DD IEC/PAS 62282-6-150:2011

BSI Standards Publication

Fuel cell technologies

Part 6-150: Micro fuel cell power systems – Safety – Water reactive (UN Division 4.3) compounds in indirect PEM fuel cells

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This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature. It should be applied on this provisional basis, so that information and experience of its practical application can be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for its conversion to an international standard. A review of this publication will be initiated not later than 3 years after its publication by the international organization so that a decision can be taken on its status. Notification of the start of the review period will be made in an announcement in the appropriate issue of *Update Standards.*

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

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Part 6-150: Micro fuel cell power systems – Safety – Water reactive (UN Division 4.3) compounds in indirect PEM fuel cells

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CONTENTS

FOREWORD 5
1 Scope 7
1.1 General 7
1.2 Fuels and technologies covered 7
1.3 Equivalent level of safety 9
2 Normative references 10
3 Terms and definitions 11
4 Materials and construction of micro fuel cell power systems, micro fuel cell power units and fuel cartridges 16
4.1 General 16
4.2 FMEA / hazard analysis 16
4.3 General materials 17
4.4 Selection of materials 17
4.5 General construction 18
4.6 Fuel valves 18
4.7 Materials and construction – system 18
4.8 Ignition sources 19
4.9 Enclosures and acceptance strategies 19
4.9.1 Parts requiring a fire enclosure 19
4.9.2 Parts not requiring a fire enclosure 20
4.9.3 Materials for components and other parts outside fire enclosures 21
4.9.4 Materials for components and other parts inside fire enclosures 22
4.9.5 Mechanical enclosures 23
4.10 Protection against fire, explosion, corrosivity and toxicity hazard 23
4.11 Protection against electrical hazards 24
4.12 Fuel supply construction 24
4.12.1 Fuel cartridge construction 24
4.12.2 Fuel cartridge fill requirement 25
4.13 Protection against mechanical hazards 25
4.13.1 Piping and tubing other than fuel or hydrogen lines 25
4.13.2 Exterior surface and component temperature limits 26
4.13.3 Motors 26
4.14 Construction of electric device components 27
4.14.1 Limited power sources 27
4.14.2 Devices that use electronic controllers 28
4.14.3 Electrical conductors/wiring 28
4.14.4 Output terminal area 29
4.14.5 Electric components and attachments 29
4.14.6 Protection 29
5 Abnormal operating and fault conditions testing and requirements 29
5.1 General 29
5.2 Compliance testing 30
5.3 Passing criteria 30
5.4 Simulated faults and abnormal conditions for limited power and SELV circuits 31
5.5 Abnormal operation – electromechanical components 31
5.6 Abnormal operation of micro fuel cell power systems or units with integrated batteries 31

AVA Documents
Document Sharing Hub

Full document details: DD IEC/PAS 62282-6-150:2011

5.7 Abnormal operation – simulation of faults based on hazard analysis 32
6 Instructions and warnings for micro fuel cell power systems, micro fuel cell power units and fuel cartridges 32
6.1 General 32
6.2 Minimum markings required on the fuel cartridge 32
6.3 Minimum markings required on the micro fuel cell power system or micro fuel cell power unit 33
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 33
6.5 Technical documentation 34
7 Type tests for micro fuel cell power systems, micro fuel cell power units and fuel cartridges 34
7.1 General 34
7.2 Leakage, hydrogen leakage, and hydrogen gas loss, and hydrogen emission measurement and the measuring procedures 36
7.2.1 Leakage test and measuring procedure 36
7.2.2 Hydrogen leakage measurement from fuel cartridges and/or fuel management systems and measuring procedure 36
7.2.3 Hydrogen gas loss measurements from micro fuel cell power systems and micro fuel cell power units and measuring procedures 37
7.3 Type tests 44
7.3.1 Pressure differential tests 44
7.3.2 Vibration test 48
7.3.3 Temperature cycling test 49
7.3.4 High temperature exposure test 50
7.3.5 Drop test 51
7.3.6 Compressive loading test 51
7.3.7 External short-circuit test 52
7.3.8 Surface, component and exhaust gas temperature test 53
7.3.9 Long-term storage test 54
7.3.10 High temperature connection test 58
7.3.11 Connection cycling tests 59
7.3.12 Emission test 65
7.3.13 Hydrogen point source gas loss detection test 74
Bibliography 77

