

Fuel cell technologies —

Part 3-1: Stationary fuel cell power systems — Safety

The European Standard EN 62282-3-1:2007 has the status of a
British Standard

ICS 27.070

National foreword

This British Standard is the UK implementation of EN 62282-3-1:2007. It is identical to IEC 62282-3-1:2007.

The UK participation in its preparation was entrusted to Technical Committee GEL/105, Fuel cell technologies.

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

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Part 3-1: Stationary fuel cell power systems -
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Technologies des piles à combustible -
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à combustible stationnaires -
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CENELEC

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Foreword

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Endorsement notice

The text of the International Standard IEC 62282-3-1:2007 was approved by CENELEC as a European Standard without any modification.

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FUEL CELL TECHNOLOGIES –

Part 3-1: Stationary fuel cell power systems – Safety

1 Scope

This part of IEC 62282 is a product safety standard suitable for conformity assessment as stated in IEC Guide 104:1997, ISO/IEC Guide 51:1999 and ISO/IEC Guide 7:1994.

This standard applies to stationary packaged, self-contained fuel cell power systems or fuel cell power systems comprised of factory matched packages of integrated systems which generate electricity through electrochemical reactions.

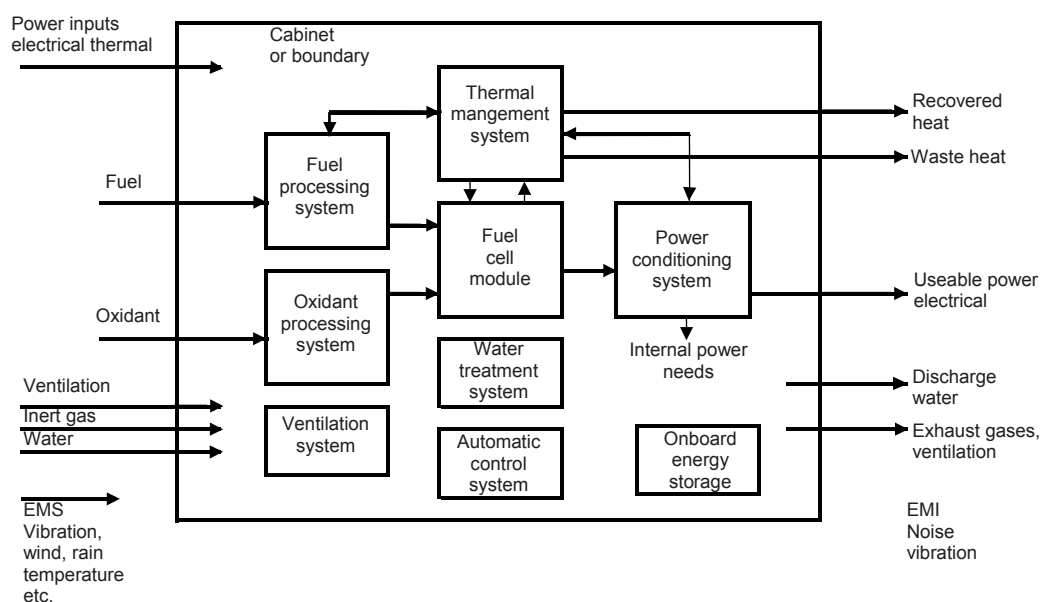
This standard applies to:

- systems intended for electrical connection to mains direct, or with a transfer switch, or to a stand-alone power distribution system;
- systems intended to provide a.c. or d.c. power;
- systems with or without the ability to recover useful heat;
- systems intended for operation on the following input fuels:
 - a) natural gas and other methane rich gases derived from renewable (biomass) or fossil fuel sources, for example, landfill gas, digester gas, coal mine gas;
 - b) fuels derived from oil refining, for example, diesel, gasoline, kerosene, liquefied petroleum gases such as propane and butane;
 - c) alcohols, esters, ethers, aldehydes, ketones, Fischer-Tropsch liquids and other suitable hydrogen-rich organic compounds derived from renewable (biomass) or fossil fuel sources, for example, methanol, ethanol, di-methyl ether, biodiesel;
 - d) hydrogen, gaseous mixtures containing hydrogen gas, for example, synthesis gas, town gas.

This standard does not cover

- portable fuel cell power systems;
- propulsion fuel cell power systems.

A typical stationary fuel cell power system is shown in Figure 1.



IEC 433/07

Figure 1 – Stationary fuel cell power systems

The overall design of the power system anticipated by this standard shall form an assembly of integrated systems, as necessary, intended to perform designated functions, as follows.

