



BSI Standards Publication

Fuel cell technologies

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

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National foreword

This British Standard is the UK implementation of EN 62282-6-100:2010+A1:2012. It supersedes BS EN 62282-6-100:2010 which is withdrawn. It is identical to IEC 62282-6-100:2010, incorporating amendment 1:2012 and corrigendum December 2011.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by IEC corrigendum December 2011 is indicated in the text by AC1 AC1.

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The UK committee voted to abstain in the adoption stage ballot for EN 62282-2-100. The positive result of the CENELEC ballot resulted in the publication of this standard.

A list of organizations represented on this committee can be obtained on request to its secretary.

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**Fuel cell technologies -
Part 6-100: Micro fuel cell power systems -
Safety
(IEC 62282-6-100:2010)**

Technologies des piles à combustible -
Partie 6-100: Système à micro-piles
à combustible - Sécurité
(CEI 62282-6-100:2010)

Brennstoffzellentechnologien -
Teil 6-100: Mikro-Brennstoffzellen-
Energiesysteme - Sicherheit
(IEC 62282-6-100:2010)

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Foreword

The text of document 105/255/FDIS, future edition 1 of IEC 62282-6-100, prepared by IEC TC 105, Fuel cell technologies, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62282-6-100 on 2010-04-01.

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- latest date by which the EN has to be implemented
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- latest date by which the national standards conflicting
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Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62282-6-100:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 62282-5-1	NOTE	Harmonized as EN 62282-5-1.
IEC 61025	NOTE	Harmonized as EN 61025.
IEC 60812	NOTE	Harmonized as EN 60812.

Foreword to amendment A1

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Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-426	2008	International Electrotechnical Vocabulary - Part 426: Equipment for explosive atmospheres	-	-
IEC 60079-15	2005	Electrical apparatus for explosive gas atmospheres - Part 15: Construction, test and marking of type of protection "n" electrical apparatus	EN 60079-15	2005
IEC 60086-4	-	Primary batteries - Part 4: Safety of lithium batteries	EN 60086-4	-
IEC 60086-5	-	Primary batteries - Part 5: Safety of batteries with aqueous electrolyte	EN 60086-5	-
IEC 60695-1-1	-	Fire hazard testing - Part 1-1: Guidance for assessing the fire hazard of electrotechnical products - General guidelines	EN 60695-1-1	-
IEC 60695-2-11	-	Fire hazard testing - Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end-products	EN 60695-2-11	-
IEC 60695-11-10	-	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10	-
IEC 60730-1 (mod) + A1 (mod) + A2 (mod)	1999 2003 2007	Automatic electrical controls for household and similar use - Part 1: General requirements	EN 60730-1 + corr. August + A1 + A2	2000 2007 2004 2008
-	-		+ A11	2002
-	-		+ A14	2005
-	-		+ A13	2004
-	-		+ A12	2003
-	-		+ A15	2007
-	-		+ A16	2007
-	-		+ corr. March	2010
IEC 60950-1 (mod)	2005	Information technology equipment - Safety - Part 1: General requirements	EN 60950-1 + A11	2006 2009
IEC 61032	1997	Protection of persons and equipment by enclosures - Probes for verification	EN 61032	1998

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 62133	2002	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications	EN 62133	2003
IEC 62281	2004	Safety of primary and secondary lithium cells and batteries during transport	EN 62281	2004
ISO 175	-	Plastics - Determination of the effects of liquid chemicals, including water	-	-
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 - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography - Part 1: Pumped sampling	-	-
ISO 7010	2003 ¹	Graphical symbols - Safety colours and safety signs - Safety signs used in workplaces and public areas	-	-

¹ ISO 7010:2003 is superseded by ISO 7010:2012, which is harmonised as EN ISO 7010:2012.