Figure 1.1 – Micro fuel cell power system block diagram for UN Division 4.3 (water reactive) compound fuel in indirect PEM fuel cell system; fuel management system in micro fuel cell power unit 8
Figure 1.2 – Micro fuel cell power system block diagram for UN Division 4.3 (water reactive) compound fuel in indirect PEM fuel cell system; fuel management system in fuel cartridge 9
Figure 2 – Fuel cartridge leakage test flow chart for pressure differential, vibration, drop, and compressive loading tests 38
Figure 3 – Fuel cartridge leakage test flow chart for temperature cycling test and high temperature exposure test 39
Figure 4 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for vibration, temperature cycling, drop and compressive loading tests 40

Documents
Document Sharing Hub

Full document details: DD IEC/PAS 62282-6-150:2011

Figure 5 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for external short-circuit test 41

Figure 6 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for 68 kPa low external pressure test 42

Figure 7 – Micro fuel cell power system or micro fuel cell power unit leakage and hydrogen gas loss test flow chart for 11,6 kPa low external pressure test 43

Figure 8 – Temperature cycling 50

Figure 9 – Fuel cartridge leakage and hydrogen gas loss test flow chart for long-term storage test. 58

Figure 10 – Operational emission rate testing apparatus 65

Figure 11 – Operational emission concentration testing apparatus 66

Figure 12 – Hydrogen emission test procedure for operating micro fuel cell power system 73

Figure 13 – Fuel cartridge leakage test flow chart for low external pressure test 74

Table 1 – Summary of material flammability requirements 21

Table 2 – Temperature limits 26

Table 3 – Limits for inherently limited power sources 27

Table 4 – Limits for power sources not inherently limited (over-current protection required) 27

Table 5 – List of type tests 35

Table 6 – Laboratory standard conditions 36

Table 7 – Emission limits 72

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FUEL CELL TECHNOLOGIES –

Part 6-150: Micro fuel cell power systems – Safety – Water reactive (UN Division 4.3) compounds in indirect PEM fuel cells

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IEC-PAS 62282-6-150 has been processed by IEC technical committee 105: Fuel cell technologies.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
105/309/PAS	105/321/RVD

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FUEL CELL TECHNOLOGIES –

Part 6-150: Micro fuel cell power systems – Safety – Water reactive (UN Division 4.3) compounds in indirect PEM fuel cells

1 Scope

1.1 General

a) This consumer safety PAS covers micro fuel cell power systems using hydrogen produced from the reaction of an aqueous solution with solid UN Division 4.3 (water-reactive) compounds in indirect PEM fuel cell systems 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 PAS establishes requirements for micro fuel cell power systems, micro fuel cell power units and fuel cartridges using hydrogen produced from the reaction of an aqueous solution with solid UN Division 4.3 (water-reactive) compounds for use in indirect PEM fuel cell systems 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 PAS 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 PAS.

d) These products are not intended for use in hazardous areas as defined by IEV 426-03-01.

1.2 Fuels and technologies covered

a) This PAS covers micro fuel cell power systems, micro fuel cell power units and fuel cartridges using hydrogen produced from the reaction of an aqueous solution with solid UN Division 4.3 (water reactive) solid compounds as fuel. These systems and units use polymer electrolyte membrane fuel cell technologies. The designs may include fuel processing subsystems to derive hydrogen gas from the water-reactive solid fuel.

b) Micro fuel cell power system block diagrams for covered systems are shown in Figures 1.1 and 1.2.

c) All portions of this PAS apply to micro fuel cell power systems, micro fuel cell power units and fuel cartridges as defined in 1.1 above.

Clauses 1 through 7 of this PAS parallel the general safety requirements given in IEC 62282-6-100, considered relevant to micro fuel cell systems of all types and further includes requirements specific to water reactive solid fuels as included in Annex F of IEC 62282-6-100:2010.

