications.

vii) Perform leak test in accordance with B.7.2.1.

Passing criteria: No fire at any time, no explosion at any time, no leakage. Leakage shall be measured using the procedure in B.7.2.1. Exterior surfaces shall not exceed temperatures in Table 3 during or after short-circuit testing. If the unit is not operational, but emissions do not violate the 'no leakage' criteria, the leakage test is acceptable.

B.7.3.8 Surface and exhaust gas temperature test

This test shall apply as written.

B.7.3.9 Long-term storage test

This test shall be modified to use the test procedure prescribed below. The test procedures prescribed in 7.3.9 are not applicable, as they are not feasible for cartridges containing hydrogen.

Test procedure:

Place sample in temperature chamber at 50 °C.

i) The temperature chamber shall be equipped with a ventilation system and a means of monitoring hydrogen concentration.

ii) The temperature chamber ventilation system shall be configured in such a way that the internal volume multiplied by the number of air changes per hour equals 10 (i.e. 1 m^3 chamber with 10 ACH).

iii) The hydrogen concentration in the chamber shall be monitored constantly.

iv) The sample shall remain in the chamber at 50 °C for at least 28 days.

Passing criteria: No fire, no explosion. The hydrogen concentration in chamber shall not exceed 25 % LFL at any time during the test.

B.7.3.10 High temperature connection test

This test shall apply as written with the following modifications.

vii) Leakage shall be checked using the hydrogen leakage test of B.7.2.1.

B.7.3.11 Fuel cell power unit internal pressure test

This test shall be subject to the following modifications. It is inappropriate to simulate pressurization of a gas-based fuel cell system using liquid, as such, water is not a suitable medium.

Pressurize the system with helium through a test fixture that has a valve to simulate the cartridge connection, or put a connection at the outboard end of a standard cartridge.

Test procedure

ii) Using helium, pressurize the fuel cartridge connection and the downstream system to a pressure of either 95 kPa plus normal working pressure or two times the normal working pressure at 55 °C. The pressure rise shall not exceed 60kPa/second.

iv) Acceptance criteria: No helium leakage greater than 3 standard milliliters per minute from any single source.

B.7.3.12 Connection cycling tests

This test shall apply as written with the following modifications.

B.7.3.12.1.1 xv) Leakage shall be checked using point source hydrogen detector and shall meet criteria for no leakage as defined in B.3.25.

B.7.3.12.1.2 x) Leakage shall be checked using point source hydrogen detector and shall meet criteria for no leakage as defined in B.3.25.

B.7.3.12.1.3 Cartridge 1 xv) Leakage shall be checked using point source hydrogen detector and shall meet criteria for no leakage as defined in B.3.25.

B.7.3.12.1.3 Final cartridge xv) Leakage shall be checked using point source hydrogen detector and shall meet criteria for no leakage as defined in B.3.25.

B.7.3.14 Emission test

The emission test of 7.3.14 shall be performed using a modified set-up, wherein a mass spectrometer, gas chromatograph, or other suitable calibrated instrument is used to monitor concentration of hydrogen within the control volume. No other emissions need to be monitored, as hydrogen is the only possible hazardous emission from these systems.

B.7.3.14.1 The concentration of hydrogen in the control volume shall not exceed 25 % LFL at any time during the test.

B.7.3.14.2 The emission test may also be used to ensure that the hydrogen leakage from fuel cartridge is below acceptable limits.

Annex C
(Normative)

Micro reformed methanol fuel cells

This annex shall apply to Micro Reformed Methanol Fuel Cells (RMFCs) that convert methanol and water through a reformer into hydrogen reformate, which is then immediately fed to the fuel cell stack.

All items in the main body of this PAS apply to Micro RMFCs. This annex outlines the additional requirements with respect to the requirements contained in the main body of this PAS for certification of such fuel cell power systems and their respective fuel cartridges. The numbering system of this annex corresponds to the numbering of clauses in the main body, and additional subclauses have been assigned new numbers.

C.1 Scope

Unless otherwise noted, Clause 1 applies as written when used in conjunction with this annex, with the following additions.

C.1.1 System boundary

C.1.1.7 Figure C.1 replaces Figure 1 in the main body.

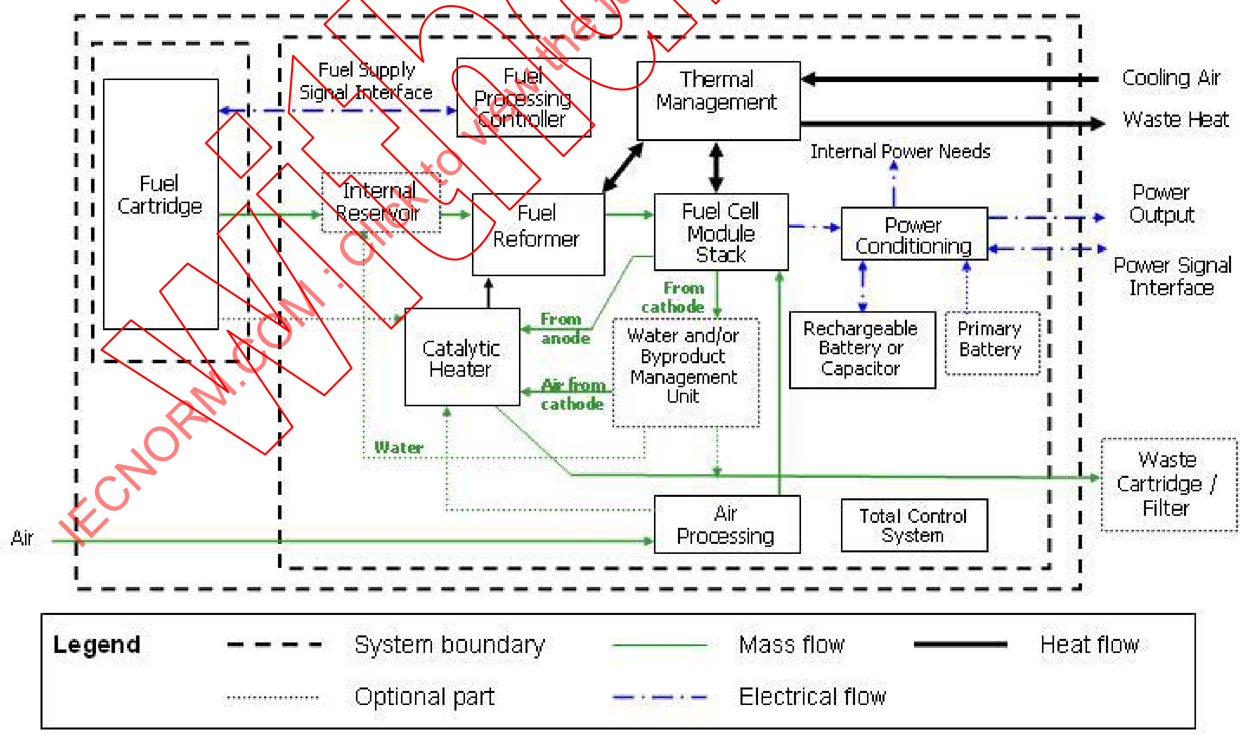


Figure C.1 – General block diagram of a reformed methanol micro fuel cell system

C.1.2 Considerations

Materials, construction, requirements and type tests shall be suitable for use with liquid methanol, as outlined in the main body of this PAS, as well as methanol vapour, water vapour and hydrogen.

C.2 Normative references

Clause 2 applies as written when used in conjunction with this annex.

C.3 Terms and definitions

Clause 3 applies as written when used in conjunction with this annex, with the following additions.

C.3.31
methanol fuel reformer (also referred to as “reformer”)
device that converts methanol and water to hydrogen reformate (hydrogen, carbon dioxide, and other by-products) for applicable systems

C.3.32
catalytic heater
device that oxidizes a fuel (e.g., methanol or hydrogen) and produces heat without flammable products for applicable systems

C.4 Materials and construction of fuel cartridge, micro fuel cell power unit and micro fuel cell power system

Clause 4 applies as written when used in conjunction with this annex, with the following additions.

C.4.5 Selection of materials

C.4.5.7 The reformed methanol micro fuel cell system shall be resistant to corrosion in the intended usage environment, including exposure to liquid methanol, methanol vapour, water vapour, and hydrogen at relevant operating temperatures.

C.4.14 Protection against fire and explosion hazards

C.4.14.4 Reformers using catalytic heaters

C.4.14.4.1 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.4.14.4.2 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.4.14.4.3 Controls for fuel and air feeds shall be designed to reliably maintain the design fuel to air ratio.

C.4.14.4.4 Upon shutdown, hazardous gases in the process system shall be safely contained, oxidized, or disposed.

C.4.14.4.5 For air-rich 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.4.14.4.6 For fuel-rich 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.4.14.4.7 The reaction initiation time 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.4.14.4.8 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 systems shall be an open design (i.e., gases flow from reformer to stack to catalytic heater to exhaust), and there may not be the possibility of building up high pressure within the components exposed to these open conditions.

C.4.18 Protection against mechanical hazards

C.4.18.1 Other tubing lines

C.4.18.1.3 Protection against mechanical hazards

Tubing and other fuel pathways will be designed in such a way that 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.5 Requirements of fuel cartridge, micro fuel cell power unit, and micro fuel cell power system

Clause 5 applies as written when used in conjunction with this annex, with the following additions.

C.6 Instructions for fuel cartridge, micro fuel cell power unit, and micro fuel cell power system

Clause 6 applies as written when used in conjunction with this annex, with the following additions.

C.7 Type tests

Clause 7 applies as written when used in conjunction with this annex, with the following additions.