- **Fuel processing system:** Catalytic or chemical processing equipment plus associated heat exchangers and controls required to prepare the fuel for utilization within a fuel cell.
- **Oxidant processing system:** The system that meters, conditions, processes and may pressurize the incoming supply for use within the fuel cell power system.
- **Thermal management system:** Provides cooling and heat rejection to maintain thermal equilibrium within the fuel cell power system, and may provide for the recovery of excess heat and assist in heating the power train during startup.
- **Water treatment system:** Provides the treatment and purification of recovered or added water for use within the fuel cell power systems.
- **Power conditioning system:** Equipment which is used to adapt the electrical energy produced to the requirements as specified by the manufacturer.
- **Automatic control system:** The assembly of sensors, actuators, valves, switches and logic components that maintains the fuel cell power system parameters within the manufacturer's specified limits without manual intervention.
- **Ventilation system:** Provides, by mechanical means, air to a fuel cell power system's cabinet.
- **Fuel cell module:** Assembly of one or more fuel cell stacks, electrical connections for the power delivered by the stacks, and means for monitoring and/or control.
- **Fuel cell stack:** Assembly of cells, separators, cooling plates, manifolds and a supporting structure that electrochemically converts, typically, hydrogen rich gas and air reactants to d.c. power, heat, water and other byproducts.

- Onboard energy storage: Internal energy source intended to aid or complement the fuel cell module in providing power to internal or external loads.

This standard is applicable to stationary fuel cell power systems intended for indoor and outdoor commercial, industrial and residential use in non-hazardous (unclassified) areas.

This standard contemplates all significant hazards, hazardous situations and events, with the exception of those associated with environmental compatibility (installation conditions), relevant to fuel cell power systems, when they are used as intended and under the conditions foreseen by the manufacturer.

This standard deals with conditions that can yield hazards on the one hand to persons and on the other to damage outside the fuel cell system only. Protection against damage to the fuel cell system internals is not addressed in this standard, provided it does not lead to hazards outside the fuel cell system.

The requirements of this standard are not intended to constrain innovation. When considering fuels, materials, designs or constructions not specifically dealt with in this standard, these alternatives shall be evaluated as to their ability to yield levels of safety and performance equivalent to those prescribed by this standard.

2 Normative references

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

IEC 60079-0, *Electrical apparatus for explosive gas atmospheres – Part 0: General requirements*

IEC 60079-2, *Electrical apparatus for explosive gas atmospheres – Part 2: Pressurized enclosures “p”*

IEC 60079-10, *Electrical apparatus for explosive gas atmospheres – Part 10: Classification of hazardous areas*

IEC 60079-16, *Electrical apparatus for explosive gas atmospheres – Part 16: Artificial ventilation for the protection of analyzer(s) houses*

IEC 60079-20, *Electrical apparatus for explosive gas atmospheres – Part 20: Data for flammable gases and vapours, relating to the use of electrical apparatus*

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

IEC 60300-3-9, *Dependability management – Part 3: Application guide – Section 9: Risk analysis of technological systems*

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

IEC 60335-2-51, *Household and similar electrical appliances – Safety – Part 2-51: Particular requirements for stationary circulation pumps for heating and service water installations*

IEC 60384-14, *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification: Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

IEC 60417, *Graphical symbols for use on equipment*

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

IEC 60730-1, *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 systems*

IEC 60730-2-6, *Automatic electrical controls for household and similar use – Part 2-6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements*

IEC 60730-2-9, *Automatic electrical controls for household and similar use – Part 2-9: Particular requirements for temperature sensing controls*

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 60730-2-19, *Automatic electrical controls for household and similar use – Part 2-19: Particular requirements for electrically operated oil valves, including mechanical requirements*

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

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

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 61000-3-4, *Electromagnetic compatibility (EMC) – Part 3-4: Limits – Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A*

IEC 61000-3-5, *Electromagnetic compatibility (EMC) – Part 3-5: Limits – Limitation of voltage changes, voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current greater than 16 A*

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 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 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

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 61779-4, *Electrical apparatus for the detection and measurement of flammable gases – Part 4: Performance requirements for group II apparatus indicating up to 100% lower explosive limit*

IEC 61779-6, *Electrical apparatus for the detection and measurement of flammable gases – Part 6: Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of flammable gases*

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

IEC 62086-1, *Electrical apparatus for explosive gas atmospheres – Electrical resistance trace heating – Part 1: General and testing requirements*

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

IEC 62282-3-2, *Fuel cell technologies – Part 3-2: Stationary fuel cell power systems – Performance test methods*

IEC Guide 104:1997, *The preparation of safety publications and the use of basic safety publications and group safety publications*

ISO 3864-2:2004, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

ISO 4413, *Hydraulic fluid power – General rules relating to systems*

ISO 4414, *Pneumatic fluid power – General rules relating to systems*

ISO 5388, *Stationary air compressors – Safety rules and code of practice*

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

ISO 10439, *Petroleum, chemical and gas service industries – Centrifugal compressors*

ISO 10440-1, *Petroleum and natural gas industries – Rotary-type positive-displacement compressors – Part 1: Process compressors (oil-free)*

