IEC 62282-5-1

Edition 2.0 2012-09

INTERNATIONAL STANDARD

Fuel cell technologies –
Part 5-1: Portable fuel cell power systems – Safety

IEC 62282-5-1:2012(E)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

Useful links:

IEC publications search - www.iec.ch/searchpub

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,…).
It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

IEC 62282-5-1

Edition 2.0 2012-09

INTERNATIONAL STANDARD

Fuel cell technologies –
Part 5-1: Portable fuel cell power systems – Safety

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE XB

ICS 27.070

ISBN 978-2-83220-320-0

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

FUEL CELL TECHNOLOGIES –

Part 5-1: Portable fuel cell power systems – Safety

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62282-5-1 has been prepared by IEC technical committee 105: Fuel cell technologies.

This second edition cancels and replaces the first edition, published in 2007, and constitutes a technical revision.

The major technical changes with respect to the first edition are as follows:

- IEC normative references and definitions have been updated (e.g., hazardous locations, micro fuel cell power systems, transportable equipment, etc.);
- subclause 4.2.2 has been updated referencing an alternative test method in response to a comment;
- the limit on flammable atmospheres has been reduced from 50 % of LFL to 25 % of LFL in 4.5.4 and in 7.20;
- subclause 4.14 and the corresponding tests in 7.22 have been updated to include more effluents and criteria to establish if a system is suitable for indoor or outdoor operation;

- specific criteria for oxygen detector sensor performance requirements have been revised in 7.21;
- subclause 7.18 has been updated with a new test method and new drop heights in response to comments;
- Table 1 has been added giving limits on emission of effluents using limits drawn from the micro fuel cell power system standard.

The text of this standard is based on the following documents:

FDIS	Report on voting
105/396/FDIS	105/404/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62282 series, published under the general title *Fuel cell technologies*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version may be issued at a later date.

FUEL CELL TECHNOLOGIES –

Part 5-1: Portable fuel cell power systems – Safety

1 Scope

This part of IEC 62282 covers construction, marking and test requirements for portable fuel cell power systems. These fuel cell systems are movable and not fastened or otherwise secured to a specific location. The purpose of the portable fuel cell power system is to produce electrical power.

This standard applies to a.c. and d.c. type portable fuel cell power systems, with a rated output voltage not exceeding 600 V a.c., or 850 V d.c. for indoor and outdoor use. These portable fuel cell power systems are not to be used in hazardous locations as defined by IEV 426-03-01 unless additional protective measures are added in accordance with IEC 60079-0.

This standard does not apply to portable fuel cell power systems that are

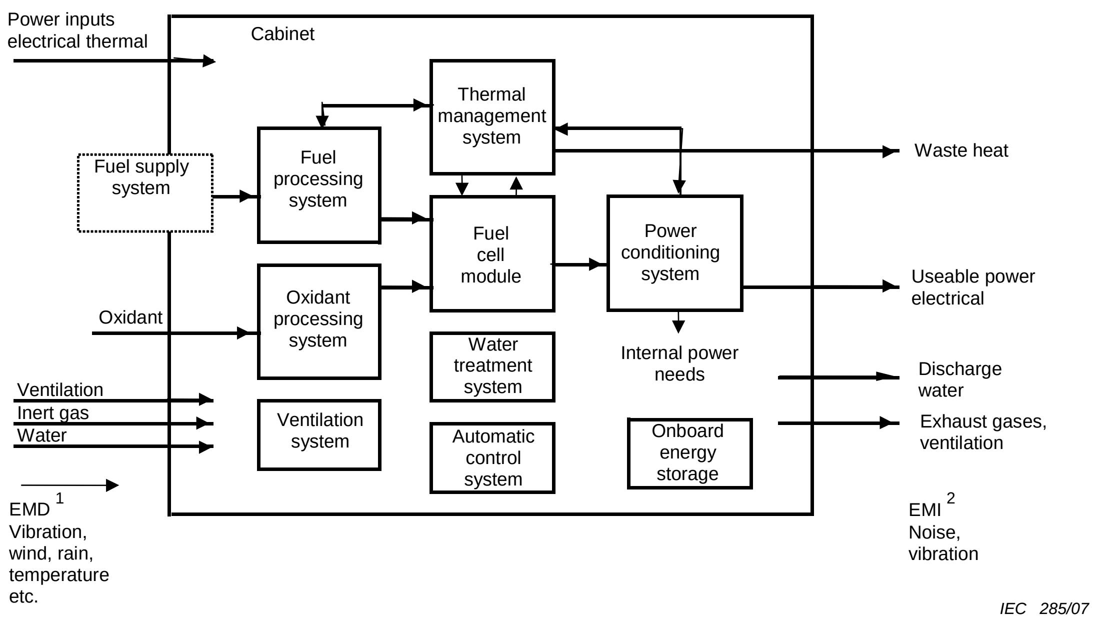
a) permanently connected (hard wired) to the electrical distribution system,
b) permanently connected to a utility fuel distribution system,
c) exporting power to the grid,
d) for propulsion of road vehicles,
e) intended to be used on board passenger aircraft.

Fuel cells that provide battery charging for hybrid vehicles where the battery provides power and energy for propulsion of the vehicle are not included in the scope of this standard

The following fuels and fuel feedstocks are considered within the scope of this standard:

- natural gas;
- liquefied petroleum gas, such as propane and butane;
- liquid alcohols, for example methanol, ethanol;
- gasoline;
- diesel;
- kerosene;
- hydrogen;
- metals (e.g. Mg, Al or Zn) or metal alloys immersed in electrolyte (e.g. aqueous solutions of salts or alkali) in air or oxygen;
- chemical hydrides.

This standard does not preclude the use of similar fuels or oxidants from sources other than air provided the unique hazards are addressed through additional requirements.



Key

1 EMD electromagnetic disturbance

2 EMI electromagnetic interference

Figure 1 – Portable fuel cell power systems

The overall design of a portable fuel cell power system anticipated by this standard shall form an assembly of some or all of the following systems (see Figure 1), integrated as necessary, to perform designated functions, as follows*:*

Fuel processing system – chemical processing equipment including any associated heat exchangers and controls required to convert input fuel to a composition suitable for the fuel cell stack.

Oxidant processing system – subsystem that meters, conditions, processes and may pressurize the incoming oxidant supply for use within the fuel cell power system.

Thermal management system – subsystem intended to provide cooling and heat rejection in order to maintain thermal equilibrium within the fuel cell power system, and, if necessary, to provide for the recovery and utilization of excess heat and to assist in heating the fuel cell power systems during start-up.

Power conditioning system – equipment which is used to change the magnitude or waveform of the voltage, or otherwise alter or regulate the output of a power source.

Automatic control system – assembly of sensors, actuators, valves, switches and logic components (including process controllers) that maintains the fuel cell power system parameters within the manufacturer's specified limits without manual intervention.

Fuel cell module – assembly, including a fuel cell stack(s), which electrochemically converts chemical energy to electric energy and thermal energy intended to be integrated into a power generation system.

Fuel supply system – either integral to the portable fuel cell power system or supplied through a removable and refillable container assembly.

Onboard energy storage system – an internal energy source intended to aid or complement the fuel cell module in providing power to internal or external loads.

Ventilation systems – subsystem of the fuel cell power system that provides, by mechanical means, air to its cabinet.

Water treatment systems – provides for treatment and purification of recovered or added water for use within the portable fuel cell power system.

These requirements are not intended to prevent the design and construction of a portable fuel cell power system not specifically described in this standard, provided that such alternatives have been considered and equivalent testing yields equivalent safety performance to that prescribed by this standard. In considering alternative designs or construction, this standard may be used to evaluate the alternative materials or methods to be used as to their ability to yield equivalent performance to that prescribed by this standard.

This standard does not cover requirements of pressurized or non-pressurized fuel supply containers upstream of the appliance gaseous or liquid fuel supply connector that are not integral to the portable fuel cell power system.

All pressures in this standard are considered to be gauge pressures, unless otherwise specified.

2 Normative references

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

IEC 60034 (all parts), *Rotating electrical machines*

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-2, *Explosive atmospheres – Part 2: Equipment protection by pressurized enclosures "p"*

IEC 60079-10, *Explosive atmospheres* (all Parts 10) – *Part 10: Classification of areas*

IEC 60079-15, *Explosive atmospheres – Part 15: Equipment protection by type of protection "n"*

IEC 60079-20-1, *Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data*

IEC 60079-29-1, *Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases*

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

IEC 60204-1:2005, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens –Single-chamber ovens*

IEC 60335-1:2010, *Household and similar electrical appliances – Safety – Part 1: General requirements*

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

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

IEC 60695-2-13, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

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

IEC 60695-11-20, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

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

IEC 60730-2-5, *Automatic electrical controls for household and similar use – Part 2-5: Particular requirements for automatic electrical burner control*

IEC 60730-2-17, *Automatic electrical controls for household and similar use – Part 2-17: Particular requirements for electrically operated gas valves, including mechanical requirements*

IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

IEC 60884-1, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*

IEC 60934, *Circuit-breakers for equipment (CBE)*

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

IEC 60990:1999, *Methods of measurement of touch current and protective conductor current*

IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic currents emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection*

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standards – Immunity for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61025, *Fault tree analysis (FTA)*

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

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61508-1, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements*

IEC 61511-1, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements*

IEC 61511-3, *Functional safety – Safety instrumented systems for the process industry sector – Part 3: Guidance for the determination of the required safety integrity levels*

IEC 61882, *Hazard and operability studies (HAZOP studies) – Application guide*

IEC 62040-1, *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*

IEC 62040-2, *Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements*

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 62282-2, *Fuel cell technologies – Part 2: Fuel cell modules*

ISO 3864 (all parts), *Graphical symbols – Safety colours and safety signs*

ISO 4080, *Rubber and plastics hoses and hose assemblies – Determination of permeability to gas*

ISO 7000, *Graphical symbols for use on equipment – Index and synopsis*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

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 or MS-FID*

ISO 16017-1:2007, *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 16110-1:2007, Hydrogen generators using fuel processing technologies – Part 1: Safety

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

ISO 16528, *Boilers and pressure vessels – Registration of Codes and Standards to promote international recognition*

3 Terms and definitions

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

3.1
basic insulation
insulation of hazardous-live-parts which provides basic protection

[SOURCE: IEC 60050-195:1998, definition 195-06-06, modified – Note not included] [1][1]

3.2
double insulation
insulation comprising both basic insulation and supplementary insulation

[SOURCE: IEC 60050-195:1998, definition 195-06-08]

3.3
electromagnetic interference
EMI
degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, definition 161-01-06, modified – Notes not included] [2]

3.4
electromagnetic disturbance
EMD
any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter

[SOURCE: IEC 60050-161:1990, definition 161-01-05, modified – Notes not included]

1 References in square brackets refer to the Bibliography.

3.5
enclosure
housing affording the type and degree of protection suitable for the intended application

[SOURCE: IEC 60050-195:1998, definition 195-02-35]

Note 1 to entry: one type of enclosure can be inside another type (e.g. an electrical enclosure inside a fire enclosure or a fire enclosure inside an electrical enclosure). Also, a single enclosure can provide the functions of more than one type (e.g. those of both an electrical enclosure and a fire enclosure). Enclosures may be electrical, mechanical, fire or another type of enclosures to provide protection from these hazards or from wind, weather and other hazards.

3.6
electrical enclosure
enclosure providing protection against the foreseen dangers created by electricity

[SOURCE: IEC 60050-195:1998, definition 195-06-13]

3.7
fire enclosure
part of the equipment intended to minimize the spread of fire or flames from within

3.8
mechanical enclosure
part of the equipment intended to reduce the risk of injury due to mechanical and other physical hazards

3.9
hazardous location
any area or space where combustible dust, ignitable fibres, or flammables, volatile liquids, gases, vapours or mixtures are or may be present in the air in quantities sufficient to produce an explosive atmosphere or ignitable mixtures

3.10
explosive atmosphere
mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour, dust, fibres, or flyings which, after ignition, permits self-sustaining propagation

[SOURCE: IEC 60050-426:2008, definition 426-01-06] [3]

3.11
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

[SOURCE: IEC 60950-1:2005, definition 1.2.8.10]

3.12
hazardous voltage
voltage exceeding 42,4 V peak, or 60 V d.c., existing in a circuit that does not meet the requirements for either a limited current circuit or a TNV circuit

[SOURCE: IEC 60950-1:2005, definition 1.2.8.6]

3.13
heat deflection temperature
HDT
measure of a polymer’s resistance to distortion under a given load at elevated temperatures

Note 1 to entry: The deflection temperature is the temperature at which a test bar, loaded to the specified bending stress, deflects by 0,25 mm.

3.14
limited current circuit
circuit that is so designed and protected that, under both normal operating conditions and single fault conditions, the current that can be drawn is not hazardous

Note 1 to entry: The limit values of currents under normal operating conditions and single fault conditions (see 1.4.14 of IEC 60950-1:2005) are specified in 2.4 of IEC 60950-1:2005.

[SOURCE: IEC 60950-1:2005, definition 1.2.8.9]

3.15
live part
conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:1998, definition 195-02-19]

3.16
maximum allowable working pressure
MAWP
maximum pressure at which a fuel cell or fuel cell power system may be operated

Note 1 to entry: The maximum allowable working pressure is expressed in Pa.

Note 2 to entry: The maximum allowable working pressure is the pressure used in determining the setting of pressure limiting and relieving devices installed to protect a component or system from accidental over-pressuring.

Note 3 to entry: For the purpose of this standard, all pressures are to be given and used as gauge pressures unless absolute pressure is indicated.

3.17
maximum operating pressure
maximum pressure, specified in gauge pressure by the manufacturer, of a component or system at which it is designed to operate continuously

Note 1 to entry: The maximum operating pressure is expressed in Pa.

Note 2 to entry: This includes all normal operation, both steady state and transient.

3.18
operator access area
area for which under normal operating conditions

a) access is gained without the use of a tool; or
b) the means of access is deliberately provided to the operator; or
c) the operator is instructed to enter regardless of whether or not tools are needed to gain access

Note 1 to entry: In this standard, the terms "access" and "accessible", unless qualified, relate to operator access as defined above.

3.19
portable fuel cell power system(s)
fuel cell power system that is not intended to be permanently fastened or otherwise secured in a specific location

3.20
portable stand-alone fuel cell power system
portable fuel cell power system that is not designed to be connected to the energized mains

3.21
reinforced insulation
insulation of hazardous-live-parts which provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

[SOURCE: IEC 60050-195:1998, definition 195-06-09]

3.22
secondary circuit
circuit that has no direct connection to a primary circuit and derives its power from a transformer, converter or equivalent isolation device, or from a battery

Note 1 to entry: Conductive parts of an interconnecting cable may be part of a secondary circuit as stated in 1.2.11.6 of IEC 60950-1:2005.

[SOURCE: IEC 60950-1:2005, definition 1.2.8.5]

3.23
SELV
Safety Extra Low Voltage
a) for a.c. the peak value of the voltage does not exceed 42,4 V;
b) for d.c. the voltage does not exceed 60 V

Note 1 to entry: When safety extra low voltage is obtained from the supply mains, it is to be through a safety isolating transformer or a converter with separate windings, the insulation of which complies with double insulation or reinforced insulation requirements.

Note 2 to entry: The voltage limits specified are based on the assumption that the safety isolating transformer is supplied at its rated voltage.

Note 3 to entry: Safety Extra Low Voltage is also known as SELV.

[SOURCE: IEC 60335-1:2010, definition 3.4.2, modified]

3.24
SELV circuit
Safety Extra Low Voltage Circuit
secondary circuit that is so designed and protected that under normal operating conditions and single fault conditions, its voltages do not exceed a safe value

Note 1 to entry: For commercial, industrial and telecommunication applications, the SELV voltage limits provided in IEC 60950-1:2005 are applicable. For household applications, the SELV voltage limits in IEC 60335-1:2010 shall be used.