C.7.3 Type test procedures

C.7.3.15 Hydrogen emissions and leakage test

C.7.3.15.1 After executing the type tests in accordance with the test procedure described in 7.3, the micro fuel cell power unit shall be monitored for emissions and leakage using the procedure detailed below.

C.7.3.15.2 Emission test procedure

C.7.3.15.2.1 The emission test in 7.3.14 shall be performed using a modified set-up, wherein a mass spectrometer, gas chromatograph, or other suitable calibrated instrument is used to monitor concentration of hydrogen within the control volume. Following this emission test, one of three results is possible.

C.7.3.15.2.2 Hydrogen concentration is less than 0,0162 mg/h (0,018 % vol). This level would result from one single source venting pure hydrogen at 3 cc/min. If hydrogen concentration is less than 0,0162 mg/h (0,018 % vol), device passes leakage test; no further testing required.

C.7.3.15.2.3 Hydrogen concentration is greater than 25 % LFL. Device fails leakage test. No further testing required.

C.7.3.15.2.4 Hydrogen concentration is greater than 0,0162 mg/h (0,018 % vol) but less than 25 % LFL. Proceed to leakage test of C.7.3.15.2 to determine that no single source emits pure hydrogen at greater than 3 cc/min.

C.7.3.15.3 Leakage test procedure

C.7.3.15.3.1 The leakage test shall be performed to determine that no single source on the device can support a flame in all cases where such compliance cannot be definitively determined by the emission test.

C.7.3.15.3.2 The testing shall be conducted in a space with no substantial air movement. A measurement of wind speed 10 cm above the device shall not exceed 0,02 m/s.

C.7.3.15.3.3 The surface of the device shall be systematically swept with a point source hydrogen detector. This hydrogen detector may be either a mass spectrometer, hand-held hydrogen leak detector, or other device suitable for measuring small quantities of hydrogen leakage from a point source that is at least as accurate, if not more so, than the afore-mentioned devices. The hydrogen detector must be tuned to detect a level of hydrogen that is at 25 % of LFL.

C.7.3.15.3.4 The sensor of the hydrogen detector shall sweep the device at a distance no more than 3 mm normal to the surface of the device. Consecutive linear sweeps shall not be more than 8 mm apart along the surface of the device. The entire surface of the device shall be swept in this manner.

i) 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 device 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.

ii) The sensor should always face directly downward, and the device should be moved beneath it such that the surface directly below the sensor is always horizontal.

C.7.3.15.3.5 If no points are found where the hydrogen concentration is greater than 25 % LFL, the test is complete and the device shall be considered to have passed.

C.7.3.15.3.6 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 3 cc/min of pure hydrogen from any single source.

C.7.3.15.3.7 The second test shall be performed using the following procedure: the sensor height shall be adjusted from 3 mm above the device to 6,5 mm above the device.

C.7.3.15.3.8 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.

C.7.3.15.3.9 If the spiral sweep at 6,5 mm above the device detects a concentration of hydrogen that is 25 % of LFL or greater, the device fails. If the spiral sweep does not detect any hydrogen concentrations of 25 % LFL or greater, the device passes.

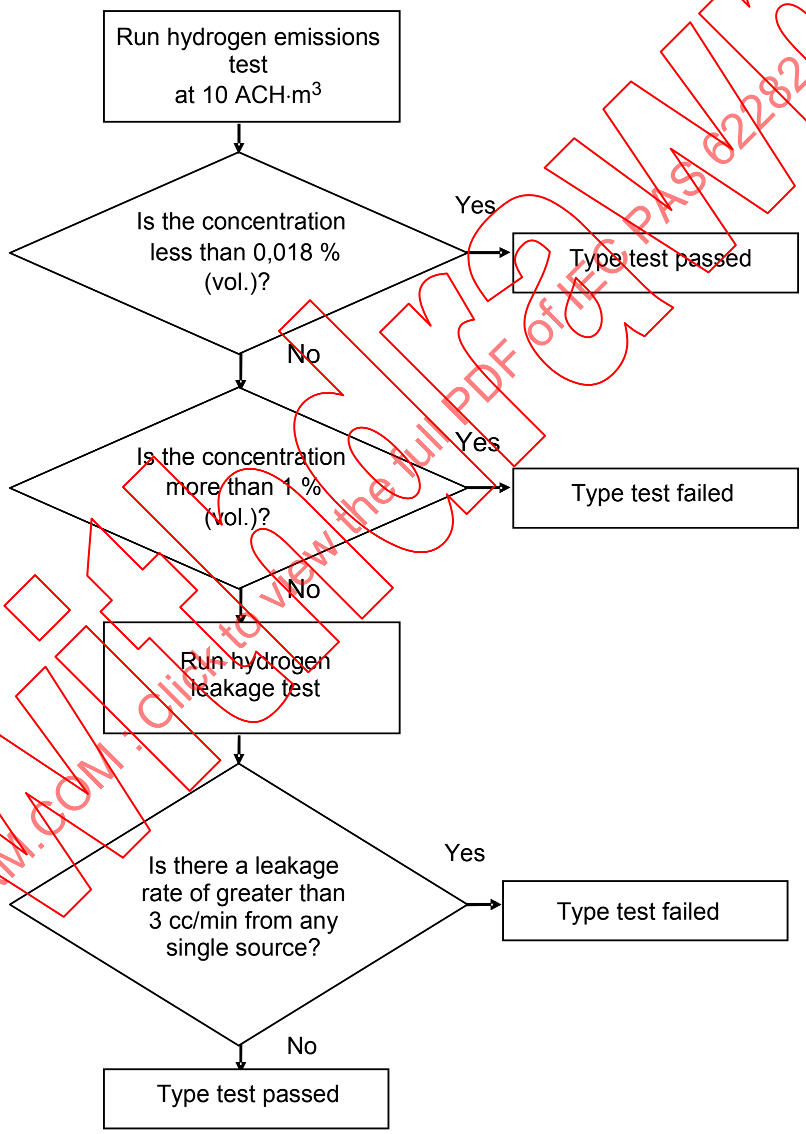


Figure C.7.1 – Flow chart for hydrogen tests

C.7.3.16 Automatic system shutdown due to abnormally high temperature

C.7.3.16.1 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.

C.7.3.16.2 Verify that the system shutdown sequence is initiated within 5 s of the reformer reaching the temperature set point.

C.7.3.17 Safe operation under high reformer temperature

C.7.3.17.1 This test requires that the system operate safely, even if the reformer is at a temperature of 30 °C above the maximum operating temperature.

C.7.3.17.2 To run the test, disable the automatic system suspension mechanism described in C.7.3.1. Set the reformer temperature at 30 °C above the maximum operating temperature. Run the system at full load as specified by the manufacturer for 1 h at this elevated temperature. There shall be no emission of flame, and the system shall be in compliance with the emission requirements in Table 8 and C.7.3.15.2.

Annex D
(Normative)

Methanol clathrate compound

This annex, for direct methanol fuel cell systems powered by methanol clathrate compound, outline the additional or modified requirements with respect to the requirements contained in the main body of this PAS, for certification of such fuel cell power systems and their respective fuel cartridges. Where possible, the numbering system of this annex corresponds to the numbering of clauses in the main body. Requirements from the main body of this PAS not specifically discussed in this annex apply to direct methanol fuel cell systems powered by methanol clathrate compound as written. Modified clause numbers reflect their counterpart clause in the main body. Any additional clauses have been assigned new numbers. This annex establishes modifications and additions to the main body of the PAS for application to the fuel and technologies addressed by this annex.

D.1 Scope

D.1.1 System boundary

Except where specifically noted, 1.1 shall apply as written when used in conjunction with this annex.

D.1.1.6 Fuel and technologies covered by this annex

D.1.1.6.1 This annex shall apply to micro fuel cells, which are direct methanol fuel cells (DMFC) powered by methanol clathrate compound (MCC).

D.1.1.6.2 This annex includes equipment designs that include direct methanol fuel cell (DMFC) module stacks.

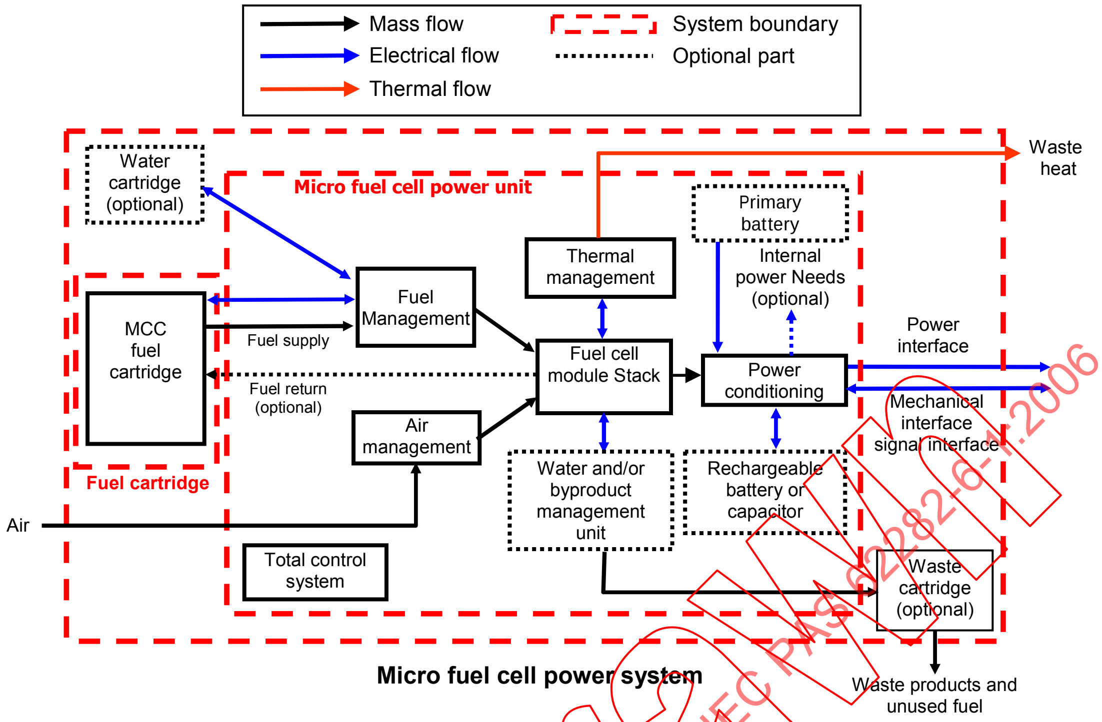


Figure D.1 – General block diagram of direct methanol fuel cells powered by methanol clathrate compound

D.1.3 Considerations

Methanol clathrate compound (MCC)[1] is a solid[2] that includes methanol. Since the fuel cartridge containing the MCC does not contain liquid prior to use, liquid leakage does not occur (Figure D.1) and MCC does not come under the United Nations classification recommendation on transport of dangerous goods.