ISO 10440-2, *Petroleum and natural gas industries – Rotary-type positive-displacement compressors – Part 2: Packaged air compressors (oil-free)*

ISO 10442, *Petroleum, chemical and gas service industries – Packaged, integrally geared centrifugal air compressors*

ISO 13631, *Petroleum and natural gas industries – Packaged reciprocating gas compressors*

ISO 13707, *Petroleum and natural gas industries – Reciprocating compressors*

ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

ISO 13850, *Safety of machinery – Emergency stop – Principles for design*

ISO 14121, *Safety of machinery – Principles of risk assessment*

ISO 14847, *Rotary positive displacement pumps – Technical requirements*

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

ISO/TR 15916, *Basic considerations for the safety of hydrogen systems*

ISO/TS 16528, *Boilers and pressure vessels – Registration of codes and standards to promote international recognition*

ISO/IEC Guide 7:1994, *Guidelines for drafting of standards suitable for use for conformity assessment*

ISO/IEC Guide 51:1999, *Safety aspects – Guidelines for their inclusion in standards*

3 Terms and definitions

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

3.1

accessible

area to which, under normal operating conditions, one of the following applies:

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

NOTE The terms "access" and "accessible", unless qualified, relate to operator access area as defined above.

3.2

circuit, extra low voltage (ELV)

secondary circuit with voltages between any two conductors of the circuit, and between any one such conductor and earth not exceeding 42,4 V peak, or 60 V d.c., under normal operating conditions, which is separated from hazardous voltage by basic insulation, and which neither meets all of the requirements for an SELV circuit nor meets all of the requirements for a limited current circuit

[IEC 60950]

3.3

circuit, limited current

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

[IEC 60950]

3.4

circuit, primary

circuit which is directly connected to the a.c. mains supply. It includes, for example, the means for connection to the a.c. mains supply, the primary windings of transformers, motors and other loading devices

[IEC 60950]

3.5

circuit, safety-control

circuit or portion thereof involving one or more safety controls in which failure due to grounding, opening or shorting of any part of the circuit can cause unsafe operation of the controlled equipment

3.6

circuit, safety extra low voltage (SELV)

secondary circuit which is so designed and protected that under normal operating conditions and single-fault conditions, its voltages do not exceed a safe value

[IEC 60950]

3.7

circuit, secondary

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

[IEC 60950]

3.8

circuit, telecommunications network voltage (TNV)

circuit which is in the equipment and to which the accessible area of contact is limited and that is so designed and protected that, under normal operating conditions and single-fault conditions, the voltages do not exceed specified limit values

[IEC 60950, 1.2.8.8 for specific limits]

3.9

class I equipment

equipment where protection against electric shock is achieved by

- a) using basic insulation;
- b) providing a means of connection to the protective earthing conductor in the building wiring to those conductive parts that are otherwise capable of assuming hazardous voltages if the basic insulation fails

NOTE Class I equipment may have parts with double insulation or reinforced insulation.

3.10

design pressure

pressure used in the design of a component together with the coincident design material temperature, for the purpose of determining the minimum permissible thickness or physical characteristics

3.11

effluent

products of combustion plus the excess air being discharged from gas utilization equipment (also see flue gases)

3.12

electrical equipment

see 3.14

3.13

ELV circuit

see 3.2

3.14

equipment, electrical

general term including material, fittings, devices appliances, fixtures, apparatus and the like used as part of, or in connection with, and electrical installation

3.15

flame failure lock-out time

see 3.31

3.16**fuel cell**

electrochemical device that converts the chemical energy of a fuel, such as hydrogen or hydrogen rich gases, alcohols, hydrocarbons and oxidants to DC power, heat and other reaction products

3.17**gas vent**

passageway, composed of listed factory-built components assembled in accordance with the terms of listing, for conveying flue gases from gas utilization equipment or their vent connectors to the outside atmosphere (see also 3.56)

3.18**heat exchanger**

vessel in which heat is transferred from one medium to another

3.19**igniter**

device which utilizes electrical energy to ignite gas at a pilot burner or main burner

3.20**ignition, automatic**

ignition of gas at the burner when the gas controlling device is turned on, including re-ignition if the flames on the burner have been extinguished by means other than by the closing of the gas-controlling device

3.21**ignition device**

a) device for igniting gas at a burner. It may be a pilot or an igniter

b) **direct ignition**

igniter utilized to ignite gas at a main burner

3.22**ignition system, automatic**

system designed to ignite and reignite a main burner. Such systems

- a) prove the presence of either the ignition source or main burner flame, or both;
- b) automatically ignite gas at the main burner or at the pilot burner so that the pilot can ignite the main burner;
- c) automatically act to shut off the gas supply to the main burner or to the pilot burner and main burner, when the supervised flame or ignition source is not proved