Note 2 to entry: The limit values of voltages under normal operating conditions and single fault conditions (see 1.4.14 of IEC 60950-1:2005) are specified in 2.2 of IEC 60950-1:2005. See Table 1A of IEC 60950-1:2005.

Note 3 to entry: This definition of a SELV Circuit differs from the term “SELV system” as used in IEC 61140.

[SOURCE: IEC 60950-1:2005, definition 1.2.8.8, modified]

3.25
service personnel
trained persons having familiarity and experience with the construction and operation of the system and the risks involved

3.26
supplementary insulation
independent insulation applied in addition to basic insulation in order to reduce the risk of electric shock in the event of a failure of the basic insulation

3.27
thermal stability
stable temperature conditions, pseudo steady-state, arbitrarily indicated by temperature changes of no more than 3 K or 1 % of the absolute operating temperature, whichever is higher between two readings 15 min apart

3.28
tool
screwdriver, coin, key, or any other object that may be used to operate a screw, latch, or similar fastening means

3.29
touch voltage
voltage between conductive parts when touched simultaneously by a person or an animal

NOTE 1 to entry: The value of the effective touch voltage may be appreciably influenced by the impedance of the person or the animal in electric contact with these conductive parts.

3.30
uninterruptible power system
UPS
combination of convertors, switches and energy storage devices (for example, batteries), constituting a power system for maintaining continuity of load power in case of input power failure

3.31
wet cell battery
battery in which the electrolyte is in liquid and mobile form

3.32
transportable equipment
movable equipment that is intended to be routinely carried by a user

Note 1 to entry: Examples include laptop and notebook personal computers, pen-based tablet computers, and their portable accessories such as printers and CD-ROM drives.

[SOURCE: IEC 60950-1:2005, definition 1.2.3.3]

3.33
hand-supported equipment
equipment that is physically supported by any part of the body of the user during the performance of its intended functions

3.34
hand-held equipment
portable and intended to be held in the hand during normal use

[SOURCE: IEC 60050-151:2001, 151-16-48]

3.35
highly ventilated area
an area that is provided with clean, fresh air at a minimum flow rate of 140 m^3/h (approximately 10 air changes per hour in a room of 14 m^3)

Note 1 to entry: Different ventilation rates may be used. See 4.14.

3.36
PEN conductor
conductor combining the functions of both a protective earthing conductor and a neutral conductor

[SOURCE: IEC 60050-195:1998, definition 195-02-12]

3.37
PEM conductor
conductor combining the functions of both a protective earthing conductor and a mid-point conductor

[SOURCE: IEC 60050-195:1998, definition 195-02-13]

3.38
PEL conductor
conductor combining the functions of both a protective earthing conductor and a line conductor

[SOURCE: IEC 60050-195:1998, definition 195-02-14]

4 Design and construction requirements

4.1 Physical environment and operating conditions

4.1.1 General requirements

The portable fuel cell system and its protective systems shall be so designed and constructed as to be capable of performing their intended functions in their expected physical environment and operating conditions.

4.1.2 Electrical power input

The fuel cell power system input limits shall be designed to operate correctly with the conditions of 4.3 of IEC 60204-1:2005 or as otherwise specified by the manufacturer.

4.1.3 Handling, transportation, and storage

The portable fuel cell power system shall be designed to withstand, or suitable precautions shall be taken to protect against, the effects of transportation and storage temperatures. The fuel cell power system or each component part thereof shall be packaged or designed so that it can be stored safely and without damage (e.g. adequate stability, special supports, etc.).

The manufacturer shall specify special means for handling, transportation and storage if required.

4.2 Material compatibility

4.2.1 General requirements for material compatibility

All parts and all substances used shall be suitable for the range of temperatures and pressures to which they are subjected during expected usage; and suitably resistant to the reactions, processes, environments and other conditions to which they are exposed during expected usage. The following provisions apply.

1) Appropriate pressure relief devices or methods shall be used to protect parts from damage due to overpressure as indicated by the safety and reliability analysis carried out in accordance with 4.11. Pressure relief devices or methods shall be used to prevent the system, or portions of the system, from exceeding the maximum allowable working pressure of the system, or portion of the system.
2) Any part that is exposed directly to liquid fuel, moisture, condensate, etc. as well as fasteners used to attach any part that needs to be adjusted or removed for servicing, shall be corrosion-resistant and suitable for the application.

3) Ferrous materials used in the construction of the outside casing, and in an outside cabinet which is the sole enclosure of current-carrying parts, shall be adequately protected against corrosion.

4) Asbestos or asbestos-containing material(s) shall not be used in the construction of a portable fuel cell power system.

4.2.2 Polymeric and elastomeric components

Polymeric and elastomeric piping, tubing and components shall be permitted under the following conditions:

1) materials shall be demonstrated to be suitable for the combined maximum operating temperatures and pressures and compatible with other materials and chemicals with which they will come into contact in normal operation, service and maintenance over the manufacturer-defined life span of the product. Guidance can be found in ISO 4080;

2) polymeric or elastomeric components shall be protected from mechanical damage within the enclosure. Shielding may be used as appropriate to protect components against failure of rotating equipment or other mechanical devices housed within the portable fuel cell power system;

3) any compartment enclosing polymeric or elastomeric components used to convey flammable gases shall be protected against the possibility of overheating. A control system shall be provided to terminate fuel flow before temperatures reach 10 °C below the lowest heat deflection temperatures (HDT)of the materials used in the fuel conveying components;

4) non-metallic tubing may be used if it is demonstrated through testing that the end-to-end resistance is less than 1 MΩ, at a test voltage up to 1 000 V, when measured between two metal fittings and provided that at least one end of the tubing is connected to a metal fitting that is electrically continuous with the equipment frame and other associated metal parts are bonded such that discharges through air cannot occur (see future IEC/TR 60079-32 [4]). Air gaps less than 1 cm between a semi-conductive tubing wall and other metal parts are not permissible. Compliance is determined through the conductivity test of 7.29.

   Alternatively, the non-metallic tubing may be tested using the accumulation of static electricity test of 7.30 to determine that under normal and abnormal operating conditions including refueling, an incendive electrostatic charge on the tubing material would not be generated as a result of fluid flow through the tubing.

5) Appropriate pressure relief devices or methods shall be used to protect polymeric and elastomeric components from damage due to overpressure as indicated by the safety and reliability analysis carried out in accordance with 4.11.

4.2.3 Fuel connection devices

Fuel connection devices shall be resistant to stress corrosion cracking.

NOTE Guidance can be found in ISO 15156-1 [5].

4.3 Protection against mechanical hazards

Protection shall be provided against accidental contact with moving parts. All parts that may be contacted during normal usage, adjustment or servicing shall be free from sharp projections or edges.

The portable fuel cell power systems shall resist reasonably foreseeable impacts and not be susceptible to tipping during operation and handling. Compliance is demonstrated through the type tests in 7.16, 7.17, and 7.18.

4.4 Protection against toxicity of fuels and fuel feedstocks

Precautions shall be taken in the design of the portable fuel cell power system and fuel supply to avoid spillage or unnecessary exposure of personnel to fuels that are potentially harmful due to flammability, corrosive effects, ingestion, inhalation or skin absorption.

The operating and storage instructions shall describe the possible hazards resulting from the use of fuels and any precautions to be taken when handling the materials. This shall include the maximum tolerable exposure levels in continuous use, and means to deal with spillage or contamination of personnel.

4.5 Protection against explosion hazards

4.5.1 General requirements for protection against explosion hazards

The portable fuel cell power system shall be designed and constructed to minimize the risk of fire or explosion posed by the portable fuel cell power system itself, or by gases, liquids, dust, vapours or other substances produced or used by the portable fuel cell power system.

4.5.2 Flammable atmospheres within the portable fuel cell power system

Within the portable fuel cell power system, compartments with sources of flammable gas or vapour shall be classified and the extent of hazardous areas determined. The boundary for dilution to below 25 % of the lower flammability limit (LFL) may be determined by computational fluid dynamics analysis, tracer gas, or similar methods such as those given in IEC 60079-10 or IEC 60079-2.

Within areas classified as hazardous, the manufacturer shall eliminate ignition sources by ensuring that:

- the installed electrical equipment is suitable for the area classification;
- the surface temperatures do not exceed 80 % of the auto-ignition temperature, expressed in degrees Celsius, of the flammable gas or vapour. See IEC 60079-20-1 for guidance regarding auto-ignition temperatures of various flammable fluids;
- the potential for static discharge has been eliminated by proper bonding and earthing;
- equipment containing materials capable of catalyzing 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.

4.5.3 Normal operation

The concentration of fuel vapour within the system enclosure shall be less than 25 % of the LFL under normal operating conditions. Where mechanical ventilation is required to meet a safety limit or maintain the LFL limits, the portable fuel cell power system shall safely shut-down in a controlled manner upon failure of the ventilation system Compliance with this requirement is demonstrated in 7.4.

4.5.4 Abnormal operation

In the event of an internal release of flammable gas, a safety device within the portable fuel cell power system shall shutdown the system prior to concentrations reaching 25 % of the LFL at the ventilation outlet.

4.5.5 Purging

Means shall be provided to purge those systems of the portable fuel cell power system where, for safety reasons, it requires a passive state after shutdown or prior to initialization as specified by the manufacturer. A suitable purge system, utilizing a medium specified by the manufacturer such as but not limited to nitrogen, or air or steam in a non-hazardous situation within the intended use, meets the intent of this provision.

NOTE If safety can be secured by procedures other than the purge, purging is not required.

4.5.6 Electrostatic discharge

Protection against electrostatic discharges shall be provided in locations where a flammable gas may accumulate. This may be achieved through the selection of materials for non-metallic tubing and through the grounding and bonding of isolated metal parts. An electrostatic test instrument shall be used to verify there is no spark-capable generation of charge during equipment operation or when re-fueling (see 7.29, Non-metallic tubing conductivity test and 7.30, Non-metallic tubing test for accumulation of static electricity).

Non-metallic tubing carrying fluids, such as hydrogen gas, may accumulate electrostatic charge along its interior and exterior surfaces and it may transfer some of that charge to metal fittings attached at either end. Discharges from the external surface of this tube, or the fittings, may be sufficient to ignite a flammable mixture of gas or vapour in the surrounding environment. The accumulation of charge may be mitigated by specifying a tube material with a resistance less than 1 MΩ, at a test voltage up to 1 000 V, as measured between metal fittings on either end of the tube (see future IEC/TR 60079-32 [4]). Alternatively, gas flow velocity may be limited to values below which electrostatic charge does not accumulate for that specific material. Metal braid coverings, or conductive wires within the non-metallic tubing, can reduce charge accumulation, but may also increase the chance of electrostatic discharge if those conductors become disconnected from their bonding conductor. Flexible metal tubing with isolating unions may be a practical alternative to the use of polymeric tubing.

4.6 Protection against electric shock

4.6.1 General requirements for protection agains electric shock

Except where specifically permitted for functional reasons, accessible conductive parts of equipment shall not be hazardous live parts in normal conditions, nor be, or become, hazardous live parts in any reasonably foreseeable single fault condition. Portable fuel cell power systems shall be constructed and enclosed so that there is adequate protection against accidental contact with live parts.

The electrical equipment shall provide protection of persons against electric shock from

1) direct contact,
2) indirect contact.

4.6.2 Protection against direct contact with live parts

4.6.2.1 General requirements and alternative measures for protection against direct contact with live parts

For each circuit or part of the electrical equipment, protection shall be achieved through the use of enclosures or the insulation of live parts. Where these measures are not practical, alternative measures for protection may be applied such as barriers, placing out of reach, and using obstacles (see IEC 60364-4-41).

4.6.2.2 Protection by enclosures

Opening an enclosure (i.e. opening doors, lids, covers, and the like) shall be possible only under one of the following conditions:

1) the use of a key or tool;
2) the disconnection of live parts inside the enclosure before the enclosure may be opened (i.e., interlocking the door);

3) opening without using one of the protection techniques described in a) or b) shall be possible only when all live parts are protected against direct contact to at least IP2X or IPXXB (see IEC 60529).

4.6.2.3 Protection by insulation of live parts

It shall not be possible to touch live parts or live parts protected only by lacquer, enamel, ordinary paper, cotton, oxide film, beads, or sealing compound except self-hardening resins, with the test probe B of IEC 61032.

Live parts protected by insulation shall be completely covered with insulation that can only be removed by destruction. Such insulation shall be capable of withstanding the mechanical, chemical, electrical, and thermal stresses to which it can be subjected under normal service conditions. Heat-resistant, moisture-absorption-resistant insulating material, such as phenolic composition, porcelain, cold molded composition that will withstand the most severe conditions likely to be met in service shall be used for the support of bare, live parts and for barriers used to obtain required spacings (as specified in 4.7.10) and shall comply with the test specified in 7.13.

4.6.3 Protection against indirect contact with live parts

4.6.3.1 General intent and acceptable approaches for protection against indirect contact with live parts

Protection against indirect contact is intended to prevent hazardous conditions in the event of an insulation failure between live parts and exposed conductive parts. Protection against indirect contact shall be achieved by measures to prevent the occurrence of a hazardous touch voltage; or automatic disconnection of the supply before the time of contact with a touch voltage can become hazardous.

4.6.3.2 Measures to prevent the occurrence of a hazardous touch voltage

Measures to prevent the occurrence of a hazardous touch voltage include the use of Class II equipment or by equivalent insulations (see IEC 61140), electrical separation (see IEC 60364-4-41) and the design of the supply system so that its neutral point is either insulated from or has a high impedance to earth so that an earth fault will not result in a hazardous touch voltage.

4.6.3.3 Automatic disconnection of the supply

Automatic disconnection of the supply of any circuit affected by the occurrence of an insulation failure is intended to prevent a hazardous condition resulting from a touch voltage (see IEC 60364-4-41).

4.6.4 Protection by the use of SELV

SELV (safety extra-low voltage) may be used to protect persons against electric shock from both direct and indirect contact. Accessible parts are not considered to be a shock hazard at or below SELV.

An accessible part is not considered to be live if the part is supplied at safety extra-low voltage, provided that:

a) for a.c. the peak value of the voltage does not exceed 42,4 V;

b) for d.c. the voltage does not exceed 60 V;

c) the part is separated from live parts by protective impedance. If protective impedance is used, the current between the part and the supply source shall not exceed 2 mA for d.c. and its peak value shall not exceed 0,7 mA for a.c. as described in 8.1.4 of IEC 60335-1:2010 and Figure 4 of IEC 60990:1999.

4.7 Selection of electrical components and equipment

4.7.1 Area classification and suitability

Electrical components and equipment shall be suitable for the area classification in which they are used, based on IEC 60079-10 (see 4.5.2).

4.7.2 Turning moments

Electrical components such as switches that are subjected to turning moments in normal operation or servicing shall be fastened securely and prevented from turning by means other than friction between surfaces, if turning could result in reduction of the spacings specified in 4.7.10 or 4.7.11, or in an infringement of other requirements of this standard. A lock washer shall not be considered acceptable for devices that require turning moments for their operation.

4.7.3 Fuses

If the circuits protected by the fuses extend beyond the portable fuel cell power system enclosure, fuses shall be of a type that are non-replaceable without the use of tools (e.g. soldered-in type). If the circuits protected by the fuses do not extend beyond the enclosure, the fuses may be of a readily replaceable type. If the fuse can be contacted externally, a fully touch proof fuse-holder shall be used.

4.7.4 Capacitor discharge

If the charge stored in capacitors is accessible in an operator access area, and the safety of the operator is assured by an interlock actuated by a door or cover, or by disconnecting a connector (or attachment plug), then the energy stored as determined from the following equation, shall be discharged to a safe level not exceeding 42,4 V peak or d.c. and it shall not exceed 20 J at 1 s after operation of this interlock or disconnection of the connector:

$$J = 5 \times 10^{-7} CV^2$$

where

J is the energy in joules;

C is the capacity in microfarads;

V is the voltage in volts.