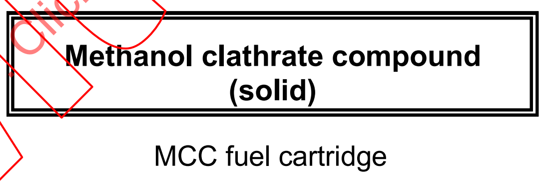


Figure D.2 – Fuel cartridge of methanol clathrate compound

When the fuel cartridge filled with the MCC is installed in the fuel cell power unit, water is injected into the 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.3).

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1) An organic addition compound that has an internal space that is completely enclosed. It is formed by the inclusion of molecules in cavities formed by crystal lattices or present in large molecules (http://efunda.intota.com/multisearch.asp?mode=&strSearchType=all&strQuery= clathrate%20compound).

2) Examined by ASTM D 4359-90: *Standard test method for determining whether a material is a liquid or a solid*.

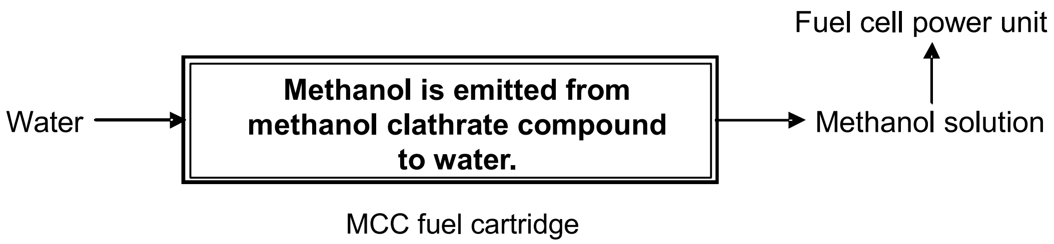

Figure D.3 – Usage of methanol clathrate compound with fuel cell power unit.

D.2 Normative references

Clause 2 applies as written when used in conjunction with this annex.

D.3 Terms and definitions

Clause 3 shall apply as written except where specifically modified below. Subclauses which have not been altered are not referenced below.

D.3.4
fuel
methanol clathrate compound (MCC), which consists of gamma-cyclodextrin and methanol. Methanol solution, which is formed by the contact of MCC and water, is used to produce electricity in a fuel cell unit

D.3.31
no MCC powder leakage
no accessible MCC powder outside the system or cartridge

D.3.32
no accessible MCC powder
consumer cannot come into physical contact with MCC powder

D.4 Materials and construction of fuel cartridge, micro fuel cell power unit, and micro fuel cell power system for portable devices

Clause 4 applies as written when used in conjunction with this annex.

D.5 Abnormal operation requirements and tests

Clause 5 applies as written when used in conjunction with this annex.

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

Clause 6 applies as written when used in conjunction with this annex.

D.7 Type tests for a fuel cartridge, a micro fuel cell power unit, and a micro fuel cell power system

Clause 7 shall apply as written except where specifically modified below. Subclauses which have not been altered are not referenced below.

D.7.2 Leakage measurement of MCC and methanol, and the measuring procedure

Because MCC powder is packed in an unused MCC fuel cartridge, inspection of MCC powder leakage shall be executed in type tests. The leakage measurement of MCC powder and methanol shall be executed in principle in accordance with the procedure shown in Figures D.4 through D.7 respectively. Exceptions will be noted in the various subclauses.

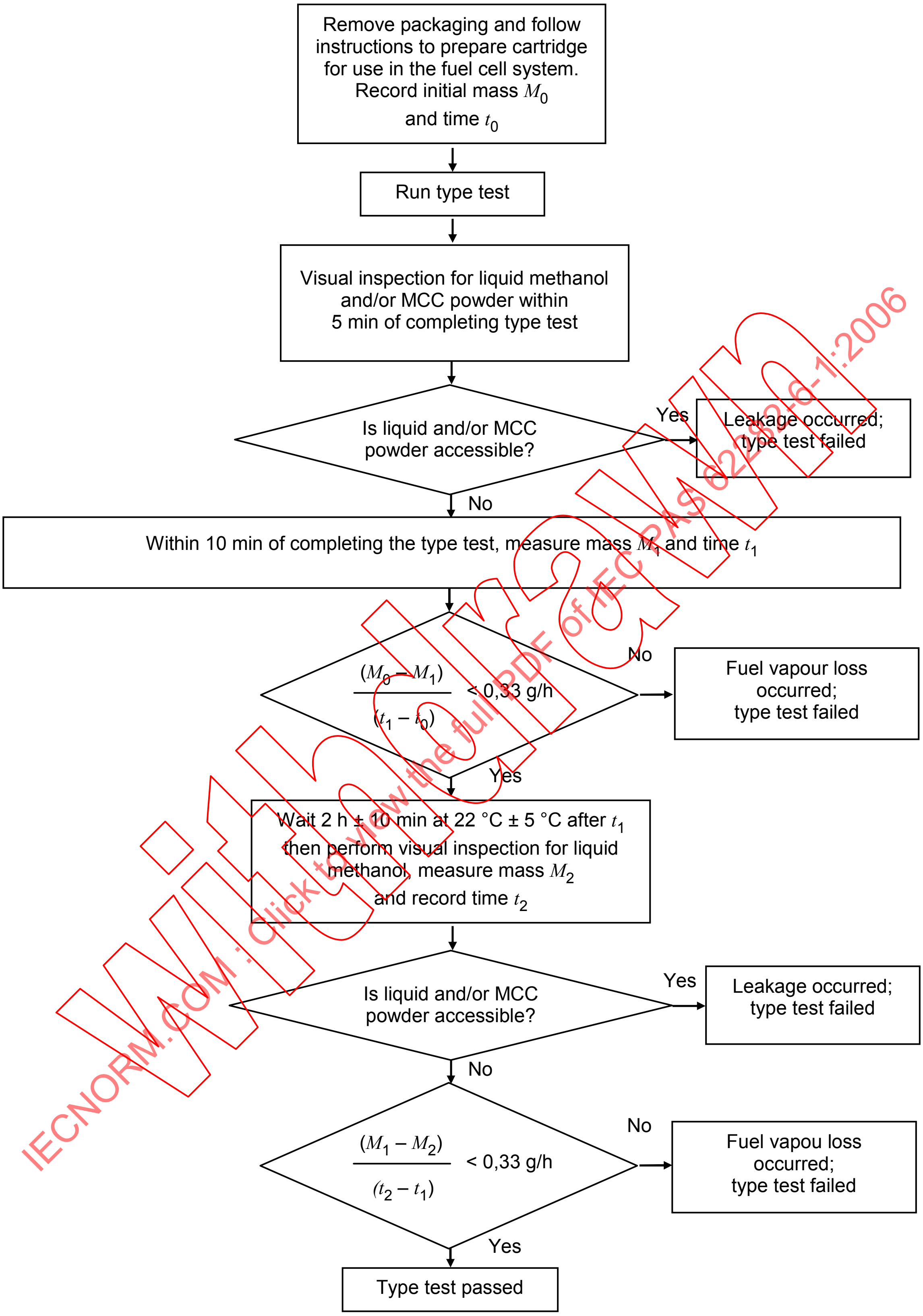

Figure D.4 – Cartridge leakage and mass-loss test flow chart for low external pressure, vibration, drop, and compressive loading tests