3.23**ignition system timings**

a) **flame-establishing period**

period of time between initiation of gas flow and proof of the supervised flame or between the proof of supervised flame and initiation of gas flow. This may be applicable to proof of the ignition source or main burner flame, or both;

b) **ignition activation period**

period of time between energizing the main gas valve and deactivation of the ignition means prior to the lockout time;

c) **lockout time**

period of time between the initiation of gas flow and the action to shut off the gas flow in the event of failure to establish proof of the supervised ignition source or the supervised main burner flame. Reinitiating the lighting sequence requires a manual operation;

- d) **maximum time**
maximum allowable time for the specified function of any device;
- e) **purge time**
period of time intended to allow for the dissipation of any unburned gas or residual products of combustion
 - 1) **pre-purge time**
purge time which occurs at the beginning of a burner operating cycle prior to initiating ignition;
 - 2) **post-purge time**
purge time which occurs at the end of a burner operating cycle;
- f) **recycle time**
period of time between shutoff of the gas supply following loss of the supervised ignition source or the supervised main burner flame and reactivation of the ignition source

3.24

insulation

- a) **basic**
insulation to provide basic protection against electric shock
- b) **double**
insulation comprising both basic insulation and supplementary insulation
- c) **functional**
insulation that is necessary only for the correct functioning of the equipment
- d) **reinforced**
single insulation system which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this standard

NOTE 1 Functional insulation by definition does not protect against electric shock. It may, however, reduce the likelihood of ignition and fire.

NOTE 2 The term "insulation system" does not imply that the insulation should be in one homogenous piece. It may comprise several layers which cannot be tested as supplementary insulation or basic installation.

3.25

interlock

control to prove the physical state of a required condition and to furnish that proof to the safety shutoff device circuit

3.26

joints

points of connection between heat transfer surfaces, between positive and negative pressure zones within components of the fuel cell power system, and between fuel cell power system components

3.27

labelled

equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labelled equipment or materials and by whose labelling the manufacturer indicates compliance with appropriate standards or performance in a specified manner

3.28

limited current circuit

see 3.3

**3.29
listed**

equipment or materials included in a list published by a nationally recognized testing laboratory, inspection agency, or other organizations concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials, whose listing states either that the equipment or material meets nationally recognized standards or has been tested and found suitable for use in a specified manner

**3.30
load, normal**

maximum load that is connected to the mains for systems that utilize an external mains power source to idle, start, or maintain operation of the power system

**3.31
lock-out time, flame failure**

period of time between the signal indicating absence of flame and lock-out

**3.32
main burner**

device or group of devices essentially forming an integral unit for the final conveyance of gas or a mixture of gas and air to the combustion zone, and on which combustion takes place to accomplish the function for which the equipment is designed

**3.33
manifold**

conduit which supplies gas to or collects it from the fuel cell or the fuel cell stack

**3.34
materials****a) combustible**

when pertaining to materials adjacent to, or in contact with, heat-producing appliances, vent connectors, gas vents, steam and hot water pipes, and warm air ducts, those materials made of or surfaced with wood, compressed paper, plant fibres, or other materials that are capable of being ignited and burned. Such materials shall be considered combustible even though flame-proofed, fire-retardant treated, or plastered

b) non-combustible

for the purposes of this standard, materials which are not capable of being ignited and burned, such as materials consisting of, or a combination of, steel, iron, brick, tile, concrete, slate, asbestos, glass and plaster

**3.35
maximum allowable working pressure**
see 3.63**3.36
maximum operating pressure**
see 3.39**3.37
normal load**
see 3.30**3.38
normal operating conditions**
operation of the fuel cell power system under normal conditions, in particular:

- nominal (rated) power output with respect to voltage and current;
- nominal thermal energy output with respect to temperature and cooling media flow (if applicable);
- nominal temperature range of the all subsystems of the fuel cell power system;
- nominal fuel composition;
- nominal flows of anode and cathode media;
- nominal pressure ranges in all fluids within the power system;
- change of power output (electrical and thermal) within the nominal ranges defined in the manufacturer's specification;

unless otherwise stated, the entire fuel cell system is operated within 2 % of the rated input voltage and frequency and within 5 % of the rated fuel consumption when operated at rated output conditions, as specified by the manufacturer. Tolerances for the other values should be specified by the manufacturer

NOTE Deviations from these nominal operating conditions are defined as abnormal operating conditions.