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FUEL CELL TECHNOLOGIES –

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

1 Scope

1.1 General

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

1.2 Fuels and technologies covered

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

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

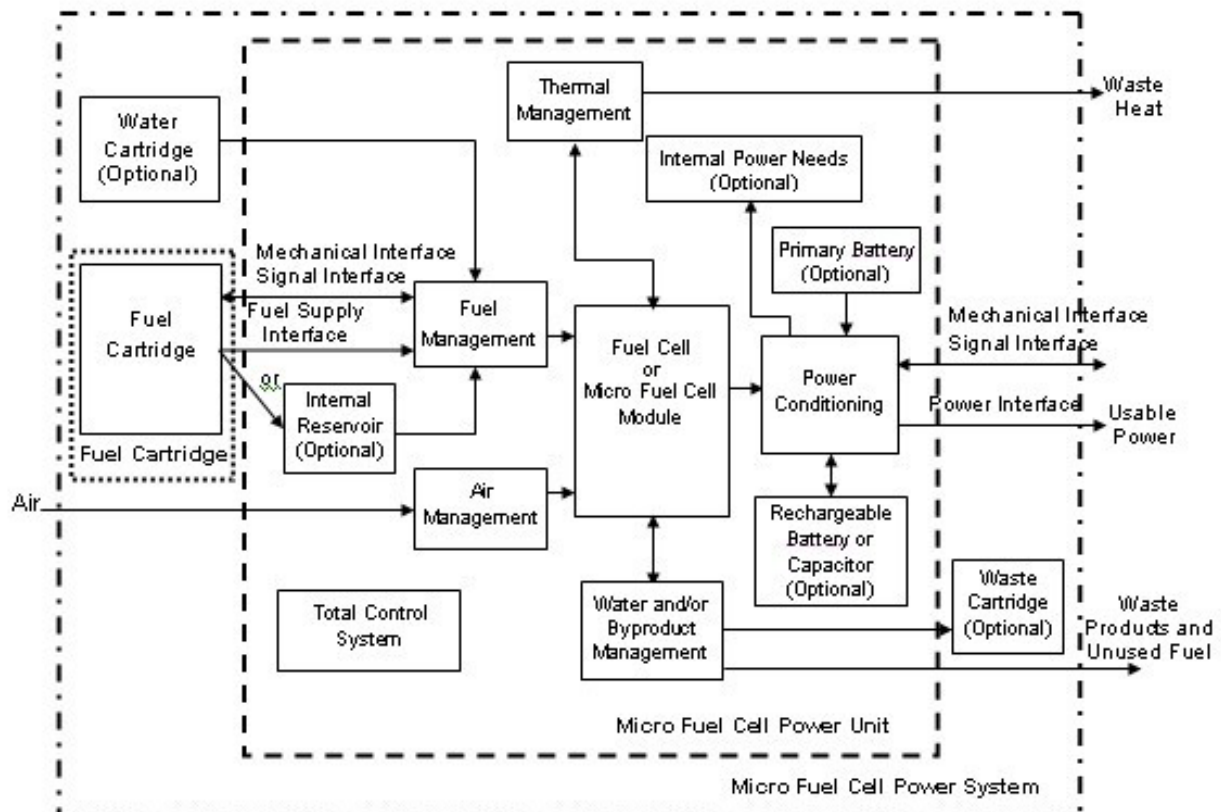


Figure 1 – Micro fuel cell power system block diagram

1.3 Equivalent level of safety

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

2 Normative references

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ISO 7010:2003, *Graphical symbols – Safety colours and safety signs – Safety signs used in workplaces and public areas*

3 Terms and definitions

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

3.1

attached cartridge

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

3.2

electrical enclosure

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

3.3

exterior cartridge

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

3.4

fire enclosure

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

3.5

fuel

any of the following substances:

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

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

3.6

fuel cartridge

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

3.7

fuel cell power system

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

3.8

hazardous liquid fuel

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

3.9

insert cartridge

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

3.10

internal reservoir

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

3.11

leakage

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

3.12

limited power sources

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

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

3.13

toxic material

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

3.14

mechanical enclosure

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

3.15

micro fuel cell

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

3.16

micro fuel cell power system

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

3.17

micro fuel cell power unit

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

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

3.18

no accessible liquid

liquid fuel that is not subject to contact by consumers

3.19

no fuel vapour loss

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

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

3.20

normal use conditions

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

3.21

partially filled fuel cartridge

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

3.22

rated power

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

3.23

satellite cartridge

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

3.24

refill valve

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

3.25

shut-off valve

component of a fuel cartridge that controls the release of fuel

3.26

waste cartridge

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

3.27

water cartridge

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

3.28

fuel management

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

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

3.29

air management

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

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

3.30

total control system

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

3.31

primary battery (optional)

non-rechargeable battery

3.32

fuel cell

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

3.33

micro fuel cell module

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

3.34

fuel cell stack

assembly of two or more fuel cells which are electrically connected

3.35

non-operating

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

3.36

hazardous energy level

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

[1.2.8.10 of IEC 60950-1:2005]

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

4.1 General

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

4.2 FMEA / hazard analysis

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

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

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

4.3 General materials

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

4.4 Selection of materials

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

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

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

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

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

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

4.5 General construction

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

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

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

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

4.6 Fuel valves

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

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

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

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

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

4.7 Materials and construction – system

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

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

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

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

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

4.8 Ignition sources

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

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

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

Immediate and controlled oxidation shall be ensured by the following:

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

4.9 Enclosures and acceptance strategies

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

4.9.1 Parts requiring a fire enclosure

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

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

See Table 1 for material flammability requirements.