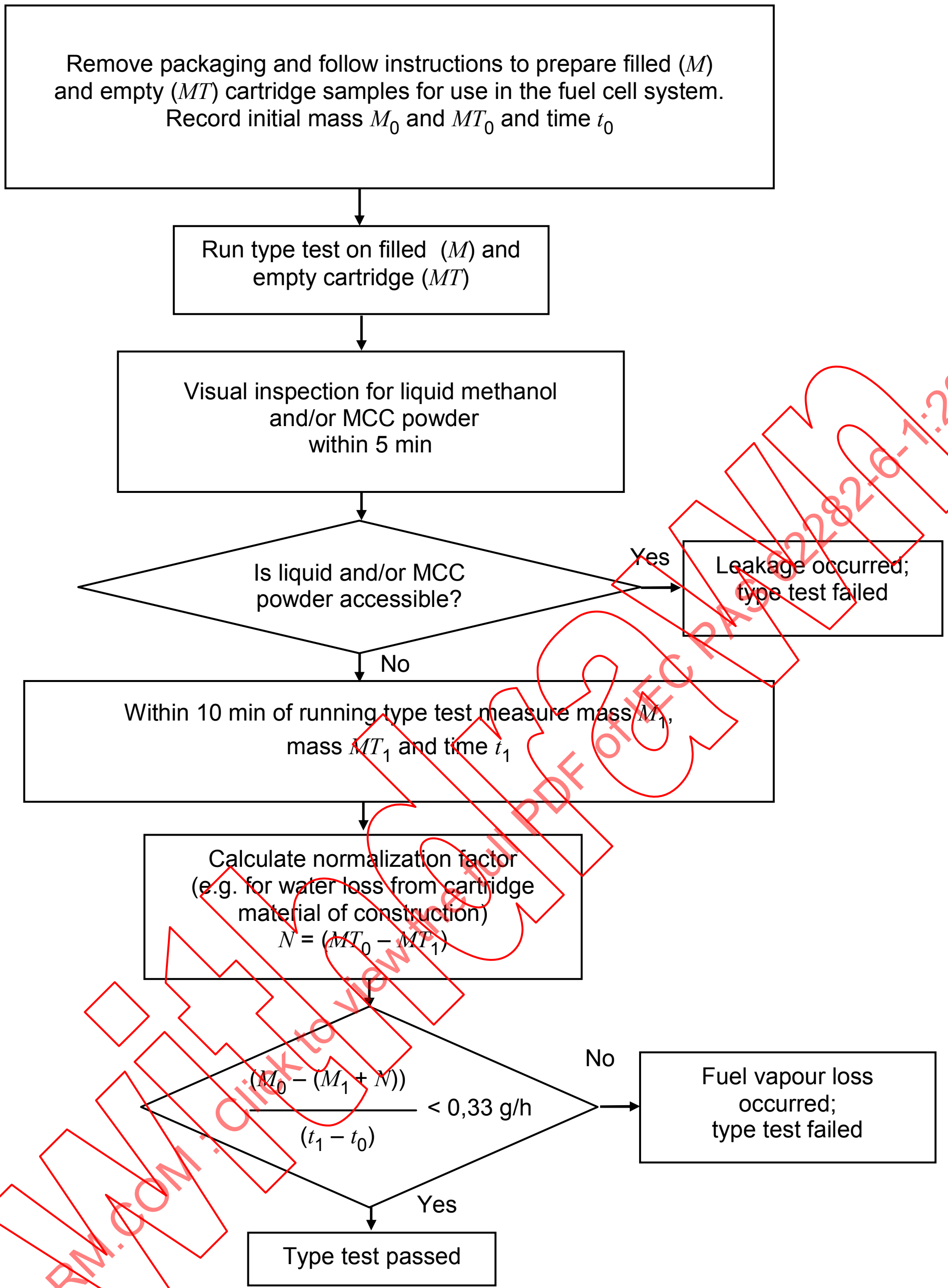

Figure D.5 – Cartridge leakage and mass loss test flow chart for temperature cycling type test and high temperature exposure test

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

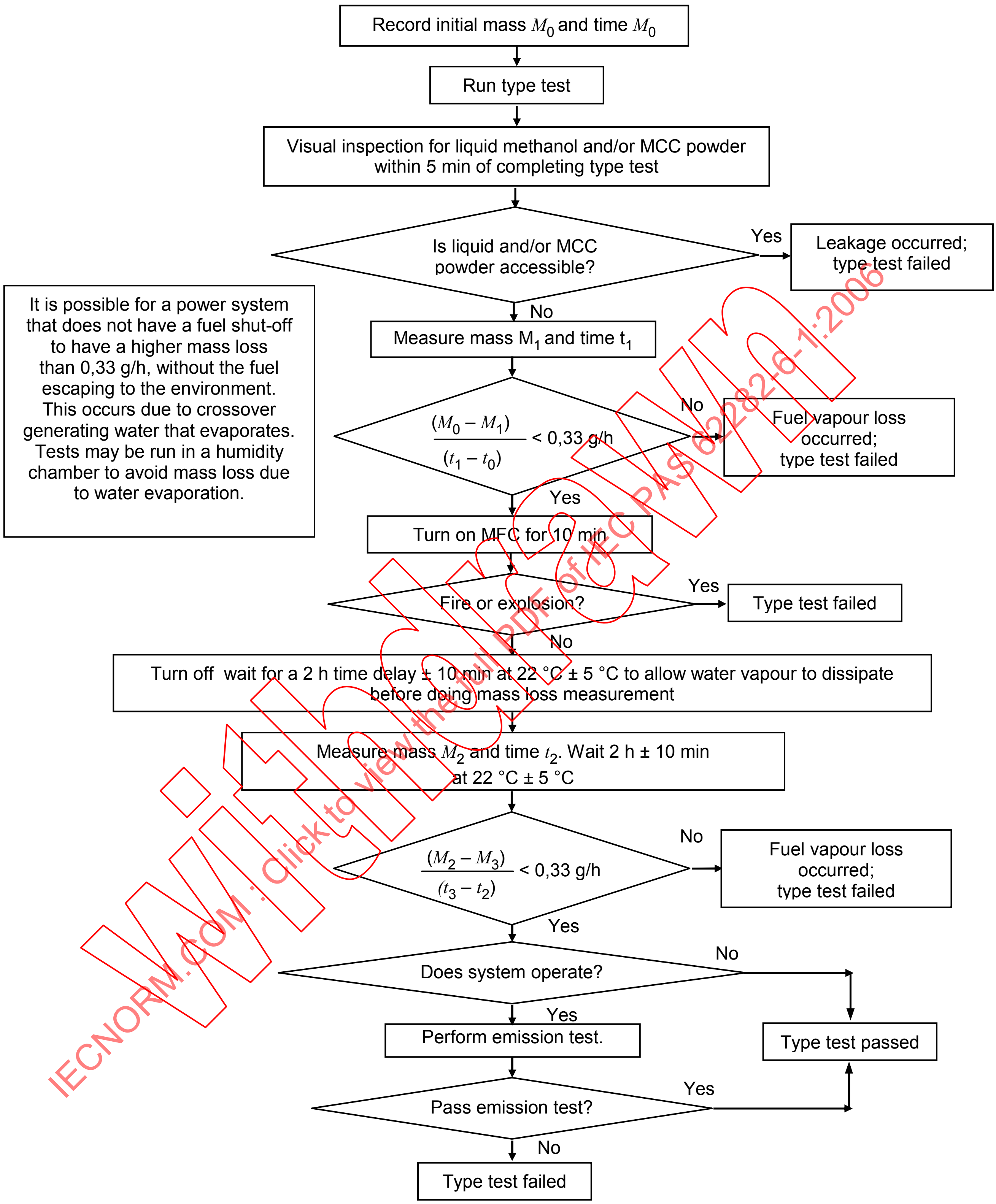

Figure D.6 – Micro fuel cell system/unit leakage and mass-loss flow chart for vibration, drop, pressure differential and compressive loading tests

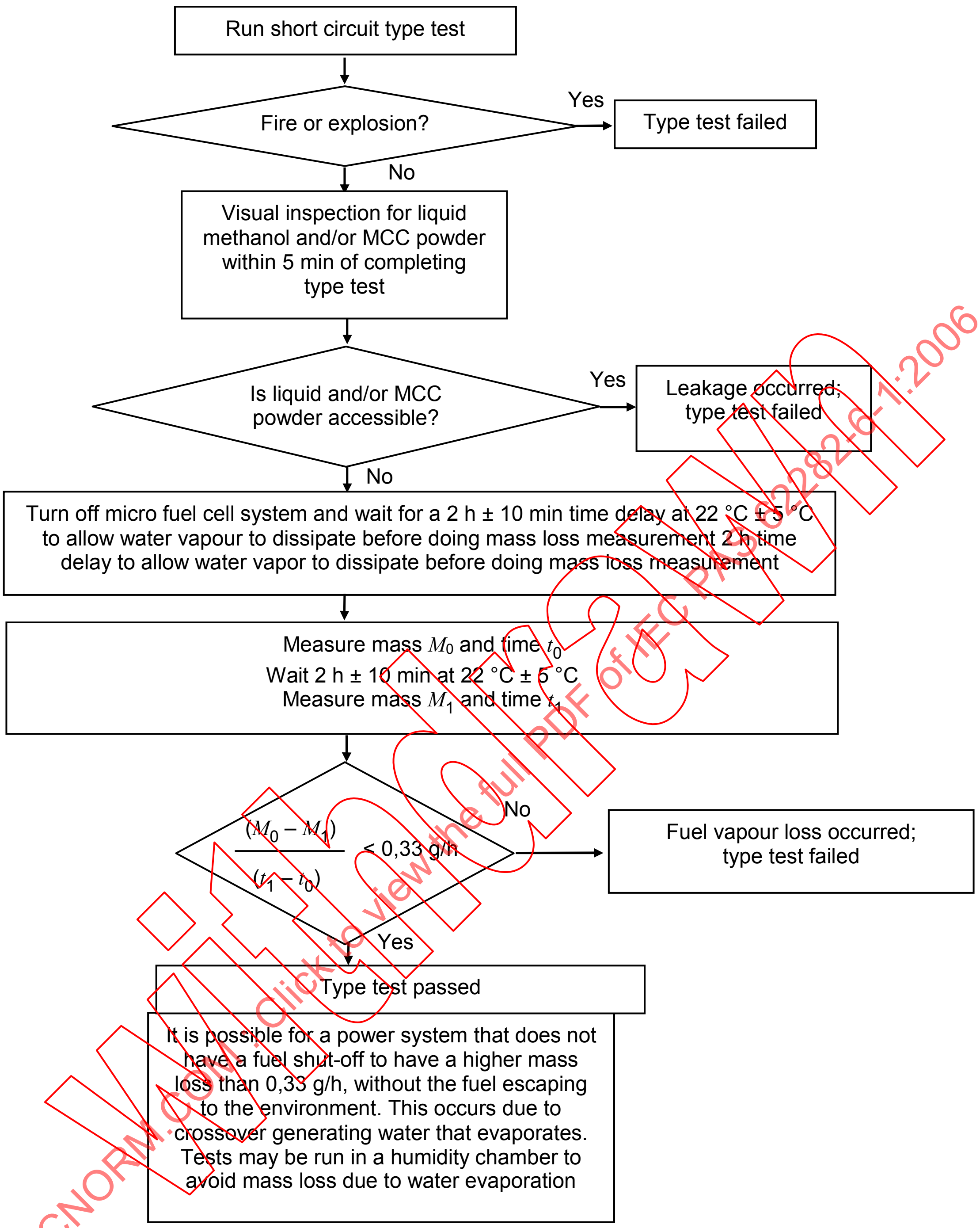

Figure D.7 – Micro fuel cell system/unit leakage and mass-loss flow chart for short-circuit type test