3.39

operating pressure, maximum (MOP)

highest gauge pressure of a component or system that is expected during normal operation including starts, stops and transients

3.40

passive state

state for the fuel cell power system internal components normally entered when the fuel cell power system is purged with steam, air or nitrogen, or according to the manufacturer's instructions when the fuel cell power system is turned off, or prior to when the fuel cell power system is turned on (initialization)

3.41

pilot

small gas flame used to ignite the gas at the main burner

a) **continuous**

pilot that burns without turndown throughout the entire time the burner is in service, whether the main burner is firing or not;

b) **expanding**

continuous pilot that is automatically expanded so as to reliably ignite the main burner. This pilot may be turned down at the end of the main burner flame-establishing period;

c) **intermittent**

pilot which is automatically lighted each time there is a signal for initialization. It burns during the entire period that the main burner is firing;

d) **interrupted**

pilot which is automatically lighted each time there is a signal for initialization. The pilot fuel is cut off automatically at the end of the main burner flame-establishing period;

e) **proved**

a pilot flame supervised by a primary safety control

3.42

pipng system

all piping, valves and fittings used to connect gas utilization equipment to the point of delivery

3.43**pluggable equipment type A**

equipment which is intended for connection to the building installation wiring via a non-industrial plug and socket-outlet or a non-industrial appliance coupler, or both

3.44**port**

any opening in a burner head through which gas or gas-air mixture is discharged for ignition

3.45**power system**

packaged, self-contained, automatically operated assembly of integrated systems for generating useful electrical energy and recoverable thermal energy

3.46**primary circuit**

see 3.4

3.47**purge**

freeing a gas conduit of air, gas or a mixture of air and gas

3.48**reformer**

vessel within which fuel gas and other gaseous recycle stream(s) (if present) are reacted with water vapour and heat, usually in the presence of a catalyst, to produce hydrogen rich gas for use within the fuel cell power system

3.49**regulator, draft**

device which functions to maintain a desired draft in the equipment by automatically reducing the draft to the desired value

3.50**secondary circuit**

see 3.7

3.51**SELV circuit**

see 3.6

3.52**specific gravity**

ratio of the weight or mass of a given volume of a substance to that of an equal volume of another substance (air for gases, water for liquids and solids) used as a standard, both measured under the same conditions

3.53**stop**

fixed point on a control, such as a temperature limit control, which prevents the adjustment of the control beyond the stop point

3.54**thermal equilibrium conditions**

stable temperature conditions indicated by temperature changes of no more than 3 K (5° F) or 1 % of the absolute operating temperature, whichever is higher between two readings 15 min apart

3.55**TNV circuit**

see 3.8

3.56

vent

passageway or conduit for conveying products of combustion from gas utilization equipment, or their vent connectors, to the outside atmosphere

3.57

vent connector

that portion of the venting system which connects the flue outlet of gas utilization equipment to the gas vent or single-wall metal pipe

3.58

vent gases

products of combustion from gas utilization equipment plus excess air, plus dilution air in the venting system above the draft regulator or similar device

3.59

vent terminal (vent cap)

fitting at the end of the vent pipe that directs the flue products into the outside atmosphere

3.60

ventilation

natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space

3.61

venting system

gas vent or single-wall metal pipe, and vent connector if used, assembled to form a continuous open passageway from the flue collar of gas utilization equipment to the outside atmosphere for the purpose of removing vent gases

3.62

voltage, hazardous

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

[IEC 60950]

3.63

working pressure, maximum allowable (MAWP)

highest gauge pressure of the working fluid (gas or liquid) to which the process equipment or system is rated with consideration for initiating fault management above normal operation

NOTE A margin is usually provided between the MOP and set-points of pressure relief devices which are set at, or below, the MAWP.

4 Safety requirements and protective measures

4.1 General safety strategy

The manufacturer shall ensure that

- all foreseeable hazards, hazardous situations and events associated with the fuel cell power systems throughout their anticipated lifetime have been identified;
- 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 according to ISO 14121, IEC 61882, IEC 60300-3-9, or IEC 61511-3 as applicable, or equivalent;

- the two factors which determine each one of the estimated risks (probability and severity) have been eliminated or reduced as far as possible during the design including reasonably foreseeable misuse (inherently safe design and construction);
- the necessary protection measures in relation to risks that are not or cannot be eliminated have been taken (provision of warning and safety devices);
- users are informed of any additional safety measures that they may be required to implement.

Based on the quantity of fuel and other stored energy (for example, flammable materials, pressurized media, electrical energy, mechanical energy, etc.) in the fuel cell systems, there is a need to eliminate potential hazards. The general safety strategy for the fuel cell systems shall be established according to the following sequence:

- eliminate hazards to outside the fuel cell system, when such energy is released nearly instantaneously; or
- passively control (for example, burst disks, release valves, thermal cut-off devices) such forms of energy to ensure a release without endangering the ambient; or
- actively control such forms of energy (for example, by electronic control equipment included in the fuel cell system, which enforces adequate countermeasures based on the evaluation of sensor signals). In this case, the remaining risk due to failures in such control equipment shall be investigated in detail. Guidance for safety critical components can be found in IEC 61508; or
- provide appropriate safety markings, concerning the remaining risks of hazards.

Using the techniques described above, special care shall be taken to address the hazards listed in Annex A.