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

4.9.2 Parts not requiring a fire enclosure

The following parts do not require a fire enclosure.

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

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

Table 1 – Summary of material flammability requirements

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

4.9.3 Materials for components and other parts outside fire enclosures

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

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

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

4.9.3.3 Connectors shall comply with one of the following:

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

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

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

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

4.9.4 Materials for components and other parts inside fire enclosures

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

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

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

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

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

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

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

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

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

4.9.5 Mechanical enclosures

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

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

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

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

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

4.10 Protection against fire, explosion, corrosivity and toxicity hazard

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

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

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

4.11 Protection against electrical hazards

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

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

4.12 Fuel supply construction

4.12.1 Fuel cartridge construction

Fuel cartridges shall conform to the following requirements.

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

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

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

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

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

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

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

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

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

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

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

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

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

4.12.2 Fuel cartridge fill requirement

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

4.13 Protection against mechanical hazards

4.13.1 Piping and tubing other than fuel lines

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

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

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

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

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

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

4.13.2 Exterior surface and component temperature limits

4.13.2.1 General

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

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

4.13.2.2 Exterior surfaces

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

4.13.2.3 Handles, knobs, grips and similar parts

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

4.13.2.4 Components

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

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

Table 2 – Temperature limits

Part	Temperature °C
External enclosure, handles, knobs, grips and the like which, in normal use, are held: <ul style="list-style-type: none">– metal– porcelain or vitreous material– moulded material, rubber, or wood	50 60 70
Parts and materials in direct contact with potentially flammable gas or vapours Exception – Areas that are separately evaluated that utilize a high-temperature process.	80 % of the auto-ignition temperature of the potentially flammable gas or vapour

4.13.3 Motors

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

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

4.14 Construction of electric device components

4.14.1 Limited power sources

Limited power sources shall meet one of the following:

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

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

Table 3 – Limits for inherently limited power sources

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

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

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

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

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

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

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

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

4.14.2 Devices that use electronic controllers

4.14.2.1 Control systems

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

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

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

4.14.3 Electrical conductors/wiring

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

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

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

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

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

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

4.14.3.6 Wireways shall be smooth and free from sharp edges.

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

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

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

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

4.14.4 Output terminal area

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

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

4.14.5 Electric components and attachments

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

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

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

4.14.6 Protection

4.14.6.1 Objective of protection devices

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

4.14.6.2 Protection from short-circuit accidents

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

4.14.6.3 Protection from electrical overloading

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

5 Abnormal operating and fault conditions testing and requirements

5.1 General

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

5.2 Compliance testing

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

5.3 Passing criteria

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

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

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

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

5.5 Abnormal operation – electromechanical components

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

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

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

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

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

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

5.7 Abnormal operation – simulation of faults based on hazard analysis

The following faults shall be simulated.

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

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

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

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

6.1 General

[A1] All micro fuel cell power systems, micro fuel cell power units and fuel cartridges shall be accompanied by appropriate safety information (instructions, warnings, or both) communicating the intended safe transportation, use, storage, maintenance and disposal of the product, including warnings regarding adequate ventilation for storage.

If space does not permit all markings on the fuel cartridge, markings corresponding to a) through f) in 6.2 may be on the smallest unit package, or on a package insert. The fuel cartridge shall also be marked with the appropriate signal word (“CAUTION”, “WARNING” or “DANGER”) and the general warning sign (W001 specified in ISO 7010:2003) plus the text:

“(See accompanying Warning Information.)”. **[A1]**

6.2 Minimum markings required on the fuel cartridge

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

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

6.3 Minimum markings required on the micro fuel cell power system

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

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

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

Usage instructions to include:

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

6.5 Technical documentation

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

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

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

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

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

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

7.1 General

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

Table 5 – List of type tests

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

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

Table 6 – Laboratory standard conditions

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

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

7.2 Leakage measurement of methanol and the measuring procedure

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

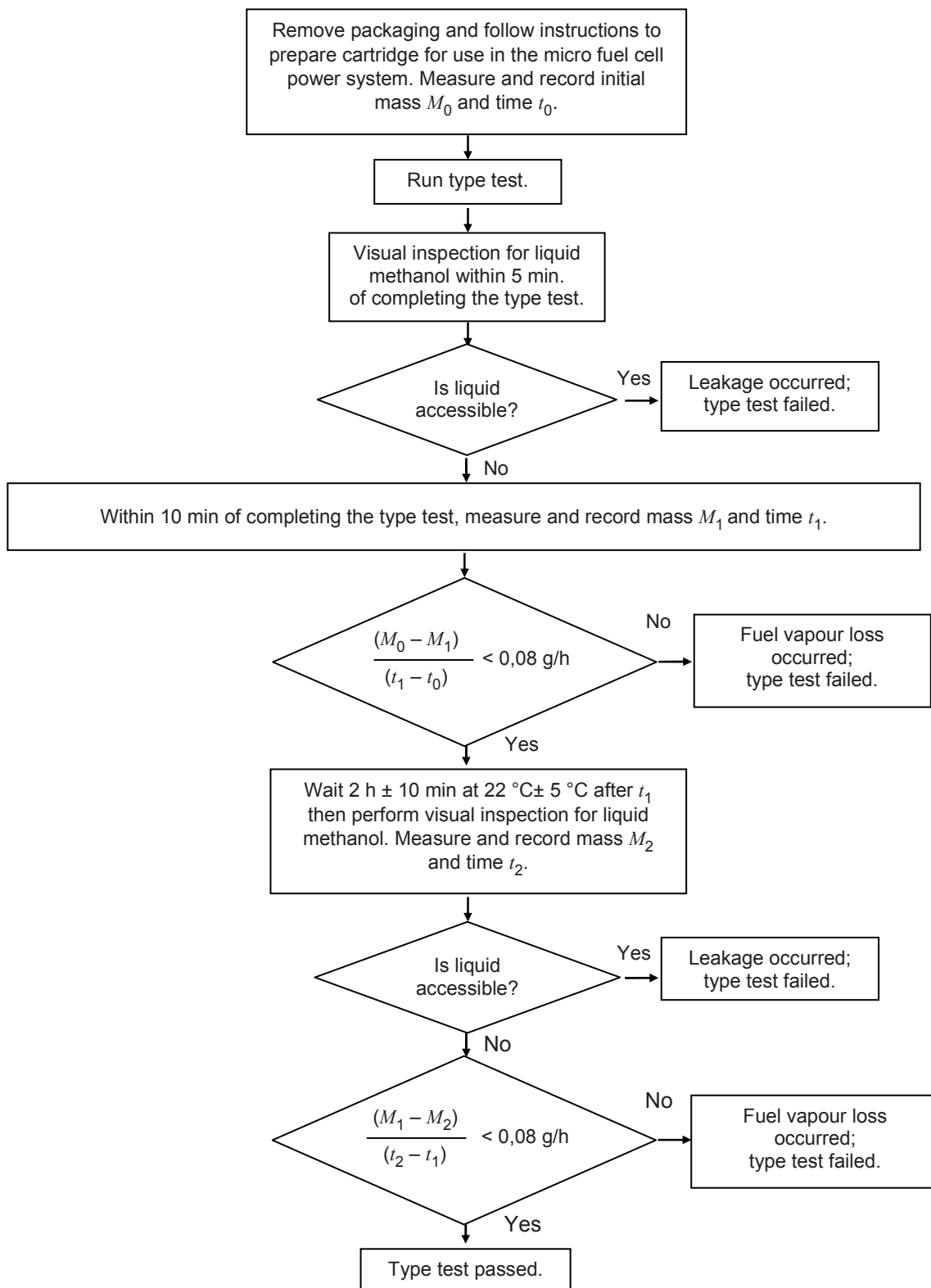


Figure 2 – Fuel cartridge leakage and mass loss test flow chart for pressure differential, vibration, drop, and compressive loading tests