D.7.3 Type test

Type test items shall be as shown in Table D.1:

Table D.1 – Type tests

	Test item	Test sample
D.7.3.1	Pressure differential test*	MCC fuel cartridge Micro FC power unit and/or power system
D.7.3.2	Vibration test*	MCC fuel cartridge Micro FC power unit and/or power system
D.7.3.3	Temperature cycling test*	MCC fuel cartridge Micro FC power unit and/or power system
D.7.3.4	High-temperature exposure test	MCC fuel cartridge
D.7.3.5	Drop test	MCC fuel cartridge Micro FC power unit and/or power system
D.7.3.6	Compressive loading test	MCC fuel cartridge Partially filled MCC fuel cartridge Micro FC power unit and/or power system
D.7.3.7	External short-circuit test	Micro FC power unit or power system
D.7.3.8	Surface and exhaust gas temperature test	Micro FC power unit or power system
D.7.3.9	Long-term storage test	MCC fuel cartridge
D.7.3.10	High-temperature connection test	Fuel cartridge and micro FC power unit
7.3.11	Fuel cell power unit internal pressure test	Micro FC power unit with a pressurized empty fuel cartridge
D.7.3.12	Connection cycling test	MCC fuel cartridge and micro FC power unit
D.7.3.14	Emission test	Micro FC power unit or power system
* The following tests shall be done in sequence, using the same system hardware: Pressure differential test → Vibration test → Temperature cycling test		

D.7.3.1 Pressure differential tests

Purpose: To simulate the effects of a high internal pressure or a low external pressure and ensure no leakage.

D.7.3.1.1 Cartridge

Use 7.3.1.1, Test A or D.7.3.1.1, Test B.

D.7.3.1.1 Low external pressure

Test B

i) 95 kPa differential applied by external vacuum test where the lower pressure is applied externally to an unused MCC fuel cartridge. This method is generally not suitable for non-rigid cartridges because the required pressure differential is not attained. For non-rigid cartridges precise pressure differential measurement shall be used.

ii) Passing criteria: No fire at any time, no explosion at any time, no leakage, and no MCC powder leakage. See Figure D.4.

D.7.3.1.2 Micro fuel cell power unit or micro fuel cell power system

Both pressure differential Test A and Test B shall be carried out.

Test A: Power unit and/or system: Test samples in unused condition shall be stored at a pressure of 68 kPa for 6 h at ambient temperature (22 °C ± 5 °C). Methanol leakage and MCC powder leakage shall be measured on the basis of the procedure described in Figure D.6.

Test B: Power unit and/or system: Test samples in unused condition shall be stored at a low external pressure of 95 kPa differential pressure. External vacuum shall be applied for 30 min at ambient temperature (22 °C ± 5 °C). Methanol leakage and MCC powder leakage shall be measured on the basis of the procedure described in Figure D.6 with the acceptance criteria changed to “vapour loss less than 20 g/h” based on not exceeding 25 % of the LFL.

D.7.3.2 Vibration test

Test sample: an unused fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system used in D.7.3.1.

Purpose: To simulate the effects of normal transportation vibration and ensure no leakage.

Test procedure:

i) Test sample of subject in unused condition firmly secured to the platform of the vibration machine without distorting the sample in such a manner as to properly transmit the vibration.

ii) 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.

iii) 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.

iv) 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.

v) Perform emissions testing in accordance with 7.3.14.

Passing criteria: No fire at any time, no explosion at any time, no leakage, and no MCC powder leakage. Leakage shall be measured based upon the procedure described in Figures D.4 and D.6. Emissions shall meet the acceptance criteria in 7.3.14. If the unit does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

D.7.3.3 Temperature cycling test

Test sample: an unused fuel cartridge, a micro fuel cell power unit fuelled in accordance with manufacturer's specifications or a micro fuel cell power system used in D.7.3.2.

Purpose: To simulate the effects of low-temperature and high-temperature exposure and the effects of extreme temperature change.

Test procedure (see Figure D.8):

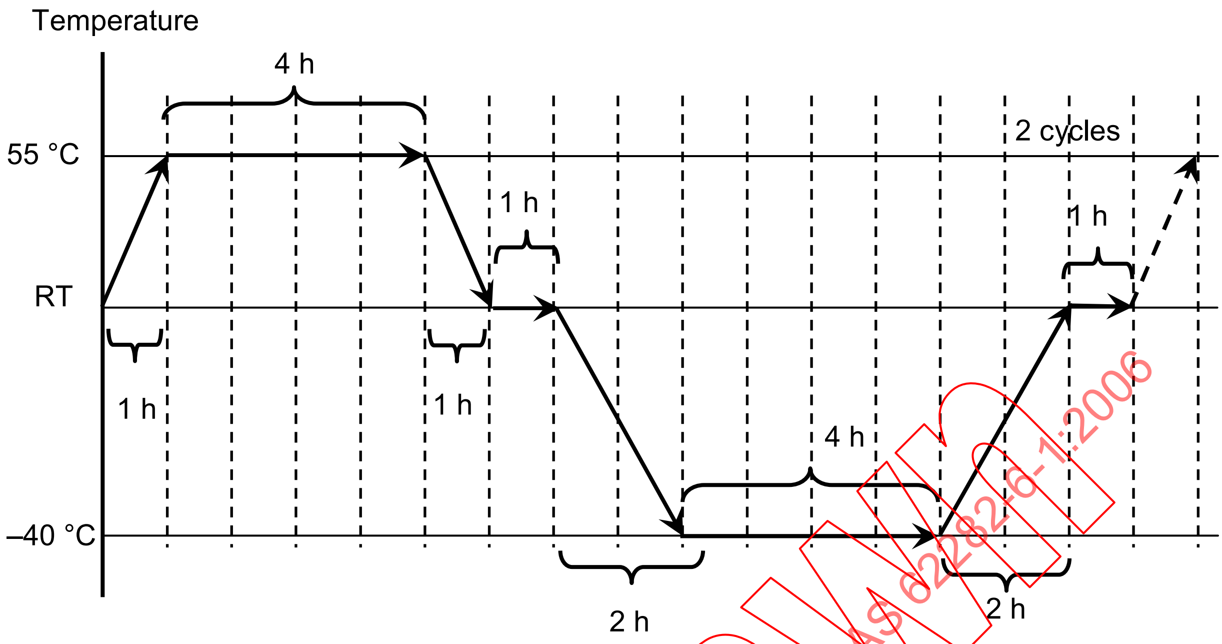

Figure D.8 – Temperature cycling

i) Place the test sample in a temperature controlled test chamber and increase the chamber temperature from room temperature (22 °C ± 5 °C) to 55 °C ± 2 °C within 1 h and keep it at 55 °C ± 2 °C for a minimum of 4 h.

ii) Decrease the chamber temperature to 22 °C ± 5 °C within 1 h and keep it at 22 °C± 5 °C for 1 h ± 5 min, then decrease the chamber temperature to –40 °C ± 5 °C within 2 h and keep it at –40 °C ± 5 °C for a minimum of 4 h.

iii) Increase the chamber temperature to 22 °C ± 5 °C within 2 h and keep it at 22 °C ± 5 °C for 1 h ± 5 min.

iv) The above process is repeated twice.

v) Perform emissions testing in accordance with 7.3.14.

Passing Criteria: No fire at any time, no explosion at any time, no leakage, and no MCC powder leakage. After 2 h at 22 °C ± 5 °C, leakage shall be measured based upon the procedure described in Figure D.5. Emissions shall meet the acceptance criteria in 7.3.14. If the unit does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

D.7.3.4 High-temperature exposure test

Test sample: an unused fuel cartridge

Purpose: To simulate the effects of a fuel cartridge left in high-temperature environments

Test procedure:

i) Place the test sample into a temperature-controlled test chamber that is at a temperature of 70 °C ± 2 °C and allow chamber temperature to recover to 70 °C ± 2 °C and maintain that temperature for at least 4 h with the sample in the chamber.

ii) Remove the test sample to a room temperature of 22 °C ± 5 °C.

iii) Passing Criteria: No fire at any time, no explosion at any time, no leakage, and no MCC powder leakage. Leakage shall be measured based upon the procedure described in Figure D.5.

D.7.3.5 Drop test

Test sample: an unused 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.

Purpose: To simulate the effects of an inadvertent drop and ensure no leakage.

Test procedure:

i) 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.

ii) The height of the drop shall be;

a) 1200 mm ± 10 mm: in the case of a micro fuel cell power unit and/or a micro fuel cell power system;

b) 1500 mm ± 10 mm: in the case of a fuel cartridge more than 200 ml;

c) 1800 mm ± 10 mm: in the case of a fuel cartridge up to 200 ml.

iii) For the cartridge tests, the drop test shall be carried out in four drop directions with the same sample. For the power unit or the power system, one device may be used for all four drop directions, or more than one device may be used in subsequent drops, at the discretion of the manufacturer.

iv) Drop directions

- Valve up
- Valve down
- Two other mutually perpendicular directions

v) For power system or power unit tests, perform emissions testing in accordance with 7.3.14.