4.7.5 Securing of parts

Screws, nuts, washers, springs or similar parts shall be secured so as to withstand mechanical stresses occurring in normal use if loosening would create a hazard, or if clearances or creepage distances over supplementary insulation or reinforced insulation would be reduced to less than the values specified in 4.7.10.

Bare live parts (including conductors) shall be fixed to their bases or mounting surfaces so that they shall be prevented from turning or shifting so as to reduce the spacings required by 4.7.10. Friction between surfaces is not an acceptable means of preventing the turning of live parts, but a suitable lockwasher will be acceptable if properly applied.

Compliance is checked by inspection, by measurement and by manual test.

For the purpose of assessing compliance, it is assumed that

- *two independent fixings will not become loose at the same time,*
- *parts fixed by means of screws or nuts provided with self-locking washers or other means of locking are not liable to become loose.*

4.7.6 Current-carrying parts

Current-carrying parts shall have adequate mechanical strength and current-carrying capacity for the service, and shall be nonferrous or stainless steel, except that in SELV circuits the material is not specified.

The securement of contact assemblies shall be such as to ensure the continued alignment of contacts.

Misalignment of male and female connectors, insertion of a multi-pin male connector in a female connector other than one intended to receive it, and other manipulations of parts that are accessible without the use of a tool shall not result in a hazardous condition.

4.7.7 Internal wiring

The space within enclosures of equipment shall provide ample room for the distribution of wires and cables required for the proper wiring of the equipment to prevent overheating and damage to the insulation. The wire connections and wires between parts of equipment shall be protected or enclosed. Wireways shall be smooth and entirely free from projections, burrs, and sharp edges that may cause abrasion of the insulation on the conductors.

Wiring other than that of printed circuits shall consist of wire of a type, or types, that are suitable for the particular application when considered with respect to

a) conductor size (consideration shall be given to the effects of vibration, impact and handling for wires smaller than 1,5 mm^2);
b) temperature and voltage to which the wiring is liable to be subjected;
c) exposure to oil, grease or other substance liable to have a deleterious effect on the insulation;
d) exposure to moisture;
e) other conditions of service to which the wire is liable to be subjected.

All wiring joints shall be provided with insulation equivalent to that of the conductors themselves, unless they are held securely and rigidly so that the spacings required by 4.7.10 are maintained.

Cords and insulated conductors, either single or bunched, or cabled, when passing through openings in sheet metal walls, shall be effectively protected by suitable bushings or well-rounded bearing surfaces which shall not damage the cords or conductors.

Conductors identified by green or the colour combination green/yellow shall be used only for earthing or bonding connections.

Electrical connections which need to be broken to service any controls shall be made in such a manner that they may be disconnected and reconnected without breaking a soldered connection and without breaking or cutting the wire(s).

4.7.8 Cord-connected portable fuel cell power systems

Portable fuel cell power systems intended to be cord-connected at the input shall be provided with a suitable length of cord having an additional conductor for earthing non-current-carrying conductive parts. The cord shall have an ampacity at least equal to the marked input in amperes and shall be of the hard-usage type, damp/wet type, except as required by other clauses of this standard.

The supply cord shall terminate in a suitable attachment plug that conforms to IEC 60884-1 and has

- a voltage rating suitable for the voltage marked on the portable fuel cell power system,
- a current rating of not less than 125 % of the marked input current.

4.7.9 Strain relief

Strain relief shall be provided so that stress on a supply cord, as determined by the test specified in 7.26 or twisting of the cord, will not be transmitted to the connections inside the portable fuel cell power system. Portable fuel cell power systems provided with a supply cord, or intended to be connected to fixed wiring by a flexible cord, shall have a cord anchorage. The cord anchorage shall relieve conductors from strain, including twisting, at the terminals and protect the insulation of the conductors from abrasion. At least one part of the cord anchorage shall be securely fixed to the portable fuel cell power system, unless it is part of a specially prepared cord.

At the point at which a supply cord passes through an opening in a wall, a barrier or the overall enclosure, there shall be a bushing or the equivalent that is secured in place and that has a smooth, well-rounded bearing surfaces which will not damage the cord.

It shall not be possible for a flexible cord to be pushed through the cord-entry hole, if such displacement is liable to

1) subject the cord to mechanical injury;
2) expose the cord to a temperature higher than that for which the cord is recognized;
3) reduce the spacings (such as from bare live parts to a metal strain relief clamp) below the values specified in 4.7.10.

4.7.10 Creepage and clearances

Portable fuel cell power systems shall be constructed so that the clearances, creepage distances and solid insulation are adequate to withstand the electrical stresses to which the portable fuel cell power system is liable to be subjected. Guidance in determining appropriate creepage and clearance distances is specified in IEC 60664-1.

Exemption: An anode and cathode of the same cell are not subject to these clearance and creepage requirements.

In the case of explosive gas atmospheres, as determined by IEC 60079-10, the clearances, creepage distances and separations between conductive parts at different potentials shall also comply with IEC 60079-15.

4.7.11 Separation of circuits

Insulated conductors (internal wiring, including wires in a terminal box or compartment) that operate at different voltages shall comply with at least one of the following:

1) be segregated by internal barriers;
2) be segregated from each other;
3) be segregated by grounded shielding;
4) have all conductors insulated for the highest voltage;
5) have either conductor (or the group of conductors for that voltage) insulated for twice the highest voltage.

Insulated conductors shall be separated by internal barriers or shall be segregated from bare live parts at a voltage higher than that for which the conductors are insulated.

Segregation or separation of insulated conductors may be accomplished by clamping, routing or an equivalent means that ensures permanent separation.

If an internal barrier is used to provide separation between the wiring of different circuits, it shall be of adequate mechanical strength and reliably held in place. Barriers shall be firmly secured in place and have sufficient stability and durability to maintain the appropriate separation from live parts under normal service conditions, taking account of relevant external influences (see IEC 61439-1).

Barriers of insulating material shall be not less than 0,70 mm thick, if of electrical grade paper and, when located between conductors and bare live parts of different circuits, shall comply with 4.6.2.3.

4.7.12 Protection of receptacles

An output receptacle shall be protected by an overcurrent device rated or set at not more than the rating of the receptacle unless:

1) the circuit is not capable of delivering current in excess of the rating of the receptacle under any conditions of loading; or
2) electronic protection is provided that cannot be defeated by a single fault.

4.7.13 Earthing and bonding

4.7.13.1 General requirements for earthing and bonding

Where applicable, the connection between the earthing terminal or earthing contact and earthed metal parts shall have low resistance. Compliance is demonstrated in 7.14.

4.7.13.2 Portable stand-alone fuel cell power systems

The frame of a portable stand-alone fuel cell power system shall not be required to be grounded and shall be permitted to serve as the earthing electrode under the following conditions:

1) the generator supplies only equipment mounted on the portable stand-alone fuel cell power system, cord-and-plug-connected equipment through receptacles mounted on the portable stand-alone fuel cell power system, or both;
2) the non-current-carrying metal parts of the equipment and the equipment earthing conductor terminals of the receptacles are bonded to the portable stand-alone fuel cell power system frame.

4.7.13.3 Uninterruptible power systems (UPS)

Uninterruptible power systems (UPS) shall meet the earthing and grounding provisions of IEC 62040-1 and IEC 62040-2 as applicable.

Accessible conductive parts of Class I equipment, which might assume a hazardous voltage in the event of a single insulation fault, shall be reliably connected to a protecting earthing terminal within the equipment.

4.8 Protection against fire hazard

4.8.1 General intent and purpose of protection against fire hazard

This subclause specifies requirements intended to reduce the risk of ignition and the spread of flame, both within the equipment and to the outside, by the appropriate use of materials and components and by suitable construction.

4.8.2 Flammability

Components and materials inside the portable fuel cell power system enclosure shall be so constructed or shall make use of such materials, that propagation of fire and ignition is minimized. This may be demonstrated through the appropriate selection of materials meeting FV 0, FV 1 or FV 2 when tested in accordance with IEC 60695-11-10 or IEC 60695-11-20.

Exemptions:

- Membranes, or other materials within a single portable fuel cell power system or stack which comprise less than 10 % of its total mass, are considered to be of limited quantity and are permissible without flammability ratings.
- If the stack total mass is less than 200 g, stack materials are considered to be of limited quantity and are permissible without flammability ratings.

Components shall be protected against overheating under fault conditions. Where it is not practical to protect components against overheating under fault conditions, the components shall be mounted on materials of flammability Class V-1 or better. Additionally, such components shall be separated from material of a class lower than flammability Class V-1 by at least 13 mm of air, or by a solid barrier of material of flammability Class V-1.

Parts of insulating material supporting current-carrying connections, and parts of insulating material within a distance of 3 mm of such connections, are subjected to the glow-wire test of IEC 60695-2-11. However, the glow-wire test is not carried out on parts of material classified as having a glow-wire ignition temperature, according to IEC 60695-2-13, of at least

a) 775 °C, for connections which carry a current exceeding 0,2 A during normal operation,
b) 675 °C, for other connections, provided that the test sample was no thicker than the relevant part.

When the glow-wire test of IEC 60695-2-11 is carried out, the temperatures are

1) 750 °C, for connections which carry a current exceeding 0,2 A during normal operation,
2) 650 °C, for other connections.

Parts that withstand the glow-wire test of IEC 60695-2-11, but which, during the test, produce a flame that persists for longer than 2 s, are further tested as follows:

Parts above the connection within the envelope of a vertical cylinder having a diameter of 20 mm and a height of 50 mm are subjected to the needle-flame test of IEC 60695-11-5. However, parts shielded by a barrier that meets the needle-flame test of IEC 60695-11-5 are not tested. The needle-flame test is not carried out on parts of material classified as V-0 or V-1 according to IEC 60695-11-10, provided that the test sample is no thicker than the relevant part.

4.8.3 Openings in equipment

The risk of ignition caused by small metallic objects, such as paper clips or staples, shall be reduced by measures to minimize the likelihood of such objects entering the equipment and bridging bare conductive parts between which the voltage is not limited in accordance with 4.6.4.

Acceptable measures include:

a) providing openings that do not exceed 1 mm in width regardless of length;
b) providing a screen having a mesh with nominal openings not greater than 2 mm between centre lines and constructed with a thread or wire diameter of not less than 0,45 mm;
c) providing internal barriers.

Additionally, where metallized parts of a barrier or enclosure are within 13 mm of parts of circuits where the available power is greater than 15 VA, one of the following requirements applies:

1) access by a foreign metallic object shall be limited in accordance with the above acceptable measures even though the available voltage meets the limits of 4.6.4;
2) there shall be a barrier between the bare conductive parts and the enclosure;
3) fault testing shall be carried out to simulate bridging along a direct path between a bare conductive part and the nearest metallized part of a barrier or enclosure that is within 13 mm of the bare conductive part.

NOTE Examples of metallized plastic barriers or enclosures include those made of conductive composite materials or that are electroplated, vacuum-deposited, painted or foil lined. Compliance is checked by inspection and measurement and, where appropriate, by test. If simulated fault testing is carried out, no ignition of the metallized barrier or enclosure should occur.

Openings in the vertical sides of an enclosure of a portable fuel cell power system shall not allow intrusion of objects or material that would cause injury to persons or malfunction of equipment that would result in a shock or release of energy that meets or exceeds a hazardous energy level.

Portable fuel cell power systems with openings at the bottom of the enclosure shall comply with the applicable requirements of 4.6.2 of IEC 60950-1:2005.

4.9 Protection against temperature hazards

4.9.1 General requirements for protection against temperature hazards

Components working at high temperature shall be effectively shielded or separated to avoid overheating of their adjacent materials and components.

4.9.2 Surface temperatures

The maximum temperature of any surface(s) that may be contacted by personnel performing regular and routine service while the portable fuel cell power system is in operation shall not exceed the limit(s) given in Clause 11 of IEC 60335-1:2010.

Compliance is checked by determining the temperature rise of the various parts under the conditions specified in 7.5.

4.9.3 Component temperatures

The maximum temperature of any component shall not exceed the limit(s) given in Clause 11 of IEC 60335-1:2010.

Compliance is checked by determining the temperature rise of the various parts under the conditions specified in 7.6.

4.9.4 Wall, floor and ceiling temperatures

The temperatures on walls, floor and ceiling adjacent to a portable fuel cell power system shall not exceed 50 °C above ambient temperature under the test conditions of 7.7.

4.10 Protection against electromagnetic disturbances

The portable fuel cell power system shall have an adequate level of immunity to electromagnetic disturbances so that it can operate correctly in its intended environment. In addition, the equipment shall not generate electromagnetic disturbances above the levels appropriate for its intended places of use.

As applicable, the portable fuel cell power system shall comply with IEC 61000-6-1 and IEC 61000-6-3 for residential, commercial and light industrial environments. If the portable fuel cell power system is intended to be used in industrial environments, the following standards shall be referenced: IEC 61000-6-2; IEC 61000-6-4; IEC 61000-3-2 and IEC 61000-3-3, as applicable.

4.11 Hazard and risk assessment

4.11.1 General requirements for hazard and risk assesment and the approach

The manufacturer shall ensure that:

a) all foreseeable hazards, hazardous situations and events associated with the portable fuel cell power system throughout their anticipated lifetime have been identified;

b) the risk for each of these hazards has been estimated from the combination of probability of occurrence of the hazard and of its foreseeable severity in accordance with IEC 61882, IEC 61511-3 or equivalent methodology;

c) the two factors which determine each one of the estimated risks (probability and severity) have been eliminated or reduced as far as possible through design (inherently safe design and construction);

d) the necessary protection measures in relation to risks that are not eliminated have been taken (provision of warning and safety devices);

e) users are informed of any additional safety measures that they may be required to implement.

4.11.2 Safety and reliability analysis

The manufacturer shall demonstrate that the necessary protection measures in relation to risks that are not eliminated have been taken by performing a safety and reliability analysis which is intended to identify failures that have significant consequences affecting the system performance and/or safety.

The safety and reliability analysis shall be performed in accordance with IEC 60812, IEC 61025 or equivalent.

4.12 Safety control circuits

Automatic electrical and electronic controls shall be designed and constructed so that they are safe and reliable in conformance to IEC 60730-1, IEC 61508-1 or IEC 61511-1, as appropriate.

Manual controls shall be clearly marked and designed to prevent inadvertent adjustment and activation.

Protective devices, such as relays, switches and transformers, that meet the requirements of the relevant product standards shall be exempt from this component failure analysis. For example, automatic electrical burner control systems shall comply with IEC 60730-2-5. Catalytic oxidation reactors shall comply as applicable with IEC 60730-2-5.

The design of a safety-control circuit shall be such that electrical failure of an individual functional part will either

a) interrupt the intended function under its control, or

b) allow completion of an operational cycle, but will fail to start again or will lock out on the subsequent cycle.

4.13 Protection against oxygen depletion

Portable fuel cell power systems that are intended to be used indoors shall comply with 7.21, Oxygen depletion test.

For portable fuel cell power systems that are intended to be used outdoors, compliance with 7.21 is not required.

A portable fuel cell power system with the oxygen consumption rate of 0,21 m^3/h or less does not need to be equipped with an oxygen detector, and is not subject to 7.21.

The above rate is based on a 14 m^3 room with an air change rate of one-half of the room volume per hour.

For indoor portable fuel cell power systems not provided with an oxygen sensor the following warning or an equivalent warning shall be provided:

WARNING This device requires oxygen to operate which results in oxygen depletion in tight construction and poorly ventilated areas. To prevent asphyxiation, do not operate more than one system in a room at a time and make sure that the room is provided with fresh air ventilation of at least 7 m^3 per hour.