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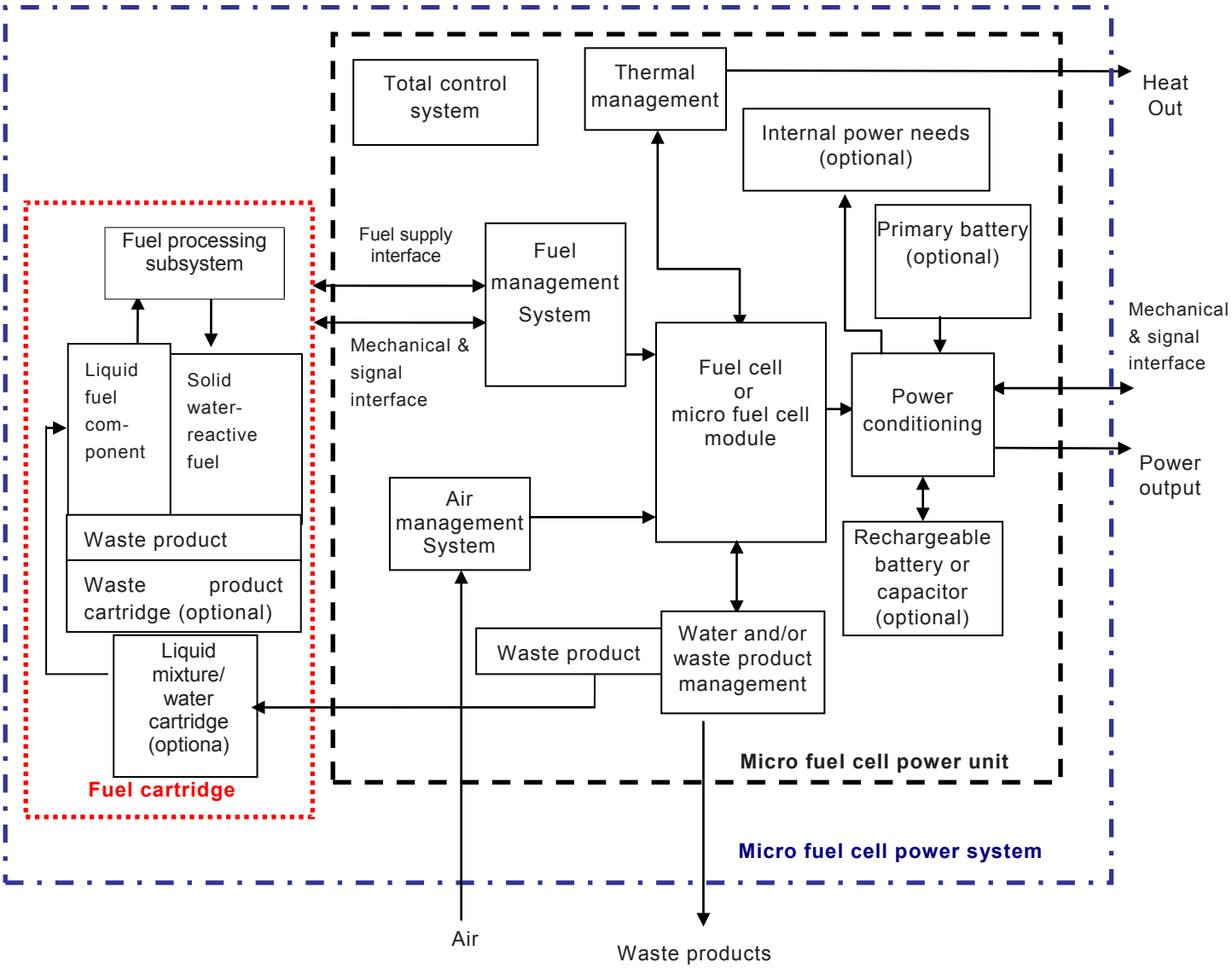

Figure 1.1 – Micro fuel cell power system block diagram for UN Division 4.3 (water reactive) compound fuel in indirect PEM fuel cell system – Fuel management system in micro fuel cell power unit