Passing criteria: No fire at any time, no explosion at any time, no leakage, and no MCC powder leakage. Leakage shall be measured based upon the procedure described in Figures D.4 and D.6. Emissions shall meet acceptance criteria in 7.3.14. If the unit or system does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

D.7.3.6 Compressive loading test

Test sample: an unused fuel cartridge, and a water filled MCC fuel cartridge which contains MCC and water (MCC : water = 1 : 1 by weight), 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: To simulate the effects of the forces reasonably encountered due to being stepped on or something heavy being placed on the fuel cartridge, fuel cell power unit, or fuel cell power system.

Test procedure:

Power unit or system

i) The power unit/system test sample is to be placed between two flat wooden blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick.

ii) A crushing force is to be applied to the exposed surfaces of the enclosure gradually at a rate of 12,7 mm/min (1/2 inch/min).

iii) Each force applicator is to exert 25 kg ± 1 kg on the sample for 5 s.

iv) The test shall be done in three different orientations as a rule. If the sample does not stand on its own, it does not need to be tested in that orientation.

v) For power system or power unit tests, perform emissions testing in accordance with 7.3.14 following the crush test.

Cartridge

i) The cartridge test sample is to be placed between two flat wooden blocks of approximately 254 mm (10 inches) long, 101,6 mm (4 inches) wide and 12,7 mm (1/2 inch) thick.

ii) A crushing force is to be applied to the exposed surfaces of the enclosure gradually at a rate of 12,7 mm/min (1/2 inch/min).

iii) Each force applicator is to exert 100 kg ± 1 kg on the sample for 5 s.

iv) Cartridge orientations are to be selected based on likely stable resting positions when accidentally dropped (e.g., those orientations having the lowest centers of gravity with respect to the resting surface). It is acceptable to test only one surface of a prismatic cartridge that is sufficiently cubic and the curved surface of a cylindrical cartridge with a longitudinal axis length longer than twice the diameter.

Passing criteria: No fire at any time, no explosion at any time, no leakage, and no MCC powder leakage. Leakage shall be measured based upon the procedure described in Figures 2 and 4 respectively. Emissions from power units or power systems shall meet acceptance criteria in 7.3.14. If the unit or system does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

D.7.3.7 External short-circuit test

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: To simulate the effects of an external short circuit.

Test procedure:

i) Each test sample shall be short-circuited by connecting the positive and negative terminals of the micro fuel cell power unit with wire having a maximum resistance load of 0,1 W for at least 5 min.

ii) Tests shall be executed in operation and non-operation of fuel cells respectively.

iii) Perform emissions testing in accordance with 7.3.14 during and after short-circuit testing.

Passing criteria: No fire at any time, no explosion at any time, no leakage, and no MCC powder leakage. The leakage is measured by the procedure in Figure D.7. Exterior surfaces shall not exceed temperatures in Table 3 during or after short circuit testing. Emissions shall meet acceptance criteria in 7.3.14. If the unit or system does not operate but emissions do not exceed the limits of 7.3.14, the emissions test is acceptable.

NOTE This test can be done sequentially with the surface and exhaust gas temperature test, using the same sample.

D.7.3.9 Long-term storage test

Test sample: an unused fuel cartridge.

Purpose: To simulate the effects of long term storage at elevated temperature and ensure no leakage.

Test procedure:

Option 1 (Preferred)

i) Use a load cell designed and calibrated for use at 50 °C.

ii) Place load cell in a temperature chamber at 50 °C. Place the fuel cartridge, on top of the load cell in such a way that all the weight is applied to the load cell. A fixture may be used to control the position of the cartridge, to ensure all the weight is applied to the load cell.

iii) 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 0,33 g/h with a sample time of 10 min or less.

iv) Calculate the fuel vapour loss by the number of hours that the test sample was in the oven (28 days × 24 h/day = 672 h). If the average mass loss does not exceed 0,33 g/h, then the test sample pass the test for fuel vapour loss.

v) If the cartridge exceeds the 0,33 g/h fuel vapour loss criteria, then the test sample fails the test.

Option 2A

For fuel cartridge containing equal to or greater than 70 ml of fuel

i) Weight measurements should be collected with a high degree of confidence to assure that the fuel vapour loss does not exceed 0,33 g/h with a minimum of once per week.

ii) The time in which the test samples are removed from the oven for measurement, shall not be included in the time the test sample is to be tested (28 days). Additional time should be added to the total test time to allow for re-heating the test sample after each removal from the oven. The test samples should only be stabilised at room temperature if the mass loss will be affected.

iii) Calculate the fuel vapour loss by the number of hours that the test sample was in the oven (28 days × 24 h/day = 672 h) and, as long as the average mass loss does not exceed 0,33 g/h, then the test sample passes the test for fuel vapour loss.

iv) If the cartridge exceeds the 0,33 g/h fuel vapour loss criteria, then the test sample fails the test.

Option 2B

For fuel cartridge containing less than 70 ml of fuel (Option 1 is preferred for test samples containing less than 70 ml of fuel)

i) Weight measurements should be collected with a high degree of confidence to assure that the fuel vapour loss does not exceed 0,33 g/h with a minimum of once every three days.

ii) The time the test samples are removed from the oven 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 °C) each time the test sample is removed from the oven. The test samples should only be stabilised at room temperature if the mass loss will be affected.

iii) Calculate the fuel vapour loss by the number of hours that the sample was in the oven (28 days × 24 h/day = 672 h) and as long as the average mass loss does not exceed 0,33 g/h then the test sample passes the test for fuel vapour loss.

iv) If the cartridge exceeds the 0,33 g/h fuel vapour loss criteria, then test sample fails the test.

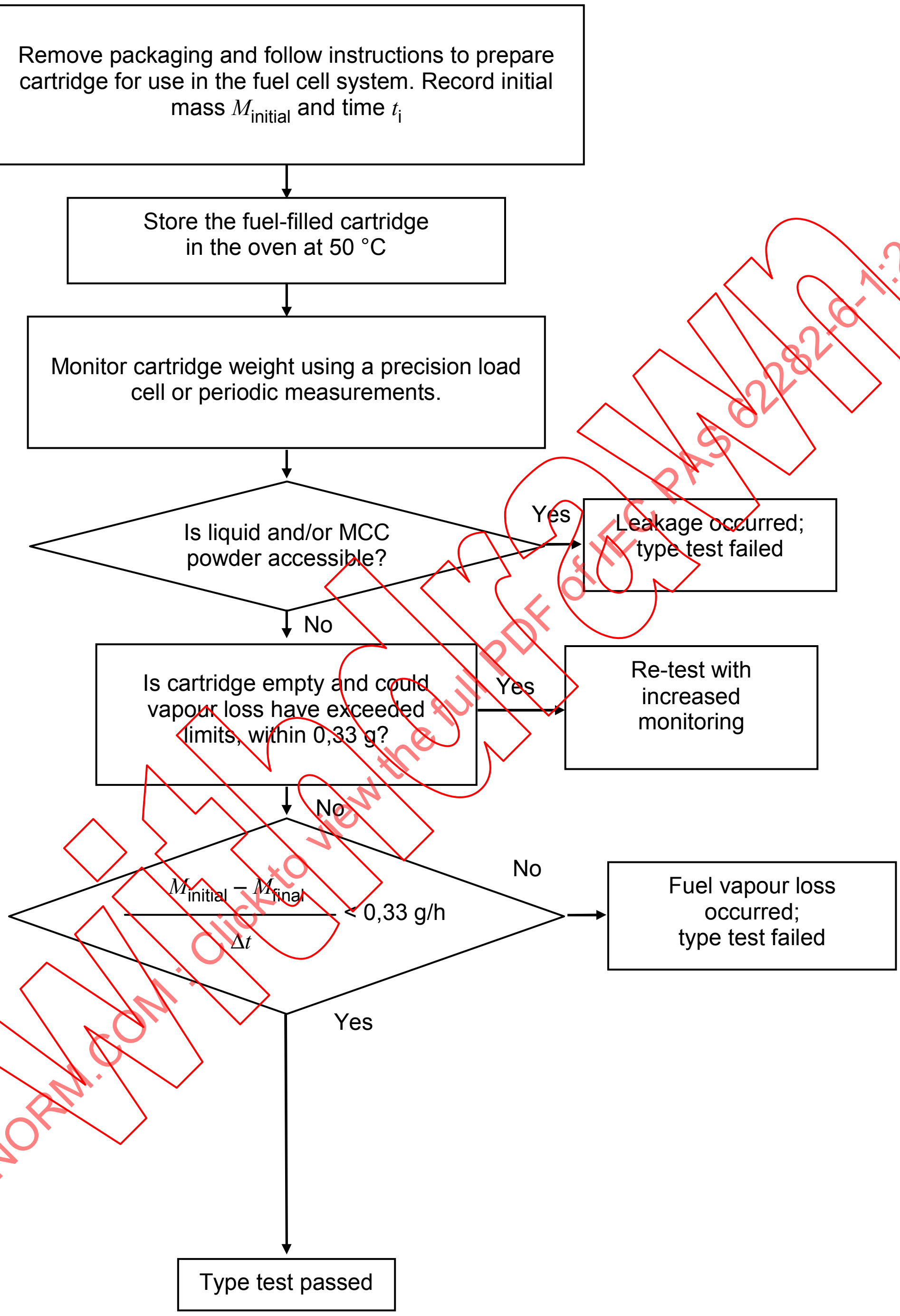

Figure D.9 – Fuel cartridge leakage and mass-loss flow chart for long-term storage

D.7.3.10 High-temperature connection test

Test sample: an unused fuel cartridge and a micro fuel cell power unit or micro fuel cell power unit valve.