4.14 Emission of effluents

Emissions of effluents are limited to provide protection from hazards due to toxic substances. Since ventilation provides dilution of effluents, the limits given are based on a small room (14 m^3) and 0,5 air changes per hour. The manufacturer may also choose to specify that the portable fuel cell power system is to be used in a highly ventilated area, in which case higher carbon dioxide limits apply. See 7.22.3 and Table 1 for limits for use where 140 m^3/h of fresh air is provided. Ventilation rates lower than 140 m^3/h may be specified by the manufacturer. If different ventilation rates are used, calculations shall be made to determine the allowable carbon dioxide rate limit and the instructions, markings and warnings shall be consistent with the ventilation rate used.

Portable fuel cell power systems that are intended to be used indoors – that are not marked "**FOR OUTDOOR USE ONLY**" – shall comply with 7.22.3, Emission of effluents – Closed room and 7.22.2, Emission of effluents at the exhaust. Carbon dioxide emissions may alternatively be evaluated using 7.23, Alternative carbon dioxide emission test.

Portable fuel cell power systems that are intended for use in highly ventilated areas only – marked "**FOR USE IN HIGHLY VENTILATED AREAS ONLY – A MINIMUM OF 140 M^3/H OF FRESH AIR VENTILATION IS REQUIRED. SEE INSTRUCTION MANUAL FOR GUIDANCE**" – may use carbon dioxide emission rate limits of 1 130 g/h.

Portable fuel cell power systems that are intended to be used outdoors and that are marked "**FOR OUTDOOR USE ONLY**" shall comply with 7.22.2, Emission of effluents at the exhaust. No other emission testing is required for portable fuel cell power systems that are intended to be used outdoors and are marked "**FOR OUTDOOR USE ONLY**".

4.15 Fuel supply

Where necessary, means shall be provided to allow for a ground connection during refueling. The replenishment port on non-standard fuel tanks shall be incompatible with standard fuel storage connections**.**

Fuel storage systems using hydrogen stored in metal hydrides shall comply with ISO 16111.

Where the fuel supply is resident within the portable fuel cell power system, in either an integral, or removable and refillable container assembly (pressurized or non-pressurized), the fuel container shall meet applicable national regulatory requirements.

Means shall be provided to secure fuel containers from becoming dislodged while in use or stored on the portable fuel cell power system. Lateral movement shall not exceed an amount that results in a hazardous condition. Compliance is checked by 7.27. Any integral compressed gas fuel container shall include a connection fixture that will not allow the flow of gas until a positive gas seal has been achieved. The fuel connection device connecting the fuel supply and the system shall be suitable for its application.

4.16 Fuel processing systems

Fuel processing systems and fuel processing components shall be able to withstand stress due to shock, vibration and temperatures anticipated during normal usage. See Annex B for guidance.

NOTE ISO 16110-1 provides requirements for stationary hydrogen generators using fuel processors. Certain aspects of that standard may be useful as a guide in the design of portable fuel processing systems.

4.17 Enclosures

4.17.1 General requirements for all enclosures

Enclosures for electrical equipment shall be formed and assembled so that they will have the strength and rigidity necessary to resist the abuse to which they may be subjected, without increasing their fire and accident hazards due to partial collapse and without reduction of spacing, loosening or displacement of parts or other serious defects.

For applications where the equipment may be exposed to moisture, dust, or other injurious materials in normal operation, the protection afforded to the enclosed components shall be compliant with the applicable ingress protection “IP” rating in accordance with IEC 60529.

Enclosures shall be sufficiently complete to contain or deflect parts that, because of failure or for other reasons, might become loose, separated or thrown from a moving part.

4.17.2 Enclosure requirements for outdoor use

Enclosures for outdoor applications shall be compliant with the applicable IP rating in accordance with IEC 60529. A portable fuel cell power system incorporating a fuel processing system and used outdoors shall not create a hazardous or unsafe condition when exposed to winds having nominal velocities up to and including 16 km/h. Compliance with this clause is demonstrated by testing required by IEC 60529 and 7.24, Wind test.

4.18 Battery supplies

4.18.1 General requirements for batteries

A battery shall be so located and mounted that the terminals of cells will be prevented from coming in contact with the terminals of adjacent cells, or with the metal parts of the battery compartment, as the result of shifting of the battery.

If transformer isolation is not provided between the a.c. input circuit of the portable fuel cell power system and the battery circuit, the battery terminals shall be guarded to reduce the likelihood of unintentional contact with the battery terminals.

A battery that requires the addition of water shall have a means to determine the fluid level. Batteries shall be protected from overcharging, reverse charging and rapid discharging in accordance with 4.3.8 of IEC 60950-1:2005.

Primary lithium batteries shall comply with IEC 60086-4. Secondary lithium batteries shall comply with IEC 62133.

4.18.2 Battery compartments

Battery compartments shall be suitable for the service and resistant to potential leakage.

A polymeric enclosure or compartment housing a wet cell battery, such as a lead-acid storage battery, shall be resistant to corrosion by acids or alkalis, as applicable.

The enclosure or compartment housing a wet cell battery, such as a lead-acid storage battery, shall be constructed so that spillage or leakage of the electrolyte from the volume of one battery container will be contained within the enclosure and prevented from

a) reaching the outer surfaces of the portable fuel cell power system where contact with the user is possible,
b) contaminating adjacent electrical components or materials,
c) bridging required electrical spacing.

A metal case or container of a battery, such as an alkaline battery, shall be insulated or spaced away so as not to contact uninsulated live parts of the portable fuel cell power system if such contact may result in a short-circuit.

An enclosure or compartment housing batteries having metal containers or cases that are conductively connected to a battery electrode shall be such that the batteries are insulated or spaced from each other, or otherwise physically arranged, to prevent short-circuiting of part or all of the battery supply after installation in the portable fuel cell power system.

4.18.3 Vented wet cell batteries

Vented wet cell batteries may be integral with the portable fuel cell power system, provided all of the following conditions are met:

a) the enclosure or compartment housing the batteries is vented;
b) arcing parts such as the contacts of switches, circuit-breakers and relays are not located in the battery compartment;
c) the battery compartment does not vent into compartments with enclosed spaces that contain arcing parts;
d) where a hazard may be present through system orientation or positioning, instructions shall be provided and the portable fuel cell power system shall be marked.

NOTE The requirements of 4.18.3 do not apply to sealed cell or valve regulated batteries.

4.18.4 Ventilation of battery compartments

If vented wet cell batteries are housed in an enclosure or compartment, the minimum ventilation rates shall comply with the requirements of Annex A.

4.19 Pressure vessels and piping

4.19.1 General requirements for pressure vessels and piping

The design and construction of both rigid and flexible components carrying fluids under high pressure, and fittings, shall be designed, constructed and tested in accordance with the appropriate national requirements as outlined in ISO 16528.

Fuel storage systems using hydrogen stored in metal hydrides shall comply with ISO 16111.

Where piping systems are designed for internal pressures over 100 kPa, they shall be designed, constructed, and tested in accordance with ISO 15649.

Piping designed for operation below 100 kPa, or piping that the applicable regional or national pressure equipment codes and standards do not consider to be pressure piping (such as low-pressure water hoses, plastic tubing or other connections to atmospheric or low-pressure tanks and similar containers) shall be constructed of suitable materials and fittings, and designed and constructed with adequate strength and leakage resistance to prevent unintended releases.

For materials (piping, accessories, joints or vessels) that will be in direct contact with hydrogen, refer to ISO 16110-1:2007, Annex B, as a source of information to prevent problems of incompatibility.

4.19.2 Piping systems

All piping materials, thread compounds and thread tapes shall not be degraded through interaction with the system constituents. Unions, when used in gas lines, shall be appropriately constructed and if a packing is used it shall be resistant to the action of the gases.

For liquid fuel piping, a filter shall be provided upstream of the fuel controls.

Special consideration shall be given to the following aspects:

a) overstressing from inadmissible free movement or excessive stresses and strains being produced, for example, on flanges, connections, bellows or hoses; overstressing can be avoided by means such as support, constraint, anchoring, alignment and pre-tension;
b) rupture events (sudden movement, high-pressure jets, etc.);
c) condensation during start-up and/or use occurring inside enclosures for gaseous fluids which could cause damage from water hammer, vacuum collapse, corrosion and uncontrolled chemical reactions; in such a case means shall be provided for drainage and removal of deposits from low areas and for access during cleaning, inspection and maintenance;
d) where explosive, flammable, or toxic fluids are contained in the piping, appropriate precautions shall be taken in the design and marking of sampling and take-off points;
e) the piping for explosive, flammable or toxic fluids shall be suitable for their purpose.

4.20 Hoses

Hoses used for liquid fuels shall be suitable for the application. Compatibility includes absence of corrosion of the hose material and no breakdown of physical properties in use.

Hoses used for liquid fuels shall be used within their maximum allowable working pressures and temperatures for all conditions of normal, abnormal, emergency and faulted operating and shutdown conditions of the portable fuel cell power system.

4.21 Automatic shut-off valves

Flammable gas supplied to the portable fuel cell power systems shall pass through at least two automatic shut-off valves, in series, each of which serves as an operating valve and a safety shutoff valve. Additionally:

a) electrically-operated safety shut-off valves shall be of a type that will close upon current failure;
b) the valve closing time of safety shut-off valves shall not exceed 1 s;
c) automatic valves shall comply with IEC 60730-2-17.

4.22 Regulators

The gas pressure regulator shall be equipped with a vent limiter or a vent line.

4.23 Process control equipment

Process control equipment and monitoring devices, such as sensors, indicators and transmitters, shall comply with the applicable parts of the IEC 60079 series such as IEC 60079-29-1, and the applicable parts of the IEC 60730 series such as IEC 60730-1 or other nationally recognized standards as appropriate for the application.

4.24 Filters

4.24.1 Air filters

Air filters shall be of a type suitable for the application and shall be reasonably accessible for inspection and replacement. The air velocity through a filter shall not exceed the filter manufacturer's recommended air velocity.

4.24.2 Liquid fuel filters

Liquid fuel filters shall be designed by the manufacturer as a pressure part, suitable for the maximum working pressure of the adjacent fuel system.

Liquid fuel filters and their filter media shall be compatible with the fuel used.

4.25 Motors

Electric motors shall be designed for continuous duty and shall be provided with overload protection in accordance with the applicable clauses/subclauses of the relevant parts of the IEC 60034 series.

4.26 Fuel pumps

Fuel pumps shall be designed for the specific fuel and for the pressures and temperatures to which it may be subjected under normal operating conditions. Fuel pumps shall be provided with the following:

a) pressure relief devices that limit both inlet and outlet piping pressure to less than the design pressure of the piping. If the shut-off head is less than the pressure rating of the piping, relief valves are not required. Relief valve discharge shall be recycled to the fuel tank or routed to a safe place;
b) an automatic shutdown on high discharge pressure;
c) suction and discharge lines shall be adequately protected from damage due to vibration;
d) shaft seals compatible with the fluids, temperatures and pressures expected in normal and abnormal operation and during normal and emergency shutdowns;
e) motors, bearings and seals suitable for the expected duty cycles.

5 Instructions

5.1 Operation and maintenance manual

Instructions to be referred to as the operation and maintenance manual shall be provided with the portable fuel cell power system. Instructions related to product safety shall be provided in printed form. This manual shall contain clearly defined, legible and complete instructions for at least the following:

a) directions that the area surrounding the portable fuel cell power system shall be kept clear and free of combustible materials, gasoline and other flammable vapours and liquids;
b) where requiring air for combustion or ventilation, instructions to provide adequate ventilation either from outside air or adjacent spaces, not to block or obstruct air

openings on the portable fuel cell power system, air openings communicating with the area in which the portable fuel cell power system is installed, and the required spacings around the portable fuel cell power system that provide clearances to secure and discharge required air;

c) portable fuel cell power systems that are intended for use in highly ventilated areas only – marked **"FOR USE IN HIGHLY VENTILATED AREAS ONLY – A MINIMUM OF 140 M^3/H OF FRESH AIR VENTILATION IS REQUIRED. SEE INSTRUCTION MANUAL FOR GUIDANCE"** – shall include instructions indicating how the minimum air ventilation may be achieved and warnings to indicate the hazards of inadequate ventilation. Ventilation rates lower than 140 m^3/h may be specified by the manufacturer. If different ventilation rates are used, calculations shall be made to determine the allowable carbon dioxide rate limit and the instructions, markings and warnings shall be consistent with the ventilation rate used. Guidance and warnings shall be provided to the user such that the user can determine if the required ventilation is provided. Such guidance could indicate that operation in an open shed, a large room or operation indoors with open windows on opposite sides of the room can provide such ventilation. Alternatively, mechanical ventilation providing a known amount of fresh air can be used;

d) instructions for electrical connections (grounding, if applicable) and starting and shutting down the portable fuel cell power system. These instructions shall illustrate and locate all components;

e) the following statement: "Do not use this portable fuel cell power system if any part has been immersed or flooded with water. Immediately call the manufacturer or manufacturer's representative to inspect the portable fuel cell power system and to replace any functional part that has been affected";

f) specifications for the frequency of filter change or cleaning and the dimensional size and type of filter for replacements. These instructions shall contain directions for removal and replacement of filters and pictorially illustrate and locate all components supplied by the manufacturer referred to in the instructions for removal and replacement of filters;

g) recommended methods for periodic cleaning of necessary parts;

h) when a means to neutralize condensate is provided, instructions and a schedule for maintenance, if required;

i) instructions for lubrication of moving parts, including type, grade and amount of lubricant;

j) instructions for examining the portable fuel cell power system installation to determine that

   1) any intake or exhaust openings are clear and free of obstructions,

   2) there are no obvious signs of deterioration of the portable fuel cell power system;

k) a list of replacement parts and the source where such parts are availiable;

l) the necessity and minimum frequency for examinations and periodic inspection of the portable fuel cell power system by the user and by qualified service personnel, if required;

m) where a hazard may be present through system orientation or positioning, instructions shall be provided and the portable fuel cell power system shall be so marked;

n) documentation of all hazardous chemicals contained within the portable fuel cell power system with a description of the hazard and instructions for remedial action should the user or service personnel be contaminated;

o) an enumeration of all regular and routine maintenance items to be performed on the equipment;

p) manufacturer's or distributor's name, address, and telephone number;

q) the following statement for portable fuel cell power systems intended only for indoor use:

CAUTION: FOR INDOOR USE ONLY

r) the following statement for portable fuel cell power system intended only for outdoor use:

WARNING: FOR OUTDOOR USE ONLY. RISK OF ASPHYXIATION OR CARBON MONOXIDE POISONING. DO NOT OPERATE INDOORS.

s) the following statement for portable fuel cell power systems intended for use in highly ventilated areas:

FOR USE IN HIGHLY VENTILATED AREAS ONLY – A MINIMUM OF 140 M^3/H OF FRESH AIR VENTILATION IS REQUIRED. SEE INSTRUCTION MANUAL FOR GUIDANCE

Ventilation rates lower than 140 m^3/h may be specified by the manufacturer. If different ventilation rates are used, calculations shall be made to determine the allowable carbon dioxide rate limit and the instructions, the markings, and the warnings shall be consistent with the ventilation rate used.

t) proper earthing connections, if applicable;

u) the composition limits and supply characteristics of the fuels to be used in the fuel cell power system;

v) proper refuelling and if applicable, disposal of depleted fuel containers;

w) periodic inspection of refuelling connections;

x) the altitude above sea level up to which the fuel cell power system shall be capable of operating correctly;

y) the range of air temperatures within which the fuel cell power system shall be capable of operating correctly;

z) the range of temperatures within which the fuel cell power system shall be stored;

aa) for outdoor portable fuel cell power systems, the considered environment for the design of the fuel cell power system where it may be used including wind speed, rain intensity and direction, airborne particles, airborne dust (protective index), and air quality (pollution component);

bb) the acceptable tilt limits for its use;

cc) if specific instructions are necessary to avoid risk of explosion, they shall be included in the operation and maintenance manual.

5.2 User's information manual

5.2.1 User’s information manual general requirements

A user’s information manual shall be provided for a portable fuel cell power system. The manual shall be provided in the official language of the countries of expected use.