4.1.2 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 safety of the system.

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

4.1.3 Behaviour at normal and abnormal operating conditions

The fuel cell system shall be manufactured in such a way that it withstands all normal operating conditions as defined by the manufacturer's specification without any damage. In case of foreseeable abnormal operating conditions, the fuel cell system shall be manufactured and designed taking into consideration 4.1.

4.2 Physical environment and operating conditions

4.2.1 General

The fuel cell power system and protective systems shall be so designed and constructed as to be capable of performing their intended function in the physical environment and operating conditions specified in 4.2.2 to 4.2.8.

4.2.2 Electrical power input

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

4.2.3 Physical environment

The manufacturer shall specify the physical environment conditions for which the fuel cell power system is suitable. Consideration should be given to

- indoor/outdoor use;
- the altitude above sea-level up to which the fuel cell power system shall be capable of operating correctly;
- the range of air temperatures and humidity within which the fuel cell power system shall be capable of operating correctly;
- the seismic zone where it may be sited.

4.2.4 Fuel input

The fuel cell power system should be designed to operate correctly with the composition limits and supply characteristics of the fuels for which its design is intended (for example, pipeline natural gas). In the user's manual, the manufacturer shall specify the composition limits and supply characteristics of the fuels to be used in the fuel cell power system.

4.2.5 Water input

The quality and supply characteristics of the water to be used in the fuel cell power systems shall be specified by the manufacturer.

4.2.6 Vibration, shock and bump

The undesirable effects of vibration, shock and bump (including those generated by the machine and its associated equipment and those created by the physical environment) shall be avoided by the selection of suitable equipment, by mounting it away from the fuel cell power system, or by the use of anti-vibration mountings. This does not include the effects of seismic shock, which shall be addressed separately if the manufacturer deems it appropriate for its product (see 4.2.3).

4.2.7 Handling, transportation, and storage

The 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 within a range of $-25\text{ }^{\circ}\text{C}$ to $+55\text{ }^{\circ}\text{C}$ and for short periods not exceeding 24 h at up to $+70\text{ }^{\circ}\text{C}$. Alternative temperature ranges may be specified by the manufacturer.

The fuel cell power system or each component part thereof shall

- be capable of being handled and transported safely, when necessary, be provided with suitable means for handling by cranes or similar equipment;
- be packaged or designed so that it can be stored safely and without damage (for example, adequate stability, special supports, etc.).

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

4.2.8 System purging

Means shall be provided in fuel cell systems to purge where for safety reasons a passive state is required after shutdown or prior to startup, as specified by the manufacturer. A suitable purge system utilizing a medium specified by the manufacturer such as, but not limited to, nitrogen, air or steam in a non-hazardous situation within the intended use may be used.

4.3 Selection of materials

All materials shall be suitable for the intended purpose.

4.3.1 When materials used to construct the fuel cell power system are known to pose hazards under certain circumstances, the manufacturer shall implement the measures and provide the information necessary to sufficiently minimize the risk of endangering persons' safety or health.

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

4.3.3 Metallic and non-metallic materials used to construct internal or external parts of the fuel cell power system, in particular those exposed directly or indirectly to moisture or that contain process gas or liquid streams as well as all parts and materials used to seal or interconnect the same, for example, welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable within the scheduled lifetime of the equipment and for all test conditions; in particular,

- they shall retain their mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) when exposed to the full range of service conditions and lifetime as specified by the manufacturer;
- they shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation; the chemical and physical properties necessary for operational safety shall not be significantly affected within the scheduled lifetime of the equipment unless replacement is foreseen; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, aging resistance, the effects of temperature variations, the effects arising when materials are put together (for example, galvanic corrosion), the effects of ultraviolet radiation, and to the degradation effects of hydrogen on the mechanical performance of a material. Guidance to account for the degradation effects of hydrogen on the mechanical performance of a material can be found in ISO/TR 15916 and Annex B.

4.3.4 Where conditions of erosion, abrasion, corrosion or other chemical attack may arise, adequate measures shall be taken to

- minimize that effect by appropriate design, for example, additional thickness, or by appropriate protection, for example, use of liners, cladding materials or surface coatings, taking due account of the intended and reasonably foreseeable use;
- permit replacement of parts which are most affected;
- draw attention, in the instructions referred to in 7.4.5, to the type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement.

4.4 General requirements

4.4.1 In so far as their purpose allows, accessible parts of the fuel cell power system shall have no sharp edges, no sharp angles, and no rough surfaces likely to cause injury.

4.4.2 The fuel cell power system or parts of it where persons are liable to move about or stand shall be designed and constructed to prevent persons slipping, tripping or falling on or off these parts.