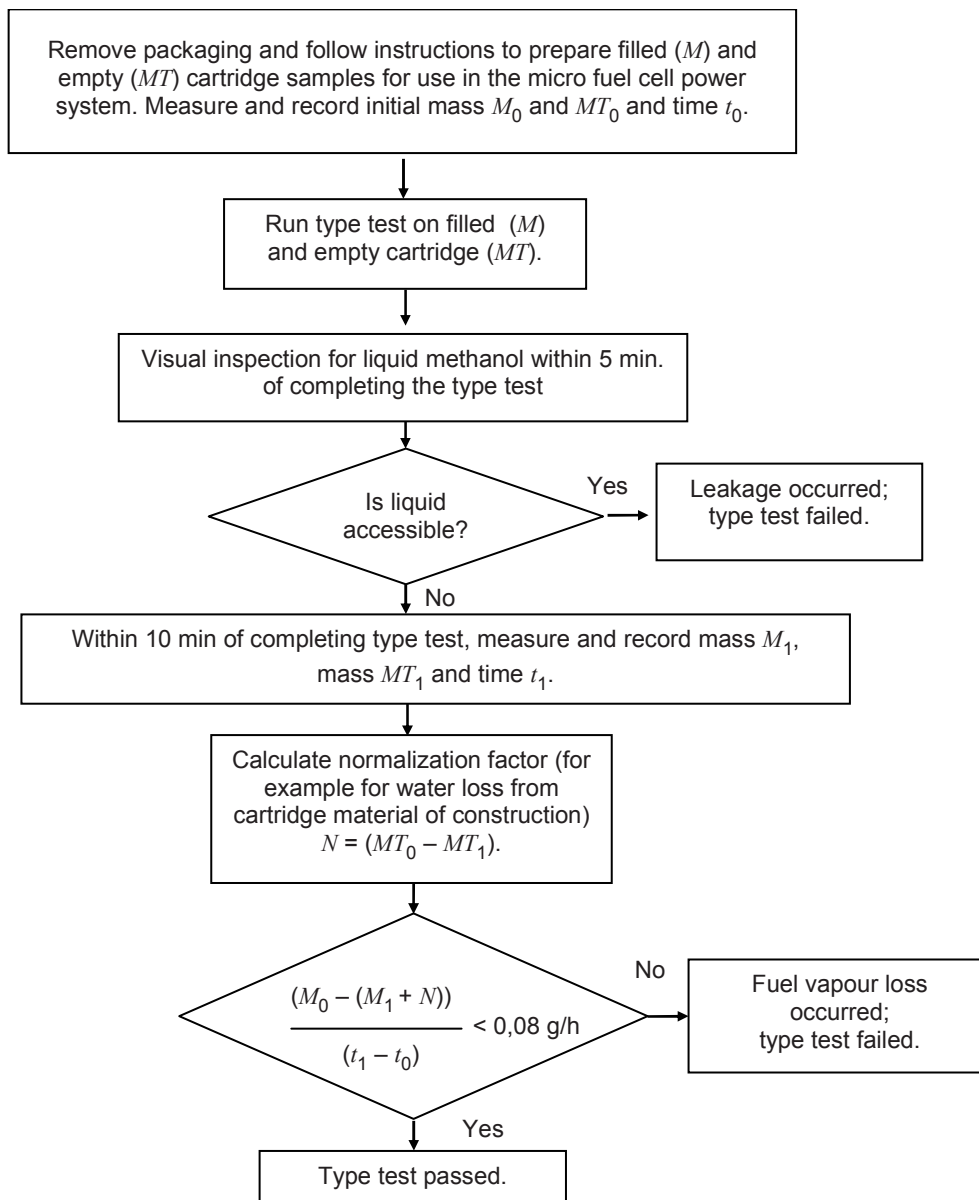


Figure 3 – Fuel cartridge leakage and mass loss test flow chart for temperature cycling test and high temperature exposure test