The user's information manuals shall be formatted to provide easy-to-follow procedures. Instructions related to product safety and operational/environmental conditions shall be provided in printed form. Illustrations should be used to identify portable fuel cell power system components, dimensions and clearances, assembled component, and connection points as needed to make the instructions clear. Illustrations should also be used to identify the location of user serviceable components and illustrate correct methods for performing service procedures.

When text is shown in quotation marks, it shall appear in the user’s information manual exactly as shown.

Each user’s information manual should be divided into appropriate chapters or sections, and should include a table of contents and clearly marked page numbers.

The user's information manual shall contain the safety information given below.

5.2.2 Users information manual front cover

The front cover shall present the user(s) with only the most important safety instructions. The front cover or, in the absence of a cover, the first page of the manual shall bear the applicable safety labelling in accordance with ISO 7010.

The boxed warning shall contain the following additional statement when the portable fuel cell power system is intended only for indoor use:

FOR INDOOR USE ONLY

The boxed warning shall contain the following additional statement when the portable fuel cell power system is intended only for outdoor use:

WARNING: FOR OUTDOOR USE ONLY. RISK OF ASPHYXIATION OR CARBON MONOXIDE POISONING. DO NOT OPERATE INDOORS.

The boxed warning shall contain the following statement for portable fuel cell power systems intended for use in highly ventilated areas:

FOR USE IN HIGHLY VENTILATED AREAS ONLY – A MINIMUM OF 140 M^3/H OF FRESH AIR VENTILATION IS REQUIRED. SEE INSTRUCTION MANUAL FOR GUIDANCE

Ventilation rates lower than 140 m^3/h may be specified by the manufacturer. If different ventilation rates are used, calculations shall be made to determine the allowable carbon dioxide rate limit and the instructions, markings and warnings shall be consistent with the ventilation rate used.

The front cover shall include a statement informing users that they need to read all instructions in the manual, and shall keep all manuals for future reference.

5.2.3 Users information manual safety section

A safety section shall be included near the front of the manual to provide portable fuel cell power system users with a listing of potential hazards and safety-related instructions for a particular portable fuel cell power system. Statements along the following lines shall be included in the safety section with references to specific clauses or pages of the manual for more information:

a) directions that the area surrounding the portable fuel cell power system needs to be kept clean and free of gasoline and other flammable vapours and liquids;

b) where requiring air for cooling or ventilation, instructions not to block or obstruct air openings on the portable fuel cell power system, air openings communicating with the area in which the portable fuel cell power system is being used, and the required spacings around the portable fuel cell power system that provide clearances for the intake and discharge of the required air;

c) instructions for starting and shutting down the portable fuel cell power system. These instructions shall pictorially illustrate and locate all user interface components;

d) portable fuel cell power systems intended for outdoor use only shall include instructions stating:

WARNING: FOR OUTDOOR USE ONLY. RISK OF ASPHYXIATION OR CARBON MONOXIDE POISONING. DO NOT OPERATE INDOORS

e) Portable fuel cell power systems that are intended for use in high ventilation areas – marked "**FOR USE IN HIGHLY VENTILATED AREAS ONLY– A MINIMUM OF 140 M^3/H OF FRESH AIR VENTILATION IS REQUIRED. SEE INSTRUCTION MANUAL FOR GUIDANCE**" – shall include instructions indicating how the minimum air ventilation may be achieved and warnings to indicate the hazards of inadequate ventilation.

   Ventilation rates lower than 140 m^3/h may be specified by the manufacturer. If different ventilation rates are used, calculations shall be made to determine the allowable carbon dioxide rate limit and the instructions, markings and warnings need to be consistent with the ventilation rate used;

f) the following statement: "Do not use this portable fuel cell power system if any part has been under water. A flood-damaged portable fuel cell power system is extremely dangerous. Attempts to use the portable fuel cell power system can result in fire or explosion. The manufacturer or manufacturer's representative should be contacted to inspect the portable fuel cell power system and to replace all fuel controls, control system parts, electrical parts that have been wet.";

g) specifications for the frequency of filter change or cleaning and the dimensional size and type of filter for replacements. These instructions shall contain directions for removal and replacement of filters and pictorially illustrate and locate all components supplied by the manufacturer referred to in the instructions for the removal and replacement of filters;

h) where a hazard may be present through system orientation or positioning, warnings shall be provided and the portable fuel cell power system shall be so marked;

i) documentation of all hazardous chemicals contained within the portable fuel cell power system with a description of the hazard and instructions for remedial action should the user or service personnel be contaminated;

j) recommended methods for periodic cleaning of necessary parts;

k) instructions for examining the portable fuel cell power system to determine that

   1) any intake or exhaust openings are clear and free of obstructions,

   2) there are no obvious signs of deterioration of the portable fuel cell power system;

l) instructions for safe refuelling of the portable fuel cell power system;

m) instructions for safe disposal of waste products, if applicable;

n) for indoor systems not provided with an oxygen sensor the following or equivalent wording shall be provided:

   "This device requires oxygen to operate which results in oxygen depletion in tight construction and poorly ventilated areas. To prevent asphyxiation, do not operate more than one system at a time in a room of approximately 14 m^3 and make sure that the room is provided with ventilation of at least 7 m^3 of fresh air per hour (1 air change per 2 h in a room of 14 m^3)."

o) if specific instructions are necessary to avoid risk of explosion, they shall be included in the user's information manual.

6 Labelling

6.1 General labelling requirements

All marking materials shall be suitable for application to surfaces upon which they are applied. Each portable fuel cell power system shall carry an indelible data plate which is visible during operation.

6.2 Marking

The equipment shall be plainly marked, in a permanent manner, in a place where the details will be readily visible after installation, with the following:

a) manufacturer's or distributor's name and location, trademark, trade name or other recognized symbol of identification;

b) catalogue, style, model or other type designation;

c) rated input voltage(s), if applicable;

d) an indication whether the equipment is rated for a.c. or d.c., or both, and, when necessary, the input and output frequency;

e) number of phases, except for equipment obviously intended for single-phase use only;

f) rated output voltage;

g) output in amperes, volt-amperes or watts;

h) the month and year of manufacture (date coding, serial numbers or the equivalent may be used);

i) range of ambient temperatures (minimum and maximum) within which the portable fuel cell power system is intended to operate;

j) type and quality of fuel;

k) fuel supply pressures (minimum and maximum) to the portable fuel cell power system;

l) proper orientation, if applicable;

m) the polarity of the output leads shall be plainly marked unless the portable fuel cell power system is provided with a polarized termination;

n) the required voltage and current rating of customer replaceable fuses and other fuses that provide current limitation for compliance with this standard, shall be marked in the vicinity of the fuse;

o) portable fuel cell power systems intended for outdoor use shall be marked

WARNING: FOR OUTDOOR USE ONLY RISK OF ASPHYXIATION
OR CARBON MONOXIDE POISONING. DO NOT OPERATE INDOORS

p) portable fuel cell power systems intended for indoor use shall be marked

WARNING: FOR INDOOR USE ONLY. Do not operate outdoors

q) portable fuel cell power systems intended for indoor and outdoor use shall be marked

"**FOR INDOOR OR OUTDOOR USE**";

r) Portable fuel cell power systems that are intended for use in HIGHLY VENTILATED AREAS ONLY shall be marked

FOR USE IN HIGHLY VENTILATED AREAS ONLY–
A MINIMUM OF 140 M^3 /H OF FRESH AIR VENTILATION
IS REQUIRED. SEE INSTRUCTION MANUAL FOR GUIDANCE.

Ventilation rates lower than 140 m^3/h may be specified by the manufacturer. If different ventilation rates are used the markings must be consistent with the ventilation rate used.

6.3 Warnings

Warning signs shall be appropriately placed to identify electrical hazards, contents from drain valves, hot components and mechanical hazards. Preference shall be given to the use of standard symbols given in applicable parts of the ISO 3864 series.

Control devices, visual indicators and displays (particularly those related to safety) used in the man-machine interface shall be clearly marked with regard to their functions either on or adjacent to the item. Preference shall be given to the use of standard symbols given in applicable parts of the ISO 3864 series and ISO 7000.

7 Type tests

7.1 General requirements for type tests

All measurements shall be carried out at rated power, voltage, current and frequency. Multi-voltage portable fuel cell power systems shall be tested at the voltage(s) that produce the highest temperatures. Except where otherwise stated in the particular clauses, measurements shall be carried out with the maximum uncertainties indicated in Annex C. A manufacturer shall specify fuel quality requirements for testing.

7.2 Test sequence

For gaseous fueled systems, the same sample shall be used for 7.4, Flammable fuel gas concentration test; subclause 7.11, Abnormal operation testing; subclause 7.17, Impact test; subclause 7.18, Free drop test; and then that same sample shall then be tested for emissions in accordance with 7.22 and its applicable subclauses. If a sample does not operate after a test, another sample may be exposed to a cumulative operating period in accordance with 7.4 and used for the subsequent tests.

For liquid fueled systems, the same sample shall be used for 7.3, Leakage test for liquid fueled systems, 7.11, Abnormal operation testing; 7.17, Impact test; 7.18, Free drop test; and then that same sample shall then be tested for emissions in accordance with 7.22 and its applicable subclauses. If a sample does not operate after a test, another sample may be exposed to a cumulative operating period in accordance with 7.3 and used for the subsequent tests.

7.3 Leakage test for liquid fuelled systems

7.3.1 General requirements for leakage tests for liquid fuelled systems

The procedures of this subclause shall be performed, when applicable, following purging as required in 4.5.5.

The system, shall comply with 7.3.2 following exposure to a cumulative operating period within the maximum operating temperature range for the lesser of 720 h, or 10 % of the system operating design life.

7.3.2 Method of test

Liquid fuelled systems shall be tested with their proper fuel for final leak testing as specified by the manufacturer.

Prior to the performance of the test, it shall be established which liquid carrying parts, through interconnection, are subject to the same internal pressure during normal operation. These parts shall comprise an individual test section which shall then be pressurized separately and, when deemed necessary, isolated from the rest of the power system by any convenient means.

A suitable pressurizing system, capable of safely providing fuel at 1,5 times the maximum operating pressure of the system, shall be connected to the test section. This test shall be conducted at an ambient temperature of 20 °C ± 5 °C.

The test section shall be isolated by any convenient means. System isolation leakage during the test shall be eliminated. High point vents shall be provided, where practical, for the purpose of venting any air, vapour or gas in the test section. If high point vents are not practical, the test section may be evacuated using suitable vacuum pumps so that the total gas volume of the system is less than 0,001 l prior to the introduction of the test fluid.

Any functional part(s) shall be made to assume the open position so the required test pressure is exerted on all parts of the test section. Pressure relief devices capable of interrupting the test shall be defeated for the purpose of this test.

The test fluid shall be introduced gradually into the test section. The test section shall be gradually pressurized using the pressurizing system, while venting any air or gas or vapour present from all high points of the test section, unless the pre-test vacuum option is used.

The test section shall be pressurized and held at 1,5 times its maximum operating pressure after filling is complete for at least 1 h while inspecting all external surfaces of the system for any sign of liquid leakage. All external surfaces of the parts that convey liquid fuels shall be made visible in order to check for leakage, or provisions shall be made to capture and route leakage down-slope to a suitable tell-tale.

No visible leakage is allowed.

7.4 Flammable fuel gas concentration test

7.4.1 General requirements for flammable gas concentration testing

This test shall determine the maximum flammable fuel concentration within the portable fuel cell power system enclosure under normal operation. The system, shall comply with 7.4.2 below following exposure to a cumulative operating period within the maximum operating temperature range for the lesser of 720 h, or 10 % of the system operating design life.

7.4.2 Method of test

The portable fuel cell power system shall be operated within its nominal temperature range until thermal stability conditions are achieved. The testing shall be carried out at the barometric pressure at the testing station and in an area free from appreciable draughts.

Measurements shall be made at multiple locations within the enclosure at a sufficient distance from the purge or points of release so that the flammable concentration measured is that of the compartment rather than the source.

The test shall be conducted for at least four measurements. The time interval between measurements shall be not less than 5 min. The test shall be continued until the final measured value is less than or equal to the mean of the four previous measurement values.

At the conclusion of the test, the highest measured value shall be compared to the lower flammability limit of the fuel being measured. The test is satisfactory if the highest concentration of flammable gas measured during the test is less than 25 % of the lower flammability limit.

7.5 Surface temperatures

The test method for determining maximum surface temperatures shall be in accordance with Clause 11 of IEC 60335-1:2010. Surface temperatures shall be measured to determine compliance with 4.9.2.

7.6 Component temperatures

The method of test for determining component temperatures shall be in accordance with Clause 11 of IEC 60335-1:2010. Component temperatures shall be measured to determine compliance with 4.9.3.

When no IEC standard exists for the relevant component, when the component is not marked or is not used in accordance with its marking, it is tested under the conditions occurring in the portable fuel cell power system.

NOTE For automatic controls, the term "marking" includes documentation and declaration as specified in Clause 7 of IEC 60730-1:2010.

7.7 Wall, floor and ceiling temperatures

The portable fuel cell power system shall be placed in direct contact (zero clearance) with a test cavity made of dull black-painted plywood panels, each approximately 20 mm thick. The temperature increase of the surfaces of walls, ceiling and floor of the test cavity shall be determined by means of fine-wire (diameter not exceeding 0,3 mm) thermocouples, that shall be attached to the back of small blackened disks of copper or brass, approximately 15 mm in diameter and approximately 1 mm thick. The front of the disk shall be flush with the surface of the boards.

As far as possible, the portable fuel cell power system is positioned so that the thermocouples detect the highest temperatures. The fuel cell power system shall be operated at maximum power output. After equilibrium temperatures have been obtained, the temperature of the test panels shall be measured and checked to determine whether or not the requirements of 4.9.4 are met.

7.8 Dielectric strength

7.8.1 General requirements for dielectric strength and testing

Adequate dielectric shall be interposed between ungrounded current-carrying parts and those external surfaces that can be contacted. In order to test this requirement, the portable fuel cell power system shall be connected in the manner intended to a supply circuit of rated voltage and frequency and the portable fuel cell power system shall be operated until thermal stability conditions are reached. At the conclusion of the operating period required to achieve thermal stability conditions, the dielectric withstand test outlined below shall be conducted.

If the portable fuel cell power system employs a component, such as a solid-state device that can be damaged by the dielectric potentials specified in this provision, the point of connection of this component to ground shall be disconnected for the purpose of this test so as to eliminate the likelihood of component damage while still retaining representative dielectric stress of the circuit.

The test as specified in 7.8.2 may be performed using a d.c. test potential, with a value equal to 150 % of the corresponding a.c. potential. .

7.8.2 Test method

The dielectric strength test shall be performed in accordance with 5.2 of IEC 60950-1:2005.

7.9 Humidity test

The humidity test is carried out for 48 h in a humidity cabinet containing air with a relative humidity of (93 ± 3) %. The temperature of the air is maintained within 1 K of any convenient value T between 20 °C and 30 °C. Before being placed in the humidity cabinet, the portable fuel cell power system is brought to a temperature of $T\,^{+4}_{\ 0}$ °C.

NOTE 1 In most cases, the portable fuel cell power system may be brought to the specified temperature by keeping it at this temperature for at least 4 h before the humidity test.

NOTE 2 A relative humidity of (93 ± 3) % can be obtained by placing a saturated solution of Na_2SO_4 or KNO_3 in water in the humidity cabinet, the container having a sufficiently large contact surface with the air.

NOTE 3 The specified conditions may be achieved by ensuring a constant circulation of the air within a thermally insulated cabinet.

The portable fuel cell power system shall then withstand the dielectric strength test described in 7.8, in the humidity cabinet or in the room in which the portable fuel cell power system was brought to the prescribed temperature after reassembly of those parts that may have been removed.

7.10 Leakage current at operating temperature

7.10.1 Leakage current testing requirement and duration

The following test shall be performed on systems with a connection to the mains supply, or an a.c. output. The portable fuel cell power system shall be operated for the duration necessary to achieve thermal stability conditions.