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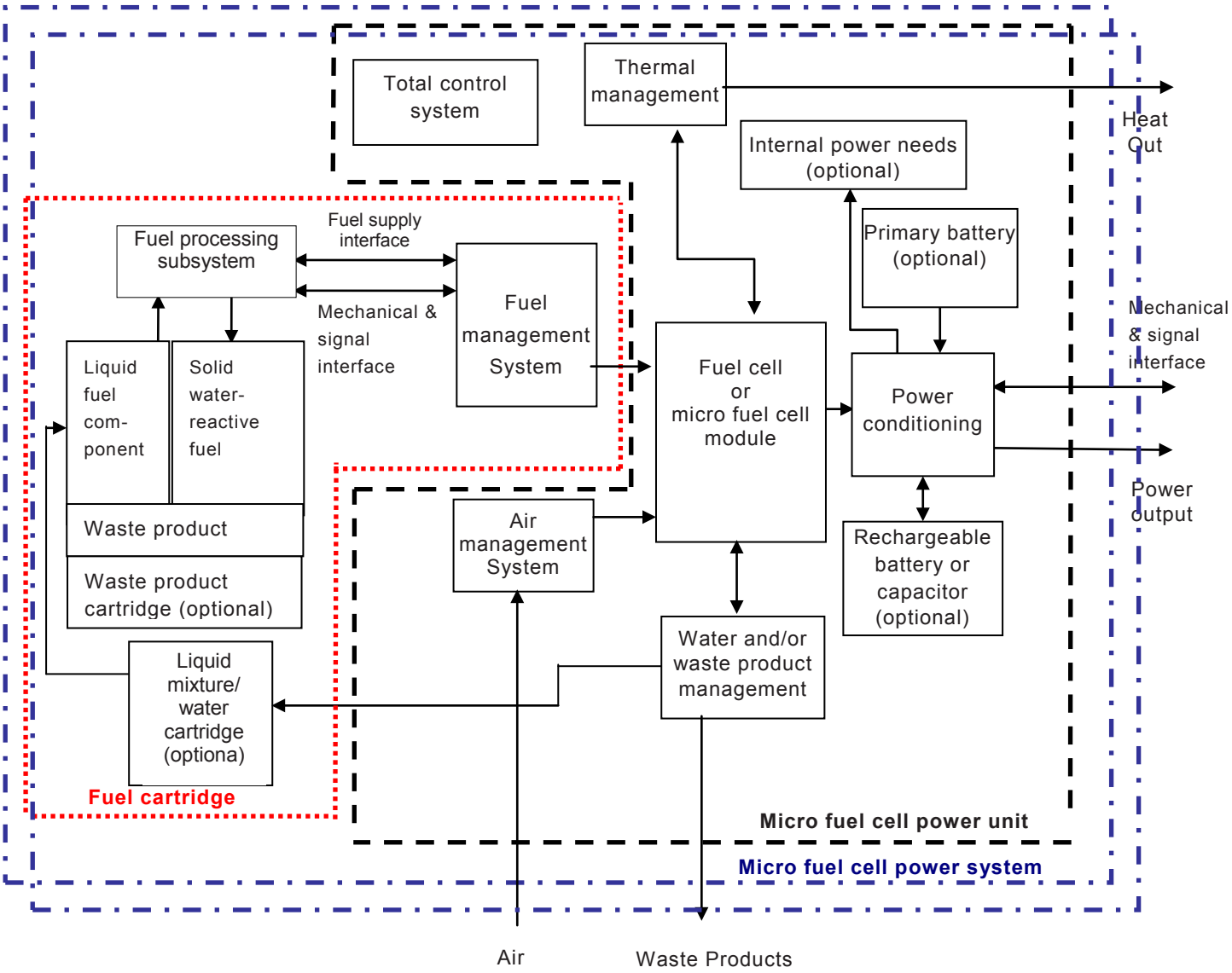

Figure 1.2 – Micro fuel cell power system block diagram for UN Division 4.3 (water reactive) compound fuel in indirect PEM fuel cell system – Fuel management system in fuel cartridge

1.3 Equivalent level of safety

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

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.