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

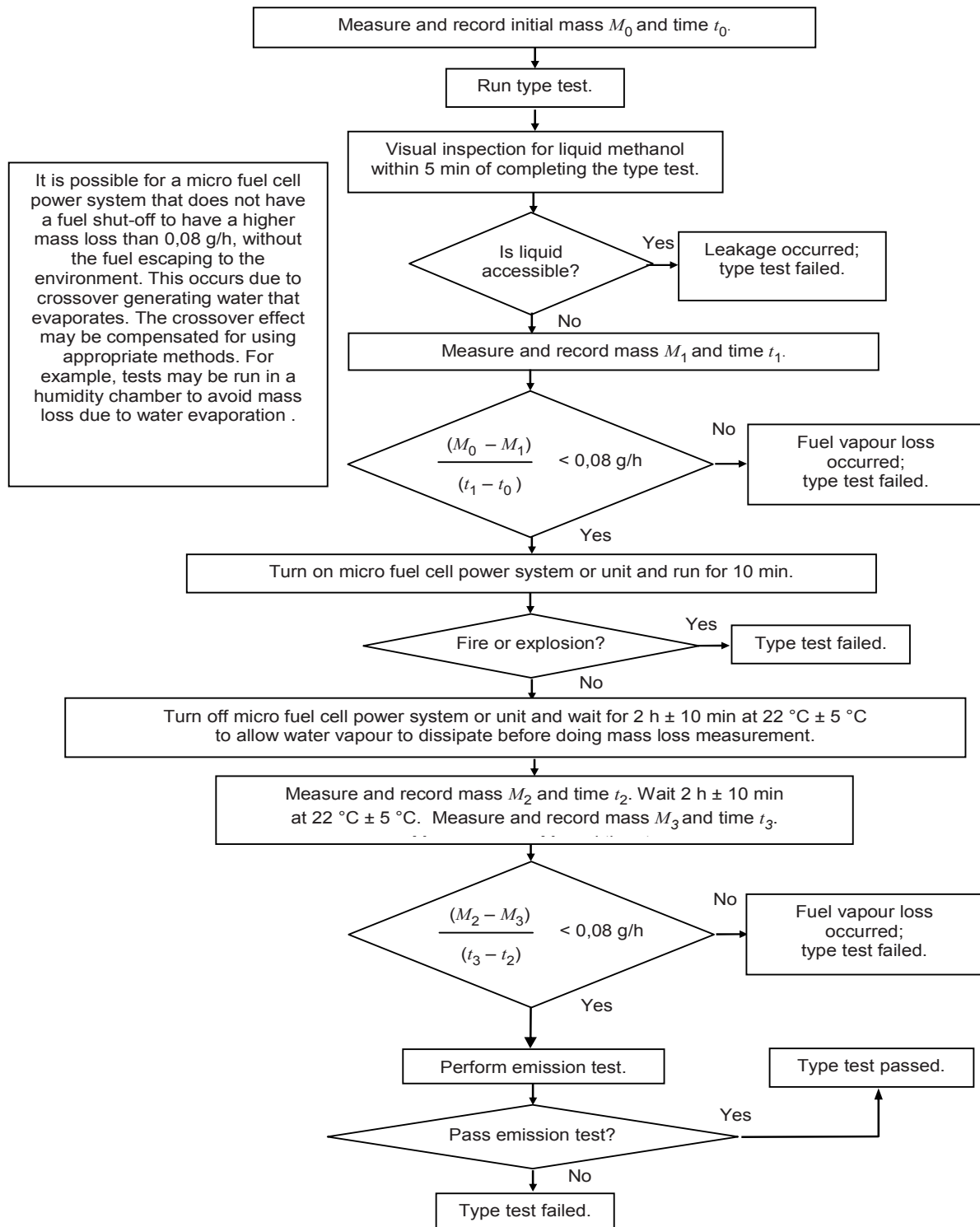


Figure 4 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for pressure differential, vibration, temperature cycling, drop and compressive loading tests