Purpose: To simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit or micro fuel cell power unit valve with the fuel cartridge at an elevated temperature and ensure no leakage, no MCC powder leakage, no fire, no explosion.

Test procedure:

i) Place the fuel cartridge test sample into a temperature-controlled test chamber that is at a temperature of 50 °C ± 2 °C for at least 4 h.

ii) The micro fuel cell power unit or micro fuel cell power unit valve is kept nearby at normal room temperature, 22 °C ± 5 °C.

iii) Remove the test sample from the chamber and connect the fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve within 5 min of removal from the chamber.

iv) Check for leakage upon connection.

v) Disconnect the fuel cartridge and check for leakage.

vi) **Acceptance criteria:** No leakage, no MCC powder leakage, no fire, and no explosion. If, using normal force, the cartridge cannot be connected, and no leakage, no fire, and no explosion occurs, this is acceptable.

vii) Leakage shall be checked visually. Invert the cartridge and the micro fuel cell power unit or micro fuel cell power unit valve over indicating paper such that the valve is pointing downward toward the indicating paper and look for signs of leakage if any accessible leakage is found, the test fails.

iv) Flame shall be checked using cheesecloth.

v) Explosion shall be checked visually to verify no disturbance to the system or the test cell.

D.7.3.12 Connection cycling test

D.7.3.12.1 Cartridge

D.7.3.12.1.1 Insert/Exterior/or attached cartridge systems

Test sample: an unused fuel cartridge and a micro fuel cell power unit or micro fuel cell power unit valve fuelled in accordance with manufacturer's instruction.

Purpose: To simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage.

Test procedure:

i) Connect the first new fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection.

ii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

iii) Turn off the unit or stop simulated fuel flow.

iv) Disconnect the fuel cartridge and check for leakage.

v) Repeat this twice more for a total of three connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the first cartridge four more times for a total of seven connections and disconnections.

viii) Invert the cartridge and the system over indicating paper such that the valve points downward toward the indicating paper and look for signs of leakage.

ix) Connect and disconnect the first cartridge three more times for a total of 10 connection and disconnections.

x) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

xi) Connect cartridge and operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

xii) Turn off the unit or stop simulated fuel flow.

xiii) Disconnect the fuel cartridge and check for leakage.

xiv) **Acceptance criteria:** No leakage, no MCC powder leakage, no fire, and no explosion.

xv) Leakage shall be checked visually and if any accessible leakage is found the test fails.

xvi) Flame shall be checked using cheesecloth.

xvii) Explosion shall be checked visually to verify no disturbance to the system or the test cell.

D.7.3.12.1.2 Satellite cartridge

Test sample: an unused satellite fuel cartridge and a micro fuel cell power unit or micro fuel cell power unit valve fuelled in accordance with manufacturer's instructions

Purpose: To simulate the effects of mating and un-mating of the fuel cartridge to the fuel cell power unit and ensure no leakage.

Test procedure:

i) Connect the first new fuel cartridge to the micro fuel cell power unit or micro fuel cell power unit valve and check for leakage upon connection.

ii) Disconnect the fuel cartridge and check for leakage.

iii) Repeat this twice more for a total of three connections and disconnections.

iv) Invert the cartridge and the system over indicating paper such that the valve points downward toward the indicating paper and look for signs of leakage.

v) Connect and disconnect the first cartridge four more times for a total of seven connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the first cartridge three more times for a total of 10 connection and disconnections.

viii) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

ix) Repeat steps a) through h) four more times for a total of 50 cycles, waiting 1 h between each set of ten cycles.

x) **Acceptance criteria:** No leakage, no MCC powder leakage, no fire, and no explosion.

xi) Leakage shall be checked visually and if any accessible leakage is found the test fails.

xii) Flame shall be checked using cheesecloth.

xiii) Explosion shall be checked visually to verify no disturbance to the system or the test cell.

D.7.3.12.3 Micro fuel cell power unit

Test sample: a minimum of two unused cartridges and an additional 98 cartridges or cartridge valves and a micro fuel cell power unit fuelled in accordance with manufacturer's instructions

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.

Cartridge 1 and cartridge 100 are inspected; the other 980 cycles are only to age the system.

Test procedure

Cartridge 1

i) Connect the first unused fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

ii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

iii) Turn off the unit or stop simulated fuel flow.

iv) Disconnect the fuel cartridge and check for leakage.

v) Repeat this twice more for a total of three connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the first cartridge four more times for a total of seven connections and disconnections.

viii) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

ix) Connect and disconnect the first cartridge three more times for a total of 10 connection and disconnections.

x) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

xi) Connect the fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

xii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

xiii) Turn off the unit or stop simulated fuel flow.

xiv) Disconnect the fuel cartridge and check for leakage.

xv) Acceptance criteria: No leakage, no MCC leakage, no fire, and no explosion.

xvi) Leakage shall be checked visually and, if any accessible leakage is found, the test fails.

xvii) Flame shall be checked using cheesecloth.

xviii) Explosion shall be checked visually to verify no disturbance to the system or the test cell.

Power unit connection ageing

Using either cartridges or cartridge valves, cycle the micro fuel cell power system connection for a total of 980 connections and disconnections. Inversion of the system or the cartridges is not necessary, but if leakage is found the test fails. Following this ageing, a final unused cartridge will be tested.

Final cartridge

i) Connect the final unused fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

ii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

iii) Turn off the unit or stop simulated fuel flow.

iv) Disconnect the fuel cartridge and check for leakage.

v) Repeat this twice more for a total of three connections and disconnections.

vi) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

vii) Connect and disconnect the final cartridge four more times for a total of seven connections and disconnections.

viii) Invert the cartridge and the system over indicating paper in such a way that the valve points downward toward the indicating paper and look for signs of leakage.

ix) Connect and disconnect the final cartridge three more times for a total of 10 connections and disconnections.

x) Invert the cartridge and the system over indicating paper such that the valve points downward toward the indicating paper and look for signs of leakage.

xi) Connect the fuel cartridge to the micro fuel cell power unit and check for leakage upon connection.

xii) Operate the fuel cell power unit or otherwise simulate fuel flow for 1 min.

xiii) Turn off the unit or stop simulated fuel flow.

xiv) Disconnect the fuel cartridge and check for leakage.

xv) Acceptance criteria: No leakage, no MCC leakage, no fire, and no explosion.

xvi) Leakage shall be checked visually and if any accessible leakage is found the test fails.

xvii) Flame shall be checked using cheesecloth.

xviii) Explosion shall be checked visually to verify no disturbance to the system or the test cell.

Annex E
(normative)

Borohydride compounds

This annex establishes modifications and additions to the main body of the PAS for application to the fuel and technologies addressed by this annex. These are fuel cells powered by borohydride compound fuels and fuel cartridges for use with these fuel cells. Where possible, the numbering system of this annex corresponds to the numbering of clauses in the main body. Requirements from the main body of this PAS not specifically discussed in this annex apply to borohydride compound fuel cell systems as written. Modified clause numbers reflect their counterpart section in the main body. Any additional clauses have been assigned new numbers.

E.1 Scope

Except where specifically noted, Clause 1 shall apply as written when used in conjunction with this annex.

E.1.1 System Boundary

Except where specifically noted, Subclause 1.1 shall apply as written when used in conjunction with this annex.

E.1.1.6 Fuel and technology covered by this annex

E.1.1.6.1 This annex shall apply to micro fuel cells which are powered by borohydride compound fuel.

E.1.1.6.2 This PAS encompasses equipment designs that include proton exchange membrane (PEM) fuel cell stacks using hydrogen from sodium and/or potassium borohydride fuel (indirect borohydride fuel cell power systems), and direct borohydride alkaline fuel cells using sodium or potassium borohydride compound fuel (direct borohydride fuel cell power systems). The designs may or may not include fuel processing subsystems to derive hydrogen gas from the fuel of choice.