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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, *Explosive atmospheres – Part 15: Equipment protection by type of protection "n"*

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 60695-1-10: *Fire hazard testing – Part 1-10: Guidance for assessing the fire hazard of electrotechnical products – General guidelines*

IEC 60695-1-11: *Fire hazard testing – Part 1-11: Guidance for assessing the fire hazard of electrotechnical products – Fire hazard assessment*

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 60730-1:2010, *Automatic electrical controls for household and similar use – Part 1: General requirements*

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

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

IEC 62133, *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, *Safety of primary and secondary lithium cells and batteries during transport*

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

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

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

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

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

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

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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 16111:2008, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

United Nations Recommendations on the Transport of Dangerous Goods – Model Regulations; Sixteenth revised edition

United Nations Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria; Fifth revised edition

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
UN Division 4.3 (water-reactive) solid formulation of compounds comprising constituents selected from the following group used as fuel for an indirect PEM micro fuel cell power system:

(water reactive) mixtures, alloys, compounds or chemical hydrides of the following materials: sodium, magnesium, borohydride compounds, silicon, silicon dioxide, iron, nickel, cobalt.

The formulation may contain a non-hazardous activator to facilitate the production of hydrogen.

Only UN Division 4.3 (water reactive) solid compounds which solely evolve hydrogen gas upon contact with water (or non-hazardous aqueous solutions) shall be permitted. Compounds with a subsidiary hazard risk, or which are not permitted to be transported by air according to the ICAO Technical Instructions, shall not be permitted under this PAS.

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3.6
fuel cartridge
removable article that contains fuel and supplies hydrogen to the micro fuel cell power unit or internal reservoir, not to be refilled by the user

3.7
fuel cell power system
generator system that uses a fuel cell module(s) electrically and thermally connected to generate usable electric energy and/or thermal energy

3.8
hazardous liquid fuel
liquid fuel component with a pH < 3,5 or > 10,5

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 fuel management system that stores hydrogen and cannot be removed

3.11
leakage
accessible fuel, hazardous fuel byproducts or hazardous liquid fuel outside the micro fuel cell power system, micro fuel cell power unit, 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

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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 or other cartridges (optional).

3.18
no accessible liquid
liquid fuel component that is not subject to contact by consumers

3.19
no fuel vapour loss
not applicable

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 utilized fuel cartridge
fuel cartridge that has been put into operation such that approximately 45 % – 55 % of the initial fuel has been utilized and that the operation of the micro fuel cell power system has been halted for at least 1 h

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 hydrogen 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 the manufacturer or by trained technicians

3.25
shut-off valve
component of a fuel cartridge that controls the release of fuel or hydrogen

3.26
waste cartridge
cartridge that stores waste and byproducts from the micro fuel cell power unit

3.27
water cartridge/liquid mixture
cartridge that is filled with water or liquid fuel component

3.28
fuel management system
optional components used to control fuel or hydrogen properties (e.g. concentration, flow rate, purity, temperature, humidity or pressure) or aspects of hydrogen generation to support micro

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fuel cell power system operation, including management and/or storage of generated hydrogen gas (e.g. via storage in and release from an internal reservoir), if applicable

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

3.29
air management system
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

NOTE Not all systems will include all functions. Some systems may 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

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

3.31
primary battery
non-rechargeable battery

3.32
fuel cell
electrochemical device that converts the energy of the chemical reaction between hydrogen or hydrogen rich gases 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

3.37
indirect PEM fuel cell power system
micro fuel cell power system in which a solid formulation of water-reactive compounds is processed to produce hydrogen which reacts at the anode of a fuel cell to produce electricity in a micro fuel cell power system

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3.38
borohydride compounds
sodium or potassium borohydride, or a mixture thereof

3.39
electrolyte
ion conducting membrane used to complete an electric circuit within a fuel cell

3.40
fuel byproducts
Class 8 (corrosive), or non-hazardous compounds produced during the generation of hydrogen and/or electricity from solid water reactive fuel; fuel byproducts shall not have any subsidiary risks.