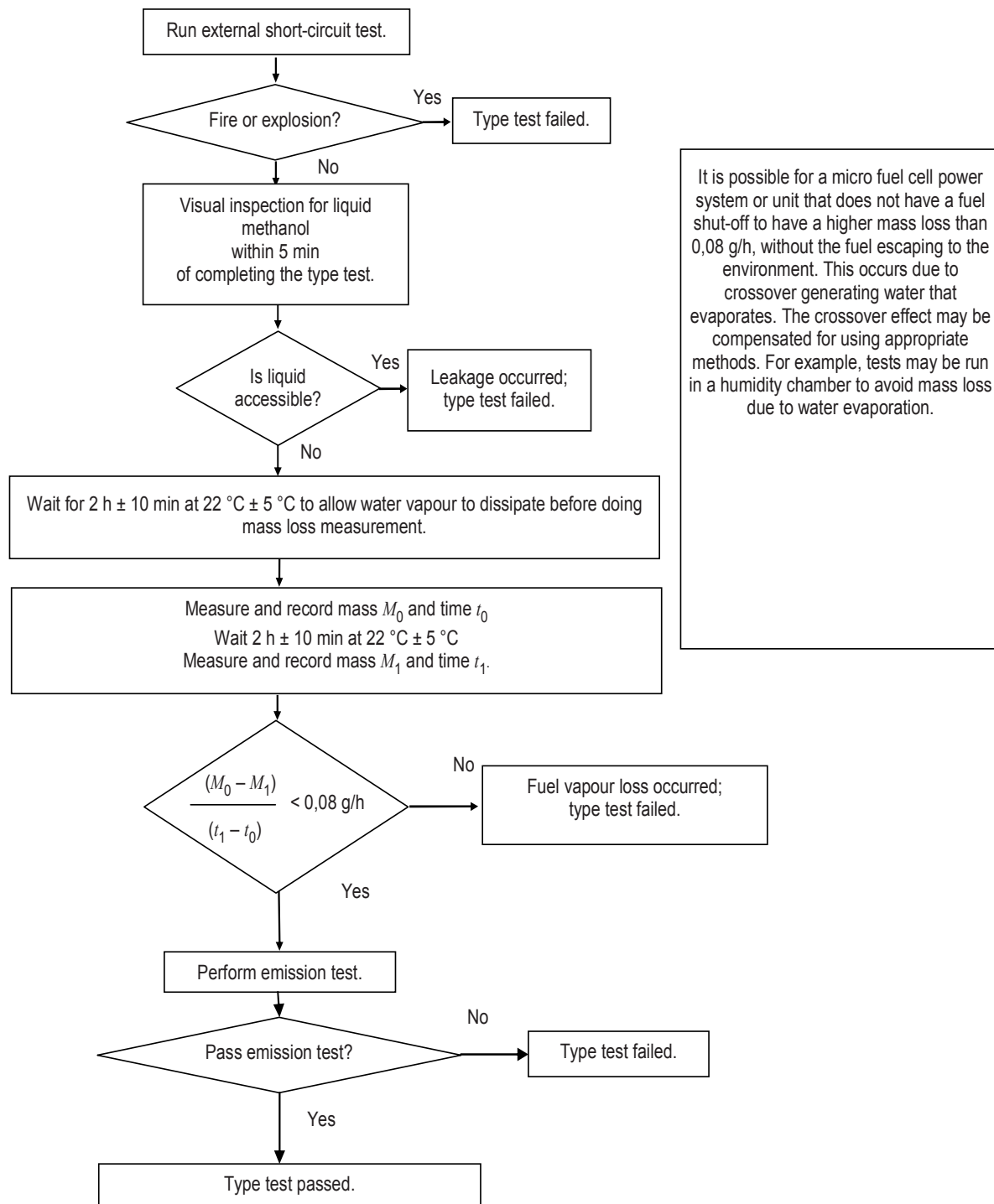


Figure 5 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for external short-circuit test

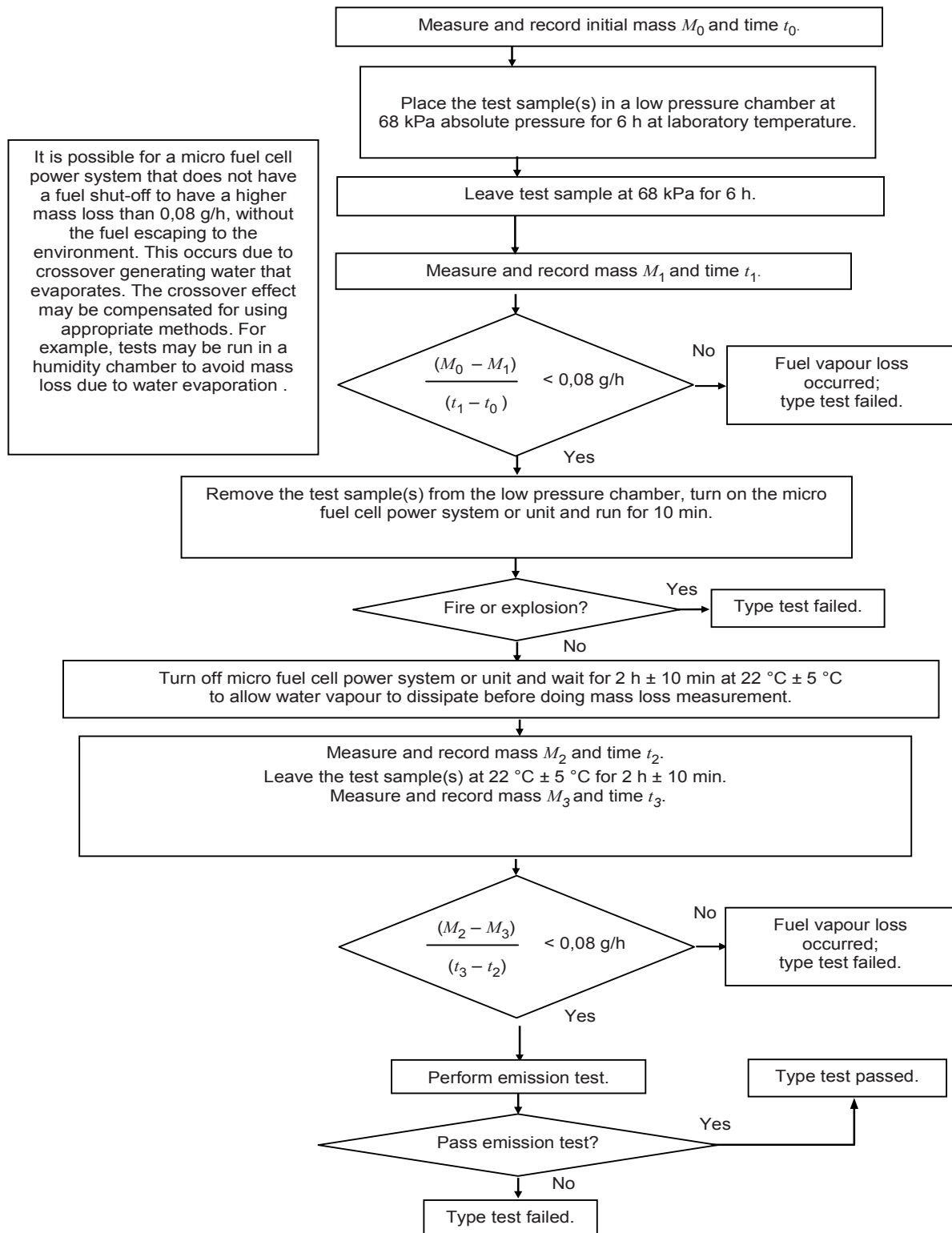


Figure 6 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 68 kPa low external pressure test