4.4.3 The fuel cell power system, components and fittings thereof shall be so designed and constructed that they are stable enough, under the foreseen operating conditions (if necessary taking climatic conditions into account) for use without risk of overturning, falling or unexpected movement. Otherwise, appropriate means of anchorage shall be incorporated and indicated in the instructions.

4.4.4 The moving parts of the fuel cell power system shall be designed, built and laid out to avoid hazards or, where hazards persist, fixed with guards or protective devices in such a way as to prevent all risk of contact which could lead to accidents.

4.4.5 The various parts of the fuel cell power system and their linkages shall be so constructed that, when used normally, no instability, distortion, breakage or wear likely to impair their safety can occur.

4.4.6 The fuel cell power system shall be so designed, constructed and/or equipped that risks due to gases, liquids, dust, or vapors released during the operation or maintenance of a fuel cell power system, or used in its construction can be avoided.

4.4.7 All parts shall be securely mounted or attached and rigidly supported. The use of shock-mounts is permitted when suitable for the application.

4.4.8 All safety shutdown system components whose failure may result in a hazardous event, as identified by the reliability/safety analysis noted in 4.9.1, shall be recognized, certified or separately tested for their intended usage.

4.4.9 Risk of injury caused by contact with, or proximity to, external surfaces of the appliance enclosure, handles, grips, or knobs at high temperatures.

- a) The manufacturer shall take steps to eliminate any risk of injury caused by contact with, or proximity to, external surfaces of the fuel cell power system enclosure, handle, grips, or knobs at high temperatures.

If external surfaces of the fuel cell power system's enclosure, handles, grips, knobs, or similar parts may be contacted by users without personal protective equipment while the fuel cell system is in operation, the manufacturer shall either limit the temperature of these surfaces according to Table 1 or the manufacturer shall fix guards or protective devices in such a way as to prevent risk of contact that could lead to accidents.

Table 1 – Allowable surface temperatures

Part	Temperature rise °C
External enclosures, except handles held in normal use	60
Surfaces of handles, knobs, grips and similar parts which are held for short periods only in normal use	
- of metal	35
- of porcelain	45
- of moulded material (plastic), rubber or wood	60

Maximum surface temperature rises above ambient of external surfaces that may be contacted during operation by people without personal protective equipment. The above values are referenced in Table 3 of IEC 60335-1.

- b) The temperatures on walls, floor and ceiling adjacent to a stationary fuel cell power system shall not exceed 50 °C above ambient temperature under the test conditions of 5.13b).

4.4.10 The fuel cell power system shall be so designed and constructed that the emission of airborne noise is reduced to a level suited for the intended use or location in compliance with applicable regional or national airborne noise codes and standards.

4.4.11 The fuel cell power system exhaust to atmosphere, under normal steady-state operating conditions, shall not contain concentrations of carbon monoxide in excess of 300 ppm in an air-free sample of the effluents, which is a sample that has its effluent CO concentration mathematically corrected as though there was zero per cent excess air.

4.4.12 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.

4.4.13 The maximum temperatures of components and materials, as installed in the fuel cell power system, shall not exceed their temperature ratings.

4.4.14 The manufacturer shall give consideration to the suitability of the fuel cell power system to operate where contaminants (for example, dust, salt, smoke, and corrosive gases) are present in the physical environment.

4.4.15 The fuel cell power system enclosure shall be designed to safely contain any anticipated hazardous liquid leaks (see 4.5.2f) for liquid fuel). The containment means shall have a capacity of 110 % of the maximum volume of fluid anticipated to leak.

4.5 Pressure equipment and piping

4.5.1 Pressure equipment

Pressurized vessels, such as reactors, heat exchangers, gas-fired tube heaters and boilers, electric boilers, coolers, accumulators and similar containers, and associated pressure relief mechanisms, such as relief valves and similar devices, shall be constructed and marked in accordance with applicable regional or national pressure equipment codes and standards. ISO 16528 provides information concerning pressure equipment standards.

Vessels that, in accordance with the applicable regional or national pressure equipment codes and standards, do not qualify as “pressure vessels”, such as tanks and similar containers, shall be constructed of suitable materials in accordance with 4.3 and shall meet the applicable requirements of 4.4. Such vessels, and their related joints and fittings, shall be designed and constructed with adequate strength for functionality and leakage resistance to prevent unintended releases.

4.5.2 Piping systems

Piping and its associated joints and fittings shall conform to the applicable sections of ISO 15649.

Piping systems designed for internal gauge pressure at or above zero but less than 105 kPa, handling fluids that are non-flammable, non-toxic and not damaging to human tissue and having a design temperature from -29°C through 186°C are not included in the scope of ISO 15649. Piping systems under these conditions shall be constructed of suitable materials in accordance with 4.3 and shall meet the applicable requirements of 4.4. Such pipes, and their related joints and fittings, shall be designed and constructed with adequate strength for functionality and leakage resistance to prevent unintended releases.