7.10.2 Test method

The leakage current of the portable fuel cell power system shall be determined in accordance with 5.1 of IEC 60950-1:2005.

7.11 Abnormal operation testing

7.11.1 Abnormal operation testing – General requirements

A portable fuel cell power system shall not become a shock hazard or a fire hazard because of electrical failure when operated under each of the following abnormal operation test conditions:

a) 7 h* with the output of the portable fuel cell power system short-circuited;

b) 7 h* with the rotor of each blower motor locked, one at a time**, with the portable fuel cell power system delivering rated load, when forced ventilation is provided within the portable fuel cell power system;

c) 7 h* with the polarity of the batteries reversed when the battery connector is not polarized or the batteries are user replaceable;

d) 7 h* at maximum available power output, unless a fuse opens;

e) 1 h at 135 % of the ampere rating of the fuse with the fuse bypassed if a fuse opens during the test specified in condition d).

* If a product feature precludes a system from operating for as much as 7 h, that feature, for example fuel supply, may be considered as a time limit for the test duration. Operation should be without regard to temperatures attained on any part of the portable fuel cell power system.

** At the discretion of the manufacturer, all fan motors of a portable fuel cell power system having more than one fan motor may be locked simultaneously.

7.11.2 Abnormal operation testing – Outcomes and further testing requirements

If a protective device opens the circuit during tests a) to d), the test shall be:

a) terminated, if a non-resettable, non-automatic protector ("one shot") functions;

b) continued for 7 h if an automatic-reset protector functions;

c) continued for 10 cycles using the minimum resetting time (but not faster than 10 operations/min), if a manual-reset protective device other than a molded case circuit breaker functions; or

d) continued for 3 cycles if the manual-reset protective device is a molded case circuit breaker complying with IEC 60934.

If the opening of a component other than a protective device, or the short-circuiting of a component terminates the abnormal operation test, an attempt shall be made to restart the portable fuel cell power system in order to continue the test.

EXAMPLE Short-circuits and open circuits of transistors, diodes and capacitors (particularly electrolytic capacitors), faults causing continuous dissipation in resistors designed for intermittent dissipation and internal faults in integrated circuits causing excessive dissipation.

7.11.3 Abnormal operation test methods

The following test procedure shall be used to determine compliance:

a) only one fault at a time shall be introduced;

b) the equipment shall be set up as for the normal temperature test except that

   – the enclosure shall be connected to ground through a 3 A fuse, and

   – the supply circuit shall be fused at not less than 400 % of the ampacity of the supply circuit conductors, unless otherwise specified by the manufacturer;

c) the test shall be continued as long as necessary to establish steady-state conditions, or up to the point of interruption of the circuit due to failure of the component or to other consequences of the simulated fault condition, whichever is the shorter.

The portable fuel cell power system shall be considered to comply with the requirements above provided

1) there is no opening of the 3 A ground fuse,

2) there is no emission of flames or molten metal from the overall enclosure,

3) there are no resultant openings in the overall enclosure that would expose live or current-carrying parts, and

4) there is no breakdown when the dielectric strength test of 7.8 is applied as soon as practical after the test.

7.12 Strain relief testing

The strain relief means required by 4.7.9 shall be subjected to a steady pull of 156 N and a push of 45 N, each applied for 1 min. There shall be no evidence of any stress being imposed on the wiring terminals, splices, or internal wiring.

7.13 Insulating material

When required by 4.6.2.3, insulating material in contact with bare live parts shall withstand the application of an a.c. voltage of 3 000 V for 1 min when placed between two 6,35 mm diameter probes after being conditioned for 96 h in air having a relative humidity of (90 ± 5) % and a temperature of (35 ± 2) °C.

7.14 Earthing test

Compliance shall be demonstrated through testing in accordance with 2.6.3 of IEC 60950-1:2005.

7.15 Tank pressure test

All fuel tanks and reservoirs shall withstand a hydrostatic pressure test at an internal gauge pressure of 95 kPa plus normal working pressure at 22 °C or 1,5 times the design pressure of the tank at 55 °C whichever is greater, unless they are pressure vessels, in which case they shall comply with 4.19.

A test section shall be filled with a liquid medium and connected to a suitable hydraulic system, including a pressure-measuring device, capable of sustaining the required test pressure. Care should be taken to liberate any air from the test section. A suitable pressurizing system, capable of supplying the liquid medium at the required test pressure, and a suitable pressure-measuring device, capable of indicating the required test pressure, shall be connected to the inlet of a test section. The pressure-measuring device shall be located between the pressurizing system and the test section to be pressurized. The outlet of the test section shall be sealed by any convenient means.

The test pressure shall be gradually increased so that a uniform gauge pressure is attained in approximately 1 min. This pressure shall be maintained for 1 min during which time no rupture, fracture, deformation or other physical damage shall occur.

7.16 Stability

Compliance with 4.3 is demonstrated in the following tests, where relevant. Each test is carried out separately. The tests shall be performed under the most disadvantageous configuration including fuel and spare container capacity and orientation. All castors and jacks, if used in normal operation, are placed in their most unfavourable position with wheels and the like locked or blocked.

The following tests and requirements shall be met:

a) A portable fuel cell power system shall not overbalance when tilted to an angle of 15° from its normal upright position. Doors, drawers, etc. are closed during this test.

   A portable fuel cell power system having a mass of 25 kg or more shall not tip over when a force F_{st} (calculated as F_{st} [N] = 0,2 × mass [kg] × 9,81 [m/s^2]), but not more than 250 N, is applied in any direction except upwards, at a height not exceeding 2 m from the floor. Doors, drawers, etc. which may be moved for servicing shall be placed in their most unfavorable position consistent with the user instructions.

b) A portable fuel cell power system shall not overbalance when a constant downward force of 800 N is applied at the point of maximum moment to any horizontal surface of at least 12,5 cm by at least 20 cm, at a height up to 1 m from the floor. Doors, drawers, etc. are closed during this test. The 800 N force is applied by means of a suitable test tool having a flat surface of approximately 12,5 cm by 20 cm. The downward force is applied with the complete flat surface of the test tool in contact with the portable fuel cell power system; the test tool need not be in full contact with uneven surfaces, for example corrugated or curved surfaces.

c) A portable fuel cell power system shall also have the stability described in a) and b) above when it is operated on a surface that is inclined by as much as 4° from horizontal.

   This stability will be judged by putting the operating systems on a rough concrete surface inclined by 4° from horizontal and rotating the supporting surface clockwise in four steps of 90° each (360° total).

   After 30 min of no load operation and 30 min of full load operation in each position, the systems shall not move more than 10 mm total.

7.17 Impact test

The portable fuel cell power system shall not have any damage that may affect its mechanical and electrical safety after finishing the test specified below.

The impact shall be applied by spring type impact test equipment in accordance with IEC 60068-2-75. The springs shall be adjusted so that the hammer can give the impact energy of 1,0 J ± 0,05 J to the test objects.

Release mechanism springs shall be adjusted so that sufficient pressure can be generated exactly by holding the release jaws at the engagement position.

The portable fuel cell power system shall be tilted until the release jaws engage the slot of the hammer shaft. The impact shall be given so that the release cone hits the target surface of the test object vertically.

Pressure shall be increased slowly so that the release cone touches the release bar; the movement of the release bar activates the release mechanism and the cone retreats until the hammer can hit the test object.

The test object shall consist of the complete enclosure, supported in its normal position, in non-operating condition. The test object shall be fixed firmly and the impact shall be given three times to each weak portion of the enclosure.

The impact shall also be applied to the protection equipment, handles, levers, knobs or similar components, and signal lamps and their covers. But the signal lamps and their covers, which protrude less than 10 mm or are of an area below 4 cm^2 will be exempt from the tests. The lamps and their covers will be subject to the tests only when these are liable to be damaged.

Compliance with this section shall be demonstrated by successfully meeting the requirements of 7.8 and 4.6.2.3.

Perform emission testing as required by 7.22 if the system is still capable of operation.

7.18 Free drop test

The portable fuel cell power system shall not sustain any damage which may affect the mechanical and electrical safety following the test specified below.

Compliance with this subclause shall then be demonstrated by successfully meeting the requirements of 7.8 and 4.6.2.3.

The portable fuel cell power system shall be equipped with all associated attachments that are likely to be installed.

The heights for the drop test shall be as follows:

a) A portable fuel cell power system having a mass of 5 kg or less shall be dropped from its most critical angle three times on a concrete surface from a height of 1 m.
b) A portable fuel cell power system having a mass greater than 5 kg but not exceeding 15 kg shall be dropped from its most critical angle three times on a concrete surface from a height of 20 cm.
c) A portable fuel cell power system having a mass greater than 15 kg but not exceeding 150 kg shall be lifted straight up from its normal level upright position and dropped straight down on a concrete surface from a height of 3 cm.

The results of the tests shall be considered acceptable if, following the test:

1) an uninsulated live part or a moving part that may involve a risk of injury to persons cannot be contacted by the probe (see Figure 2, Articulated probe);
2) the sample complies with the test specified in 7.8, Dielectric strength, with the test potential applied between live parts and accessible non-current-carrying metal parts;
3) the portable fuel cell power system meets the requirements of flammable fuel gas concentration testing in accordance with 7.4, or the leakage test for liquid fuelled systems in accordance with 7.3, whichever is applicable;
4) the portable fuel cell power system meets the requirements of emission testing in accordance with the applicable portions of 7.22 following testing, if the system is still capable of operation.

Dimensions in millimetres

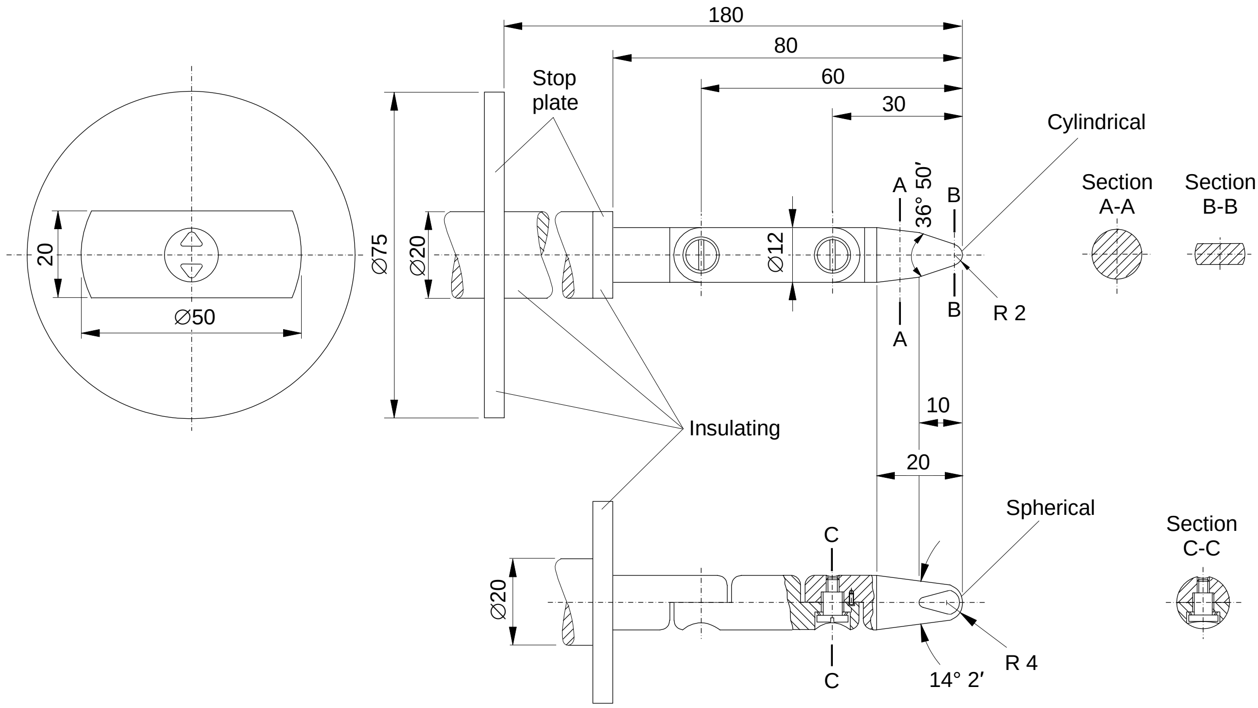


Figure 2 – Articulated probe

7.19 Adhesion and legibility of marking materials

The markings required by this standard shall be clearly legible and durable. Compliance is checked by inspection and by rubbing the marking by hand for 15 s with a piece of cloth soaked with water, and again for 15 s with a piece of cloth soaked with petroleum spirit.

After all the tests of this standard, the marking shall be clearly legible, it shall not be easily possible to remove marking plates and they shall show no curling.

NOTE 1 In considering the durability of the marking, the effect of normal use is taken into account. For example, marking by means of paint or enamel, other than vitreous enamel, on containers that are likely to be cleaned frequently, is not considered to be durable.

NOTE 2 The petroleum spirit to be used for the test is aliphatic solvent hexane having a maximum aromatics content of 0,1 % by volume, a kauri-butanol value of 29, an initial boiling point of approximately 65 °C, a dry point of approximately 69 °C and a density of approximately 0,66 kg/l.

7.20 Flammable gas accumulation

7.20.1 Flammable gas accumulation test basis and applicability

This test procedure shall verify the functionality of the means provided to prevent accumulation of fuel gas. This test applies to portable fuel cell power systems that can be used indoors. It does not apply to portable fuel cell power systems that are marked **"FOR OUTDOOR USE ONLY"**.

Means shall be provided to prevent accumulation of flammable gas from reaching 25 % of the lower flammability limit at the system ventilation outlet under simulated leakage conditions.

NOTE 1 Some examples of fuel leakage conditions are loose fittings or joints, gasket failure, regulator diaphragm failure, cracked or broken portable fuel cell power system plates, pressure relief valve activation and piping or tubing rupture.

NOTE 2 For the purposes of this part of IEC 62282, approved fuel container rupture is not considered.

7.20.2 Test set-up

Unless provided as the primary method of protection for the accumulation of fuel gas leakage, any ancillary safety system capable of interrupting the test such as an oxygen depletion sensor or thermal shut-off shall be bypassed or made inoperable for the duration of the test. The fuel gas concentration shall be verified by an independent fuel gas analyser located at the ventilation outlet.

7.20.3 Test method

Simulated leakage shall be introduced to the portable fuel cell power system by supplying fuel to the air intake(s) of the system, through a sealed conduit. This is to simulate leakage of a fuel-conveying component (i.e. gas train, fuel cell stack) within the portable fuel cell power system.

The portable fuel cell power system shall be operated at idling condition (0 A net). After 1 min of operation, a simulated fuel gas leak of 0,5 standard litres per minute shall be introduced, and the flow rate increased in 0,5 standard litres per minute increments each minute until a safety device activates.

Also, this test shall be repeated with the portable fuel cell power system under normal operating condition. After 1 min of operation, a simulated fuel gas leak of 0,5 standard litres per minute shall be introduced, and the flow rate increased in 0,5 standard litres per minute increments each minute until a safety device activates.

Under each of these conditions, the portable fuel cell power system shall operate until a safety device activates, prior to reaching 25 % of the lower flammability limit (LFL) at the ventilation outlet.

7.21 Oxygen depletion test

7.21.1 Oxygen depletion test basis and applicability

The following requirements apply to portable fuel cell power systems that are intended to be used indoors (not marked **"FOR OUTDOOR USE ONLY"**).

This test procedure shall verify the functionality of the means provided to prevent the oxygen concentration in a tight structure having a volume of 14 m^3 from being reduced down to 18 % by operation of the portable fuel cell power system under normal operation and single fault conditions.

7.21.2 Test set-up

The tight structure shall be either close-fitting or sealed construction, with exterior walls covered by a continuous, sealed vapour barrier and gypsum wallboard (drywall) or plywood or similar materials having sealed joints to prevent excessive air infiltration.