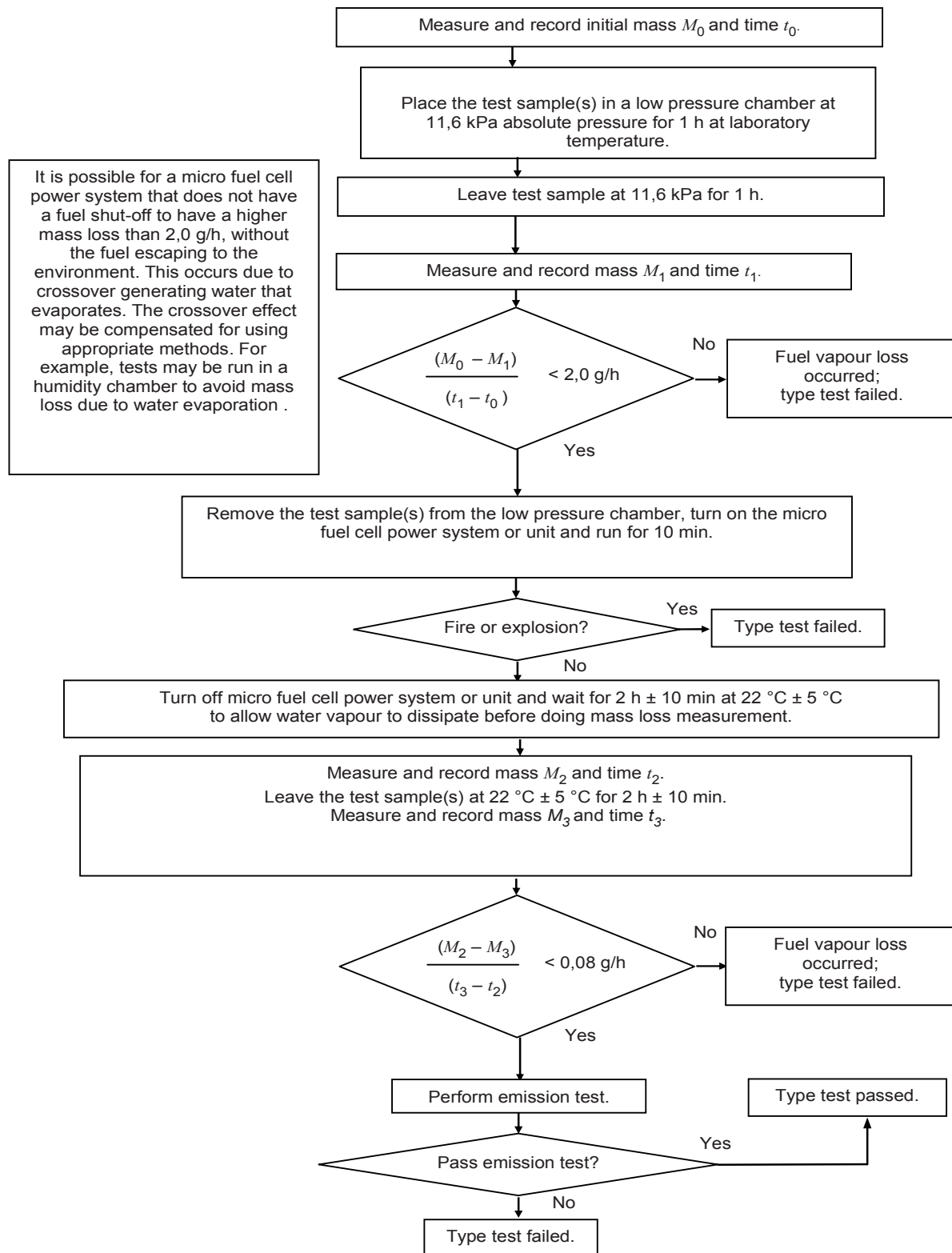


Figure 7 – Micro fuel cell power system or micro fuel cell power unit leakage and mass loss test flow chart for 11,6 kPa low external pressure test

7.3 Type tests

7.3.1 Pressure differential tests

7.3.1.1 General

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

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

7.3.1.2 Fuel cartridge internal pressurization test

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

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

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

7.3.1.3 Fuel cartridge low external pressure test

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

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

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

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

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

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

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

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

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

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

7.3.2 Vibration test

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

7.3.3 Temperature cycling test

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