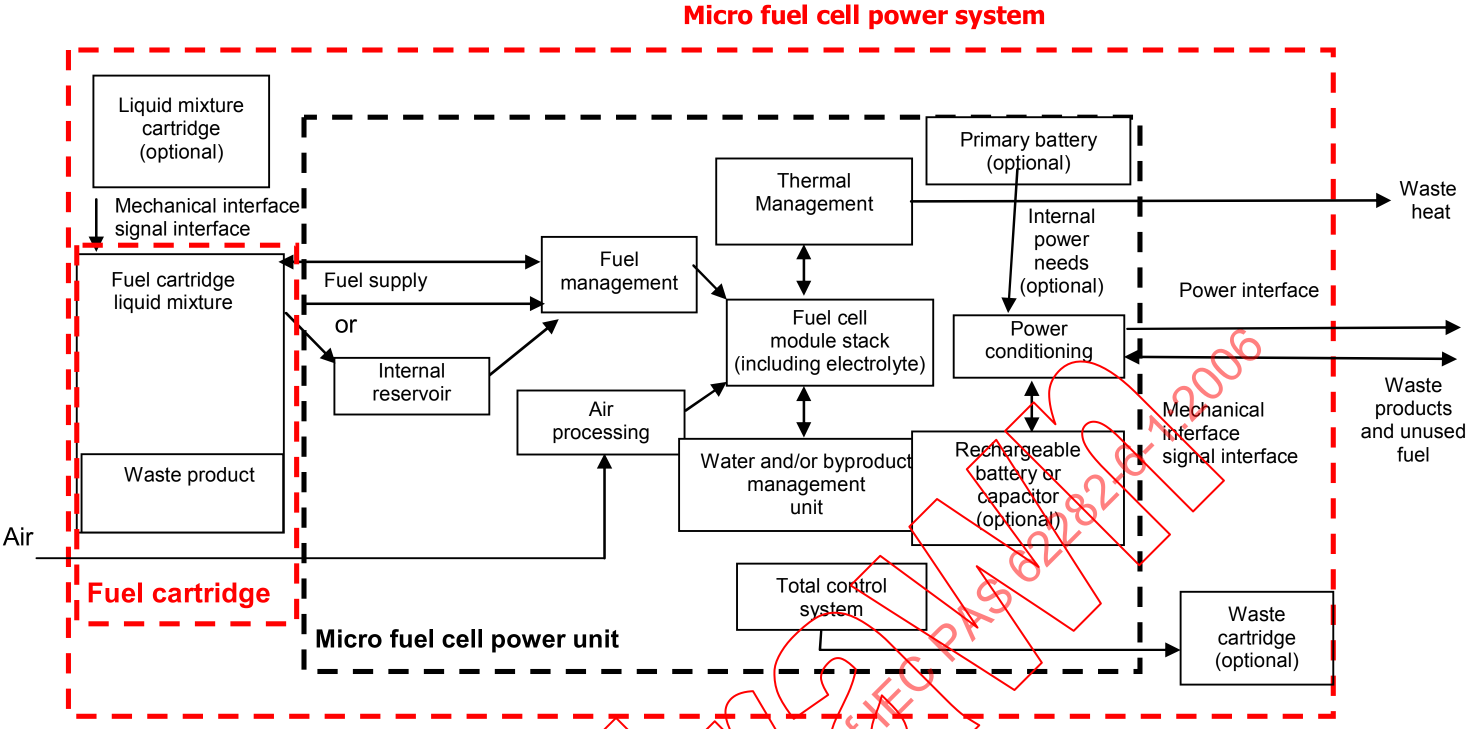

Figure E.1 – Direct borohydride fuel cell power unit

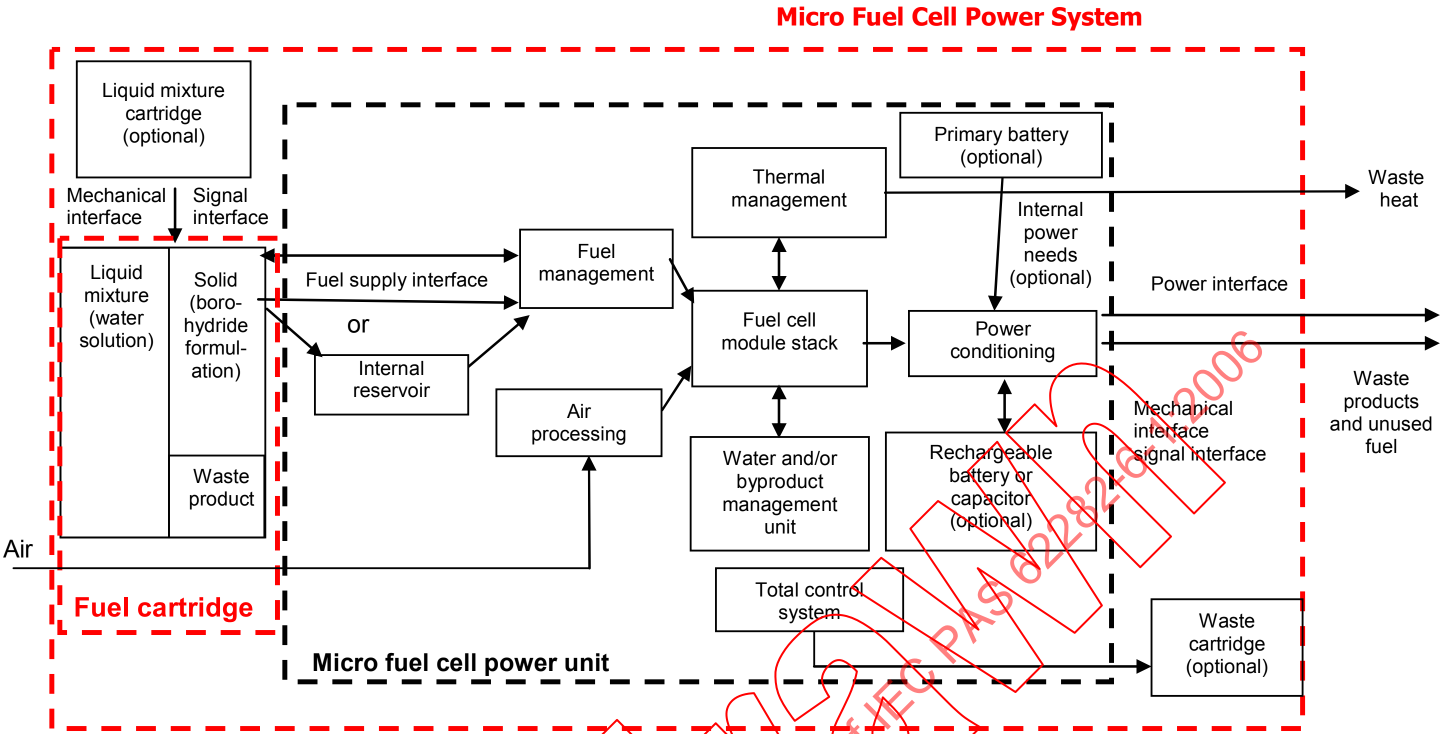

Figure E.2 – Indirect borohydride fuel cell power unit

E.1.3 Considerations

E.1.3.3 Hydrogen formed by borohydride fuel is not toxic; therefore, sentences concerning the toxicity of emissions in the main body of the PAS shall not apply in this annex.

E.1.3.3 Any descriptions contained within the main body of the PAS specifically pertaining to methanol are not applicable.

E.2 Normative references

Clause 2 applies as written when used in conjunction with this annex, with the following addition. The following reference is indispensable for the application of this annex.

ISO 16111, Transportable gas storage devices – hydrogen absorbed in reversible metal hydride[1]

E.3 Terms and definitions

Except as noted below, the terms and definitions of Clause 3 shall apply to this annex. The numeric index of definitions below correspond to the term in Clause 3 with an alternative meaning when considering a device for testing under this annex.

E.3.3
fuel
corrosive and/or water reactive formulation of borohydride compounds used to produce electricity directly or indirectly in a fuel cell power system

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[1] To be published.

E.3.3.1
solid fuel, corrosive
solid formulation of borohydride compounds and one or more alkali metal hydroxides

E.3.3.2
solid fuel, water reactive
solid formulation of borohydride compounds containing greater than 70 % borohydride compound and less than 30 % activator which is comprised of a Group VIII transition metal salt

E.3.3.3
liquid fuel, corrosive
liquid formulation of borohydride compounds and one or more alkali metal hydroxides

E.3.5.1
direct borohydride fuel cell power system
fuel cell system in which a liquid formulation of borohydride compounds chemically reacts directly on the anode of the fuel cell to produce electricity in a fuel cell unit

E.3.5.2
indirect borohydride fuel cell power system
fuel cell system in which a solid or liquid formulation of borohydride compounds, is processed to produce hydrogen which reacts on a proton exchange membrane (PEM) to produce electricity in a fuel cell unit

E.3.21
leakage
accessible fuel, fuel by-products, electrolyte or liquid fuel components outside the system or cartridge

E.3.27
borohydride compounds
sodium or potassium borohydride, or a mixture thereof

E.3.28
liquid fuel component
water solutions used to produce hydrogen within the fuel processing subsystem

E.3.29
electrolye
corrosive (alkaline) compound solution or acidic ion conducting membrane used to complete an electric circuit within a fuel cell

E.3.30
fuel by-products
compounds produced after hydrogen and/or electricity is produced from fuel

E.3.31
permissible emissions
release of hydrogen or fuel that results in one or a combination of the following situations that are deemed unsuitable:

a) hydrogen in air mixture in excess of 25 % of the lower flammability limit of hydrogen in the control volume,

b) leakage rate of hydrogen greater than 3 standard cc/min from any single source

E.3.32
accessible fuel, fuel by-products, electrolyte or liquid fuel components
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 cartridge capable of releasing hydrogen if the cartridge is immersed

E.3.33
fuel processing subsystem
subsystem within the micro fuel cell power system used to produce hydrogen from solid and/or liquid formulations of borohydride compounds

E.3.34
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 system design

E.3.35
uncontrolled mixing
mixing of incompatible materials that occurs in ways not specifically provided for by the system design

E.4 Materials and construction of fuel cartridge, micro fuel cell power unit, and micro fuel cell power system for portable devices

E.4.1 General

Except where specifically noted, Clause 4 shall apply for the purposes of this annex. Where subclauses corresponding to those in Clause 4 are not included in this annex, it shall be assumed that said subclauses are to apply to this annex as written. Due to the nature of the fuel considered for this annex, all subclauses of Clause 4 that refer to exclusively methanol or considerations for parts in contact with methanol shall not apply to devices tested under this annex.

E.4.7 General construction

Except where specifically noted, subclause 4.7 shall apply as written when used in conjunction with this annex.

E.4.7.4 The connection between the fuel cartridge and the fuel cell power unit, when engaged so as to allow transfer of fuel from the cartridge to the power unit, must not allow the fuel to leak, as defined in this annex.

E.4.9 Piping and fittings

Except where specifically noted, subclause 4.9 shall apply as written when used in conjunction with this annex.

E.4.9.8 Piping systems exposed to hydrogen shall employ materials suitable for exposure to hydrogen, as defined in ISO/TS 16111, Annex A.

E.4.10 Fuel containing parts and piping system

Except where specifically noted, subclause 4.10 shall apply as written when used in conjunction with this annex.