3.41
impermissible hydrogen gas loss
hydrogen gas escaping fuel cartridge, non-operating micro fuel cell power system, or micro fuel cell power unit greater than or equal 0,003 2 g/h

3.42
accessible fuel, hazardous fuel byproducts or hazardous liquid fuel components
fuel, hazardous fuel byproducts or hazardous liquid fuel components that the consumer may come into physical contact with during normal use, reasonably foreseeable misuse, and consumer transportation; or, water reactive components within the fuel cartridge capable of releasing hydrogen if the fuel cartridge is immersed

3.43
fuel processing subsystem
subsystem within the fuel cartridge used to produce hydrogen from formulations of water-reactive compounds

3.44
incompatible materials
materials which are likely to cause a dangerous evolution of heat, or flammable or poisonous gas or vapours if allowed to mix in ways other than those specifically provided for by the micro fuel cell power system design

3.45
uncontrolled mixing
mixing of incompatible materials that occurs in ways not specifically provided for by the micro fuel cell power system design

3.46
UN Division 4.3 (water reactive)
materials which in contact with water emit flammable gases and are classified as UN Division 4.3: Water Reactive substances under the guidelines of the 16th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations when tested in accordance with the UN Manual of Tests and Criteria for the Classification of Dangerous Goods

3.47
non-hazardous
materials which are not classified as dangerous goods subject to guidelines of the 16th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations

NOTE For clarification, a mixture or substance is not subject to the Model Regulations only if the hazard characteristics of the mixture or substance are such that they do not meet the criteria for classification for any class as a dangerous good, as identified in the UN Model Regulations and the UN Manual of Tests and Criteria.

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the Classification of Dangerous Goods. The UN Model Regulations and Manual of Tests and Criteria may be found online at:

http://www.unece.org/trans/danger/publi/unrec/rev16/16files_e.html and
http://www.unece.org/trans/danger/publi/manual/Rev4/ManRev4-files_e.html, respectively;

5th edition currently only available in print

3.48
activator
substance such as a metal salt or acid that facilitates the production of hydrogen from water-reactive fuel

3.49
hydrogen leakage
hydrogen gas outside hydrogen containment system, including fuel cartridge and fuel management system (see 7.2.2)

3.50
liquid fuel component
class 8 (corrosive), or non-hazardous, water solutions containing acids or metal salts as activators, or alcohols as freezing point suppressors

NOTE The water solutions are used to produce hydrogen within the fuel processing subsystem. Corrosive solutions may not have a subsidiary risk.

3.51
Class 8 (corrosive)
materials which are classified as Class 8: Corrosive substances under the guidelines of the 16th edition of the UN Recommendations on the Transport of Dangerous Goods, Model Regulations when tested in accordance with the UN Manual of Tests and Criteria for the Classification of Dangerous Goods

3.52
hazardous fuel byproduct
fuel by-product with a pH < 3,5 or > 10,5

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 or hydrogen 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 or hydrogen 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

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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 and IEC 60812.

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 PAS, 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.

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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.

4.4.5 Piping systems exposed to hydrogen shall employ materials suitable for exposure to hydrogen, as defined in Annex A of ISO 16111:2008.

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, consumer transportation and storage 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, reasonably foreseeable misuse, consumer transportation and storage.

4.6.3 The valves shall have means to prevent leakage through normal use, reasonably foreseeable misuse, consumer transportation, 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 leakage. Compliance shall be checked using test probe 11 of IEC 61032 and a force of 9,8 N.

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

4.7 Materials and construction – System

4.7.1 The maximum quantity of liquid fuel components stored in the micro fuel cell power unit shall not be more than 1 l. Solid fuel shall not be present in the micro fuel cell power unit.

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

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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 V-0, V-1 or V-2 in accordance with IEC 60695-1-10, IEC 60695-1-11 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 or hydrogen 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 or hydrogen, 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, normal use, reasonably foreseeable misuse, consumer transport and storage 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);

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- 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.

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Full document details: DD IEC/PAS 62282-6-150:2011

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.

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Full document details: DD IEC/PAS 62282-6-150:2011

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 m^3 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.

NOTE In this case, the term “fuel” is used in its generic sense, not as defined in 3.5.

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.

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 m^3 or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas;
- one or more layers of thin insulating material, such as adhesive tape, used directly on any surface within a fire enclosure, including the surface of current-carrying parts, provided that the combination of the thin insulating material and the surface of application complies with the requirements of flammability class V-2, or flammability class HF-2;

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

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