Unless provided as the primary method of protection for the depletion of oxygen, any ancillary safety system capable of interrupting the test such as a gas detection sensor or thermal shut-off shall be bypassed or made inoperable for the duration of the test.

The oxygen concentration shall be verified by an independent analyser located within the structure.

7.21.3 Test method

The portable fuel cell power system shall be operated at full rated power until the oxygen concentration reaches a steady state, or a safety device activates, prior to reaching 18 %.

7.22 Emission of effluents tests

7.22.1 Emission of effluents testing sequence

For gaseous fueled systems, the same sample shall be used for 7.4, Flammable fuel gas concentration test; 7.11, Abnormal operation testing; 7.17, Impact test; 7.18, Free drop test; and then that same sample shall then be tested for emissions in accordance with 7.22 and its applicable subclauses. If a sample does not operate after a test, another sample may be exposed to a cumulative operating period in accordance with 7.4 and used for the subsequent tests.

For liquid fueled systems, the same sample shall be used for 7.3, Leakage test for liquid fueled systems; 7.11, Abnormal operation testing; 7.17, Impact test; 7.18, Free drop test, and then that same sample shall then be tested for emissions in accordance with 7.22 and its applicable subclauses. If a sample does not operate after a test, another sample may be exposed to a cumulative operating period in accordance with 7.3 and used for the subsequent tests.

7.22.2 Emission of effluents at the exhaust

A portable fuel cell power system capable of producing emissions of any materials given in Table 1 shall not produce a concentration at the exhaust of the fuel cell power system of any of the materials listed in Table 1 that exceed the concentration limit in Table 1.

The portable fuel cell power system shall be operated in an open room or outdoors. During the operational cycle, a sufficient number of effluent samples shall be secured to allow a determination of compliance with this subclause.

Each effluent sample shall be secured at a point of exhaust discharge of the portable fuel cell power system where a uniform sample can be obtained and shall be analysed for the materials in Table 1 that could be produced by the portable fuel cell power system. Gaseous emission concentrations from the portable fuel cell power system shall be sampled at a distance of 0,20 m from the portable fuel cell power system exhaust. The results of the analyses shall be compared to the concentration limits in Table 1. If the measured concentration is less than the concentration limit, the portable fuel cell power system passes the test. If a particular sample cannot operate due to damage sustained in previous testing, and the emissions from that sample which is not operating are less than the concentration limit, then that sample passes the test, but that sample shall not be used for subsequent testing.

7.22.3 Emission of effluents – Closed room

The following requirements apply to portable fuel cell power systems that are intended to be used indoors (not marked **"FOR OUTDOOR USE ONLY"**) that may produce carbon monoxide and other emissions.

Portable fuel cell power systems mounted in or on a vehicle or by any means equipped with permanent exhaust to the outdoors are not required to be tested in accordance with the present subclause.

Carbon dioxide emissions may alternatively be evaluated using 7.23, Alternative carbon dioxide emission test.

a) Test sample: a portable fuel cell power system fuelled in accordance with the manufacturer's specifications.

b) Purpose: Under operating conditions (or attempted operating conditions) of a portable fuel cell power system, emissions of carbon monoxide (CO), carbon dioxide (CO_2) and organic compounds such as methanol, formaldehyde, formic acid and methyl formate, butane, gasoline, diesel, oxides of nitrogen (NO and NO_2) and volatile organic carbon compounds shall be maintained at less than the specified values in Table 1.

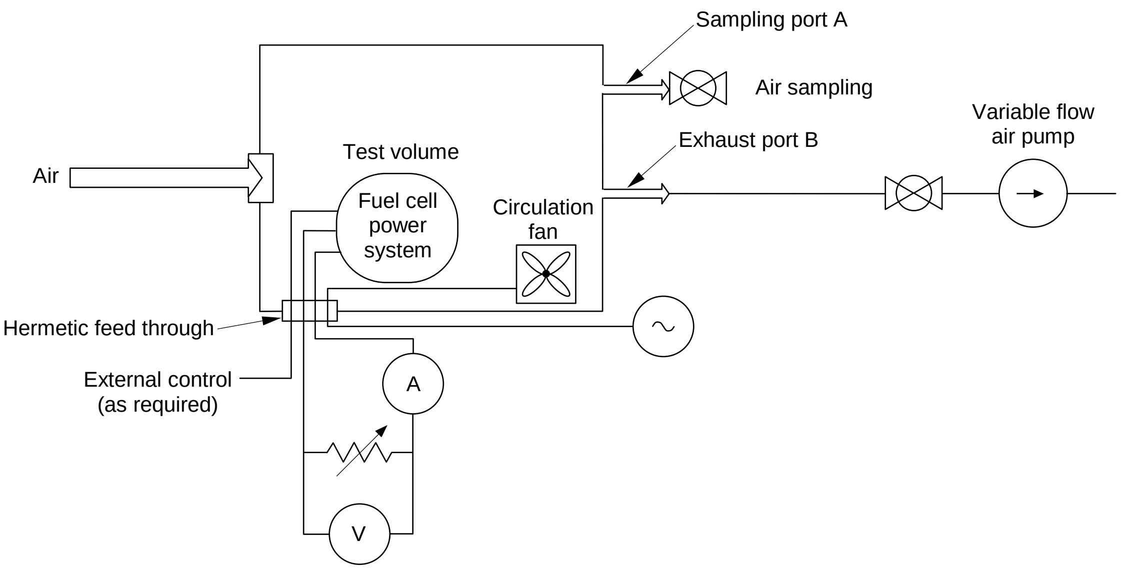


Figure 3 – Operational emission rate testing apparatus

c) Test apparatus: An example of the operational emission rate testing apparatus is shown in Figure 3. The configuration shown in Figure 3 is for emission rate testing of all portable fuel cell power systems.

Emission gases might be composed of materials such as carbon monoxide (CO), carbon dioxide (CO_2) and organic compounds such as methanol, formaldehyde, formic acid and methyl formate, butane, gasoline and diesel fumes, oxides of nitrogen (NO and NO_2) and volatile organic carbon compounds which are potentially exhausted from a portable fuel cell power system.

To analyse these organic materials, a gas chromatograph with a flame ionization detector (GC/FID) or with a mass spectrometer (GC/MS) or a high-performance liquid chromatography (HPLC) system shall be used by absorbing emission gas to a sorbent tube fixed to sampling port A of the test chamber or directly to an analyser through sampling port A in Figure 3. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments.

The concentration of CO and CO_2 gas can be measured by a nondispersive infrared absorption analyser. These analytical instruments shall comply with ISO 16000-3, ISO 16000-6 and ISO 16017-1. However, the use of other instruments is allowed, provided that the performance is equivalent to that of the above-mentioned instruments using the above mentioned standards.

d) Test procedure:

1) Emission rate sampling tests shall be performed with the portable fuel cell power system on ("DEVICE – ON") as follows:

i) Operate the portable fuel cell power system at rated power inside the small test chamber shown in Figure 3. If the portable fuel cell power system is no longer operational due to a type test, the emission test shall be performed with the portable fuel cell power system fully fuelled and the power switch in the “ON” position.

ii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.

iii) Gaseous emissions from the portable fuel cell power system shall be sampled at the outlet of the small test chamber, at air sampling port A shown in Figure 3.

iv) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilize.

v) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure 3, while simultaneously measuring and recording the flow through the test chamber. The flow through the test chamber can be computed from the sum of the variable flow air pump flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber.

vi) Record the concentrations of the chemical compounds of interest. See Table 1.

vii) Calculate the emission rate of chemical compounds of interest being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

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

See below:

$$ER = (F_{\mathrm{P}} + F_{\mathrm{S}}) \times C$$

or

$$ER = (F_{\mathrm{i}}) \times C$$

where

ER is the emission rate in grams per hour;

F_{P} is the variable flow air pump flow rate in standard litres per hour;

F_{S} is the sample flow rate in standard litres per hour;

F_{i} is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

viii) Compare the maximum measured emission rate to Table 1. If the emission rate is not less than the emission rate limit in Table 1, the portable fuel cell power system fails the test and no further testing is required. See passing criteria.

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

2) The following emission rate sampling test shall be performed with the portable fuel cell power system off (“DEVICE – OFF”) as follows:

i) Operate the portable fuel cell power system at rated power inside the small test chamber shown in Figure 3 for 10 min or until 10 % of the fuel supply is used up, whichever is less.

ii) Turn the portable fuel cell power system off ("DEVICE – OFF") and measure the emission rates with the portable fuel cell power system off ("DEVICE – OFF") inside the small test chamber shown in Figure 3.

iii) The small test chamber shall be supplied with clean air. The supply of air into the test volume should be from a known purity source. If bottled air is not used, the use of blanks to determine background concentration levels should be considered to avoid false non-compliant results.

iv) Gaseous emissions from the portable fuel cell power system shall be sampled at the outlet of the small test chamber, at air sampling port A shown on Figure 3.

v) Allow the test chamber variable flow air pump air flow, circulation fan flow and sample flow rate to stabilize.

vi) Sample and record the gaseous contents of the test chamber through air sampling port A shown in Figure 3, while simultaneously measuring and recording the flow through the test chamber. The flow through the test chamber can be computed from the sum of the variable flow air pump flow rate and the sample flow rate through air sampling port A or by measuring the inlet flow rate to the test chamber.

vii) Record the concentrations of chemical compounds of interest. See Table 1.

viii) Calculate the emission rate of chemical compounds being emitted by multiplying the maximum stabilized concentration of each constituent by the simultaneous total air flow through the system. The total air flow through the system is determined by adding the steady-state variable flow air pump flow rate through the system to the simultaneous sample flow rate or by measuring the inlet air flow rate.

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

See below:

$$ER = (F_{\mathrm{P}} + F_{\mathrm{S}}) \times C$$

or

$$ER = (F_{\mathrm{i}}) \times C$$

where

ER is the emission rate in grams per hour;

F_{P} is the variable flow air pump flow rate in standard litres per hour;

F_{S} is the sample flow rate in standard litres per hour;

F_{i} is the air flow rate at the inlet of the chamber in standard litres per hour;

C is the concentration in grams per standard litre.

ix) Compare the maximum measured "DEVICE – OFF" emission rate to Table 1. If the emission rate is not less than the emission rate limit in Table 1, the portable fuel cell power system fails the test and no further testing is required. See passing criteria.

x) This test shall be conducted for at least three hours with the “DEVICE – OFF”.

e) Passing criteria:

1) Passing criteria for testing with the device on:

The maximum emission rate for each of the constituents of interest in Table 1 shall be less than the emission rate limit value in Table 1 when tested in accordance with this procedure with the "DEVICE – ON". If the portable fuel cell power system does not operate, or shuts down in a safe manner prior to exceeding a limit, the test is acceptable.

2) Passing criteria for testing with the device off:

The maximum emission rate for each of the constituents of interest in Table 1 shall be less than the emission rate limit value in Table 1 when tested in accordance with this procedure with the "DEVICE – OFF".

Table 1 – Emission limits

	Concentration limit [d]	**Emission rate limit** [a]
Water	No limit	No limit
Methanol	0,33 g/m^3	1,8 g/h
Formaldehyde	2,5 mg/m^3 [b]	0,5 mg/h
CO	0,23 g/m^3	0,20 g/h
CO_2 limits for portable fuel cell power systems not restricted to use in highly ventilated areas	54 g/m^3	28 g/h [c]
CO_2 limits for portable fuel cell power systems restricted to use in HIGHLY VENTILATED AREAS ONLY only	54 g/m^3	1130 g/h [c]
Formic acid	0,019 g/m^3	0,07 g/h
Butane [e]	2,37 g/m^3	0,9 g/h [e]
Volatile organic carbon compounds (based on Toluene)	0,75 g/m^3	1,3 g/h
Gasoline	2,33 g/m^3	9,8 g/h
Diesel	0,1 g/m^3	0,7 g/h
NO	0,03 g/m^3	0,21 g/h
NO_2	0,009 4 g/m^3	0,039 g/h
Methyl formate	0,368 g/m^3	1,7 g/h

a The emission rate limit is based on a 14 m^3 room size and 0,5 air changes per hour and is intended to avoid exceeding the time weighted average (TWA) 8 h exposure limit (sometimes called PEL (permissible exposure limit) for the substances under consideration. These values are based on US 29 CFR (OSHA) or the US National Institute for Occupational Safety and Health (NIOSH) data or the American Conference of Governmental Industrial Hygienists (ACGIH). See Table 2 for values of the TWA limit for these compounds.

b WHO guideline limit is 0,000 1 g/m^3. Background levels are 0,000 03 g/m^3. The emission limit cannot push the background level above the guideline limit.

c A seated human adult has a CO_2 emission rate of 30 g/h. The assumed normal background CO_2 concentration is 0,72 g/m^3. The portable fuel cell power system plus human adult emission rates are limited such that the CO_2 concentration does not reach the WHO 8 h concentration limit of 9 g/m^3. In a 14 m^3 room with 0,5 air changes per hour, this limits the contribution from the portable fuel cell power system to 28 g/h. Portable fuel cell power systems that are intended for use in highly ventilated areas only (fuel cell power systems that are marked “FOR USE IN HIGHLY VENTILATED AREAS ONLY – A MINIMUM OF 140 M^3 P/H OF FRESH AIR VENTILATION IS REQUIRED. SEE INSTRUCTION MANUAL FOR GUIDANCE”) may use carbon dioxide emission rate limits of 1 130 g/h. Carbon dioxide emissions may alternatively be evaluated using 8.19. Alternative carbon dioxide emission test.

d The concentration limit is based on the short term exposure limit (STEL) such that the concentration out of the device does not pose a health risk for short term (15 min) exposures.

e The 0,9 g/h emission rate limit for butane equates to the highest leak rate that will not support a flame.

Table 2 – Occupational exposure limits

	TWA exposure limit (TWA – time weighted average over 8 h of operation)	**STEL exposure limit** (STEL – short-term exposure limit – 15 min exposure limit)
Methanol	< 200 ppmv *	< 250 ppmv
Formaldehyde	< 0,08 ppmv	< 2,0 ppmv
CO	< 25 ppmv	< 200 ppmv
CO_2	< 5 000 ppmv	< 30 000 ppmv
Formic acid	< 5 ppmv	< 10 ppmv
Butane	< 800 ppmv	< 1 000 ppmv (TLV)
Volatile organic carbon compounds (based on Toluene)	< 50 ppmv	< 200 ppmv
Gasoline	< 300 ppmv	< 500 ppmv
Diesel	< 100 mg/m^3	< 100 mg/m^3
NO	< 25 ppmv	< 25 ppmv
NO_2	< 3 ppmv	< 5 ppmv
Methyl formate	< 100 ppmv	< 150 ppmv
Hydrogen	N/A	N/A
Methanol	< 0,262 g/m^3	< 0,33 g/m^3
Formaldehyde	< 0,098 mg /m^3	< 2,5 mg/m^3
CO	0,029 g/m^3	0,23 g/m^3
CO_2	9 g/m^3	54 g/m^3
Formic acid	0,009 g/m^3	0,019 g/m^3
Butane	1,90 g/m^3	2,38 g/m^3
Volatile organic carbon compounds (based on Toluene)	0,188 g/m^3	0,75 g/m^3
Gasoline	1,40 g/m^3	2,33 g/m^3
Diesel	0,1 g/m^3	0,1 g/m^3
NO	< 25 ppmv	0,03 g/m^3
NO_2	0,005 6 g/m^3	0,009 4 g/m^3
Methyl formate	0,245 g/m^3	0,368 g/m^3
Hydrogen	N/A	N/A
NOTE These values are based on US 29 CFR (OSHA) or the US National Institute for Occupational Safety and Health (NIOSH) data or the American Conference of Governmental Industrial Hygienists (ACGIH) data.		
* ppmv = parts per million by volume.		

7.23 Alternative carbon dioxide emission test

7.23.1 Alternative carbon dioxide emission test applicability

This alternative test for carbon dioxide emissions may be used instead of the emission of effluent test method for carbon dioxide given in 7.22.3 for carbon dioxide only.