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

- a) Materials shall meet the requirements specified in 4.3.
- b) The internal surfaces of piping shall be thoroughly cleaned to remove loose particles, and the ends of piping shall be carefully reamed to remove obstructions and burrs.
- c) If fluid condensate or sediment accumulation inside gaseous fluid piping could cause damage from water hammer, vacuum collapse, corrosion and uncontrolled chemical reactions during startup, shutdown and/or use, the manufacturer shall provide means for drainage and removal of deposits from low areas and for access during cleaning, inspection and maintenance. In particular, the manufacturer shall take measures to ensure against sediment or condensate accumulation in fuel gas controls. Sediment traps or filters shall be installed or adequate guidelines shall be provided in the product's technical documentation.
- d) The manufacturer shall take measures to ensure against sediment accumulation in liquid fuel controls. Sediment traps or filters shall be installed or adequate guidelines shall be provided in the technical documentation of the product.
- e) Non-metallic piping used to convey combustible gases shall be protected against the possibility of overheating. Measures as required by the safety and reliability analysis specified in 4.1.2 shall be provided to prevent the temperature of components conveying combustible gases from surpassing their design temperatures.
- f) Liquid fuel cell power systems shall include provisions for capturing, recycling, or safe disposal of released liquid fuel. Drip pans, spill guards, or double-walled pipe shall be designed to prevent uncontrolled releases.

4.5.3 Flue gas venting systems

The fuel cell power system shall be provided with a vent system to convey products of combustion from fuel utilization equipment to the outside atmosphere. This requirement may be exempted by installation standards for small (less than 10 kW net electrical output) fuel cell power systems. The manufacturer shall design and construct the vent pipe, or provide in the product's technical documentation instructions to design and construct the vent pipe, in compliance with the following requirements.

- a) Materials shall meet the requirements specified in 4.3. In particular, the venting system shall be constructed of material resistant to corrosion by condensate. Non-metallic material shall be judged on its temperature limitation, strength and resistance to the action of condensate.
- b) The venting system parts of a fuel cell power system shall be durable. Venting system parts, including parts within the fuel cell power system, shall not break, disassemble or become damaged to the extent that they permit unsafe fuel cell power system operation.

- c) The vent pipe shall be properly supported and shall be provided with a rain cap or other feature that would not limit or obstruct the gas flow from venting vertically upward.
- d) A means, such as drainage, shall be provided to prevent water, ice and other debris from accumulating inside the vent pipe or obstructing the vent pipe.
- e) Vent pipe exhausts shall be located outdoors in a safe location, away from user areas, ignition sources, air intakes, building openings and overhangs.
- f) A venting system for a fuel cell power system shall be leak-tight.
- g) The exhaust outlet collar shall be of such size as to accommodate a vent connector of standard diameter that is commercially available or to accommodate a conduit as specified in the manufacturer's installation instructions.
- h) Pressure switches used to prove exhaust gas flow, if used, shall be factory set, or at the manufacturer's discretion, be set by authorized personnel at the construction site. The adjustment means shall then be locked. A pressure switch shall bear a marking indicating clearly the appliance manufacturer's or distributor's part number or appropriate documentation which correlates to the locked pressure setting.
- i) Parts of a pressure switch in contact with exhaust gas condensate shall be corrosion-resistant to exhaust gas condensate at the normal operating temperatures.
- j) The fuel cell power system shall be capable of starting up and shall not shut down when the vent system is exposed to a 116 Pa static pressure or 134,5 Pa velocity pressure (54 km/h wind velocity) according to the tests in 5.14.
- k) When the fuel cell power system is provided with a venting system, the average temperature of the exhaust gases conveyed by that venting system shall not exceed temperatures acceptable for the materials used to construct the venting system.

4.5.4 Gas-conveying parts shall comply with the following condition.

Gas passage shall have gas-tightness, so that the tightness shall not be undermined under ordinary transportation, installation, and use.

4.6 Protection against fire or explosion hazards

4.6.1 Prevention against fire and explosion hazards in fuel cell power systems provided with cabinets

- a) The integrated systems of the fuel cell power system shall be assembled so as to prevent hazards associated with flammable atmosphere accumulations within the fuel cell power system.
- b) The boundary for dilution of normal internal releases to below 25 % LEL (LFL for hydrogen) may be determined by computational fluid dynamic analysis, tracer gas, or similar methods, such as those given in IEC 60079-10. All devices installed within dilution boundaries shall meet the requirements specified in e). The volume within dilution boundaries shall be classified according to IEC 60079-10. The LFL of typical gases are provided in IEC 60079-20.
- c) Cabinet compartments with internal sources of flammable gas/vapour release are defined as fuel compartments. Fuel compartments shall be designed to
 - maintain gas mixtures below 25 percent LEL (LFL for hydrogen), except in dilution boundaries; and
 - limit the extent of dilution boundaries to within the fuel compartment.