This alternative test method only applies to carbon dioxide. All other emission rate limits shall be evaluated using 7.22.3, unless the fuel cell power system is intended and marked “FOR OUTDOOR USE ONLY” or is equipped with a permanent exhaust to the outdoors. Emission concentration limit testing shall still be done according to 7.22.2, Emission of effluents at the exhaust.

This alternative test procedure shall verify the functionality of the means provided to prevent the carbon dioxide concentration in a structure having a volume of 14 m^3 and one air change every 2 h (0,5 air changes per hour) from exceeding 5 000 ppmv by operation of the portable fuel cell power system under normal operating conditions.

7.23.2 Test set-up

The 14 m^3 test structure shall be either close-fitting or sealed construction, with exterior walls covered by a continuous, sealed vapour barrier and gypsum wallboard (drywall) or plywood or similar materials having sealed joints to prevent uncontrolled air infiltration. The test structure shall be provided with clean, fresh air at a rate of 7 m^3/h ± 2 m^3/h (approximately 0,5 air changes per hour).

Unless provided as the primary method of protection to prevent the carbon dioxide concentration in the area from exceeding 5 000 ppmv, any ancillary safety system capable of inadvertently interrupting the test (such as a thermal shut-off) shall be bypassed or made inoperable for the duration of the test. The primary method to prevent the carbon dioxide concentration in the area from exceeding 5 000 ppmv might be a carbon dioxide detector, an oxygen detector, or other suitable means.

The carbon dioxide concentration shall be verified by an independent high accuracy analyser (not part of the fuel cell power system) located within the structure during the test. The analyser shall be located in the room such that it measures the general carbon dioxide concentration in the room. It shall be located in an area of the room with sufficient air flow and mixing to provide a good indication of the carbon dioxide concentration in the room.

7.23.3 Test method

The portable fuel cell power system shall be operated at full rated power until the carbon dioxide concentration in the room reaches a steady state, or a safety device activates, prior to reaching 5 000 ppmv the test structure.

7.23.4 Passing criteria

The carbon dioxide concentration in the room shall be less than 5 000 ppmv at all times during the test for the test to be successfully completed. The portable fuel cell power system shall either shut down prior to exceeding this limit or the carbon dioxide concentration shall stabilize at a level below the limit with the portable fuel cell power system operating at full rated power.

If a particular sample cannot operate due to damage sustained in previous testing and the emissions from that sample which is not operating do not raise the carbon dioxide concentration in the room such that the carbon dioxide concentration in the room is always less than 5 000 ppmv for 8 h, then that sample passes the test, but that sample shall not be used for subsequent testing.

7.24 Wind test

7.24.1 Wind test applicability

This test shall be carried out if the portable fuel cell power system is intended for used outdoors and if its emissions can be affected by wind.

7.24.2 Method of test

A wind, produced by a fan/blower of sufficient capacity to develop a draught having a velocity up to and including 16 km/h, shall be directed against an outer surface of the portable fuel cell power system at the point(s) deemed most critical. The fan/blower shall be located so a uniform wind, covering the entire projected area of the outer surface, is directed horizontally toward the portable fuel cell power system at the specified velocity measured in a vertical plane 45,7 cm from the windward surface of the portable fuel cell power system.

The portable fuel cell power system shall be operated outdoors while subjected to the 16 km/h wind as described above. During the operational cycle, a sufficient number of effluent samples shall be secured at the exhaust to allow a determination of compliance with this subclause.

Each effluent sample shall be secured at a point of exhaust discharge of the portable fuel cell power system where a uniform sample can be obtained and shall be analysed for the materials in Table 1 that could be produced by the portable fuel cell power system. Gaseous emission concentrations from the portable fuel cell power system shall be sampled at a distance of 0,20 m from the portable fuel cell power system exhaust. The results of the analyses shall be compared to the concentration limits in Table 1. If the measured concentration is less than the concentration limit, the portable fuel cell power system passes the test.

7.25 Strength test

7.25.1 Strength test sequencing and alternative compliance methods

This strength test shall be performed last or, when judged feasible, on parts not used for other performance tests specified herein.

Any part(s) that are pressure-rated at not less than the maximum allowable working pressure of the portable fuel cell power system shall be considered to comply with this strength test.

A fuel cell module must comply with the allowable working pressure test requirements of IEC 62282-2.

The oxidant and fuel sides of the fuel cell stack may be interconnected and tested simultaneously at the same pressure.

7.25.2 Method of test (liquid)

Prior to performing this test, it shall be established which liquid-conveying parts, through (inter)connection, are subjected to the same internal static pressure during normal operation of the portable fuel cell power system. These parts shall comprise an individual test section, which then shall be pressurized separately and, when deemed necessary, isolated from the rest of the portable fuel cell power system by any convenient means. Any non-hazardous liquid, such as water, shall be used as the test medium.

A test section shall be filled with the liquid medium and connected to a suitable hydraulic system, including a pressure-measuring device, capable of sustaining the required test pressure. Care should be taken to liberate any air from the test section.

The test pressure shall be gradually increased so that a uniform gauge pressure of not less than 1,5 times the maximum allowable working pressure is attained in approximately 1 min. This pressure then shall be maintained for 30 min during which time no rupture, fracture, deformation or other physical damage shall occur.

7.25.3 Method of test (gas)

Prior to performing this test, it shall be established which gas-conveying parts, through (inter)connection, are subjected to the same internal pressure during normal operation of the portable fuel cell power system. These parts shall comprise an individual test section, which then shall be pressurized separately and, when deemed necessary, isolated from the rest of the portable fuel cell power system by any convenient means.

A suitable pressurizing system, capable of supplying the gaseous medium at the required test pressure, and a suitable pressure-measuring device, capable of indicating the required test pressure, shall be connected to the inlet of a test section. The pressure-measuring device shall be located between the pressurizing system and the test section to be pressurized. The outlet of the test section shall be sealed by any convenient means.

The test pressure shall be gradually increased so that a uniform gauge pressure of not less than 1,5 times the maximum allowable working pressure is attained in approximately 1 min. This pressure then shall be maintained for 30 min during which time no rupture, fracture, deformation or other physical damage shall occur.

7.25.4 Passing criteria

All parts, including joints and connections that convey a pressurized fluid shall withstand, without rupture, fracture, deformation or other physical damage, an internal static pressure of not less than 1,5 times their maximum allowable working pressure.

7.26 Stress relief test

Enclosures of molded or formed thermoplastic materials shall be so constructed that any shrinkage or distortion of the material due to release of internal stresses caused by the molding or forming operation does not result in the exposure of hazardous parts or in the reduction of creepage distances or clearances below the minimum required.

Compliance is checked by the test procedure described below or by the inspection of the construction and the available data where appropriate.

One sample consisting of the complete equipment, or of the complete enclosure together with any supporting framework, is placed in a circulating air oven (according to IEC 60216-4-1) at a temperature of not less than 70 °C, for a period of not less than 7 h, then permitted to cool to room temperature.

For large equipment where it is impractical to condition a complete enclosure, it is permitted to use a portion of the enclosure representative of the complete assembly with regard to thickness and shape, including any mechanical support members.

NOTE Relative humidity need not be maintained at a specific value during this test.

7.27 Fuel supply securement test

The fuel container (i.e. fuel cylinder) or any portion thereof shall not become dislodged from its retention means when a lateral force equal to the full weight of the fuel container or cylinder is applied in any direction at the centre of the vertical height of the fuel container or cylinder.

7.28 Shut-down parameters

Compliance with this subclause shall be established for each anomaly using a simulated test procedure or by using supportive evidence from the manufacturer, either of which verifies that the required action will occur.

Means shall be provided for automatic shutdown of the appropriate system(s) of the portable fuel cell power system for any of the critical anomalies resulting from the reliability analysis described in 4.11.

7.29 Non-metallic tubing conductivity test

7.29.1 Passing criteria

When tested as described in 7.29.2, the measured resistance of the non-metallic tubing shall not exceed 1 MΩ.

7.29.2 Test method

Three samples of the tubing shall be provided with conductive pads at various locations on the samples. The pads are to be located

a) at points as far away as possible from the points at which the tubing is mounted to grounded metal,
b) at intermediate points, and
c) at other points that result in high resistance to ground because of the configuration of the tubing being tested.

The conductive pads are to be metal foil approximately 2 cm^2, and attached to the samples by a thin film of petrolatum or similar material.

Ground point electrodes are to be provided on the samples at a point or points on the part where it is mounted to grounded metal; for example, the ground point electrode on a non-metallic tubing shall consist of metal fittings installed on the ends of the tubing for connection to grounded parts as noted in 4.2.2.

The resistance shall be measured between the ground point electrodes (i.e. metal tube fittings) and the conductive pads after the samples have been conditioned for at least 48 h at a relative humidity of 50 % ±10 %.

The resistance shall be measured with an ohmmeter that has an effective internal resistance of 100 000 Ω ± 10 000 Ω. The open-circuit potential shall be 1 000 V d.c. and the short-circuit current shall be 5 mA.

7.30 Non-metallic tubing test for accumulation of static electricity

7.30.1 Passing criteria

No sparks shall be observed when a grounded metal sphere is brought into gradual contact with the non-metallic tubing after it has been electrostatically charged.

7.30.2 Test method

Three samples of the tubing with ground point electrodes as described in 7.29.2 (i.e. metal fittings) shall be conditioned for at least 48 h at a relative humidity of 25 % ± 10 %.

Immediately after removal from the low-humidity chamber, the samples shall be supported by means of insulators in a room having a relative humidity not more than 35 % and having all sources of light, other than electrical sparks, eliminated. The ground point electrodes shall be grounded. An electrostatic charge shall be sprayed on nonconductive parts of the product using an electrostatic generator limited to 5 000 V.

A 3/8 inch (9,5 mm) diameter grounded metal sphere shall be brought into gradual contact with the sample. If no sparks appear, the sample passes the test.

8 Routine tests

8.1 Routine test requirements

Routine tests shall be performed on all systems produced.

8.2 Gas leakage test

For gaseous fueled systems, the gas leakage test shall be performed as described under 7.4 (except that samples will be tested in as-received condition, not conditioned for 720 h).

An alternative method; determining the tightness of gas conveying parts and components by using a suitable gaseous or liquid fluid to evaluate pressure drop is an equivalent means for checking leakage.

8.3 Liquid leakage test

For liquid fueled systems, the leakage test for liquid fueled systems shall be performed as described under 7.3 (except that samples will be tested in an 'as received' condition, not conditioned for 720 h).

An alternative method; determining the tightness of liquid conveying parts and components by using a suitable gaseous or liquid fluid to evaluate pressure drop is an equivalent means for checking leakage.

8.4 Dielectric strength test

This test is required for portable fuel cell power systems with output voltage above 60 V d.c or 42,4 V a.c. peak. The test shall be performed as described under 7.8.

8.5 Routine test records

Routine test records shall be included with each device.

Annex A
(normative)

Ventilation rates for batteries

A.1 Ventilation rate for valve regulated lead acid batteries

The following equation gives the ventilation rate for valve regulated lead acid batteries:

$$Q = 11 \times I \times n \quad \text{(A.1)}$$

where

Q is the air exchange (ventilation) rate in litres per hour;

I is the the maximum current (in amperes) delivered by the charging equipment during battery gassing, but not less than 25 % of the maximum rated output current of the charger, in amperes;

n is the number of cells in series.

A.2 Ventilation rate for vented wet cell batteries

The following equation gives the ventilation rate for vented wet cell batteries:

$$Q = 110 \times I \times n \quad \text{(A.2)}$$

where

Q is the air exchange (ventilation) rate in litres per hour;

I is the maximum current (in amperes) delivered by the charging equipment during battery gassing, but not less than 25 % of the maximum rated output current of the charger in amperes;

n is the number of cells in series.

Ventilation for other battery types shall be in accordance with battery manufacturer's specification.

Annex B
(informative)

Shock and vibration limits for high shock environments

NOTE This Annex B is not a mandatory part of this standard but is written in mandatory language to accommodate its adoption by anyone wishing to do so.

B.1 Field of application

The following limits are suggested for portable fuel cell power systems that are intended for use in high shock environments such as specialty vehicles.

NOTE Portions of this annex have been reprinted with permission from UL 2267, “Fuel Cell Power Systems for Use in Industrial Trucks”.

B.2 Vertical axis test

The following tests shall be performed in the vertical axis with respect to vehicle orientation:

a) 2 000 sinusoidal cycles at 5 g peak acceleration applied at the vehicle manufacturer’s recommended resonant frequency (g: terrestrial acceleration). If the manufacturer’s resonant frequency is not available, the test shall be repeated between 10 Hz and 30 Hz in increments of 1 Hz; and

b) 60 sine sweeps from 10 Hz up to 190 Hz and back to 10 Hz to be conducted at a sweep rate of 1 Hz/s for a total duration of 6 h using the load profile in Table B.1, or as specified by the vehicle manufacturer.

Table B.1 – Vertical axis vibration conditions

Frequency range Hz	**Peak acceleration** g
10–20	3,0
20–40	2,0
40–90	1,5
90–140	1,0
140–190	0,75

B.3 Longitudinal and lateral axes tests

The following tests shall be performed in both the longitudinal and lateral axes with respect to vehicle orientation:

a) 2 000 sinusoidal cycles at 3,5 g peak acceleration applied at the vehicle manufacturer’s recommended resonant frequency. If the manufacturer’s resonant frequency is not available, the test is to be repeated between 10 Hz and 30 Hz in increments of 1 Hz; and

b) 60 sine sweeps from 10 Hz up to 190 Hz and back to 10 Hz, to be conducted at a sweep rate of 1 Hz/s for a total duration of 6 h using the load profile in Table B.2, or as specified by the vehicle manufacturer.

Table B.2 – Longitudinal and lateral axes vibration conditions

Frequency range Hz	**Peak acceleration** g
10–15	2,5
15–30	1,7
30–60	1,25
60–110	1,0
110–190	0,75

Annex C
(normative)

Uncertainty of measurements

Except where otherwise stated in the particular clauses, measurements shall be carried out with the maximum uncertainties,as shown in Table C.1.

Table C.1 – Measurements and their maximum uncertainties

1	Atmospheric pressure	± 5 mbar
2	Combustion chamber and test flue pressure	± 5 % full scale or 0,05 mbar
3	Gas pressure	± 2 % full scale
4	Water-side pressure loss	± 5 %
5	Water rate	± 1 %
6	Gas rate	± 1 %
7	Air rate	± 2 %
8	Time – up to 1 h	± 0,2 s
	– beyond 1 h	± 0,1 %
9	Auxiliary electrical energy	± 2 %
10	Temperatures:	
	– ambient	± 1 K
	– water	± 2 K
	– combustion products	± 5 K
	– gas	± 0,5 K
	– surface	± 5 K
11	CO, CO_2 and O_2 for the calculation of flue losses	± 6 % full scale
12	Gas calorific value	± 1 %
13	Gas density	± 0,5 %
14	Mass	± 0,05 %
15	Torque	± 10 %
16	Force	± 10 %
17	Current	± 1 %
18	Voltage	± 1 %
19	Electrical power	± 2 %
The full range of the measuring apparatus is chosen to be suitable for maximum anticipated value.		

Bibliography

[1] IEC 60050-195:1998, *International Electrotechnical Vocabulary – Part 195: Earthing and protection against electric shock*

[2] IEC 60050-161:1990, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

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

[4] IEC/TR 60079-32, *Explosive atmospheres – Electrostatics*

[5] ISO 15156-1, *Petroleum and natural gas industries – Materials for use in H2S-containing environments in oil and gas production – Part 1: General principles for selection of cracking-resistant materials*

Additional (non cited) references

[6] IEC 60439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies*

[7] IEC 62282-6-100, *Fuel cell technologies – Part 6-100: Micro fuel cell power systems – Safety*

____

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch