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Functions concerned
Fonctions concernées

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Title : IEC 62282-3-1 Ed.1: Fuel cell technologies - Part 3-1: Stationary fuel cell power systems - Safety

Note d'introduction

Introductory note

ATTENTION	ATTENTION
CDV soumis en parallèle au vote (CEI) et à l'enquête (CENELEC)	**Parallel IEC CDV/CENELEC Enquiry**

IEC 62282-3

April 20, 2005 Draft

TC 105 Fuel Cell Technologies

Working Group #3

Stationary Fuel Cell Power Systems – Safety

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Foreword

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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 the 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 National Committees.

3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.

   In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

   The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.

   Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

   International Standard IEC 62282-3 has been prepared by IEC technical committee 105: Fuel cell technologies.

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

FDIS	Report on voting
105/XX/FDIS	105/XX/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.

   IEC 62282 consists of the following parts under the general title *Fuel cell technologies*:

   Part 1: Terminology

   Part 2: Fuel cell modules

   Part 3: Stationary Fuel Cell Power Systems - Safety

   Other parts are under consideration.

The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be reconfirmed; withdrawn; replaced by a revised edition, or amended.

A bilingual version of this publication may be issued at a later date.

1. Scope

1.1 This document 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.

1.2 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.

1.3 This standard applies to

- Systems intended for electrical connection to mains directly or with a transfer switch, or to a stand-alone power distribution system.
- Systems intended to provide AC or DC 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, e.g. landfill gas, digester gas, coal mine gas.

  b) Fuels derived from oil refining, e.g. 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, e.g. methanol, ethanol, di-methyl ether, biodiesel.

  d) Hydrogen, gaseous mixtures containing hydrogen gas, e.g. synthesis gas, town gas.

1.4 This standard does not cover:

- Portable fuel cell power systems.
- Propulsion fuel cell power systems.

1.5 A typical stationary fuel cell power system is represented in figure 1.

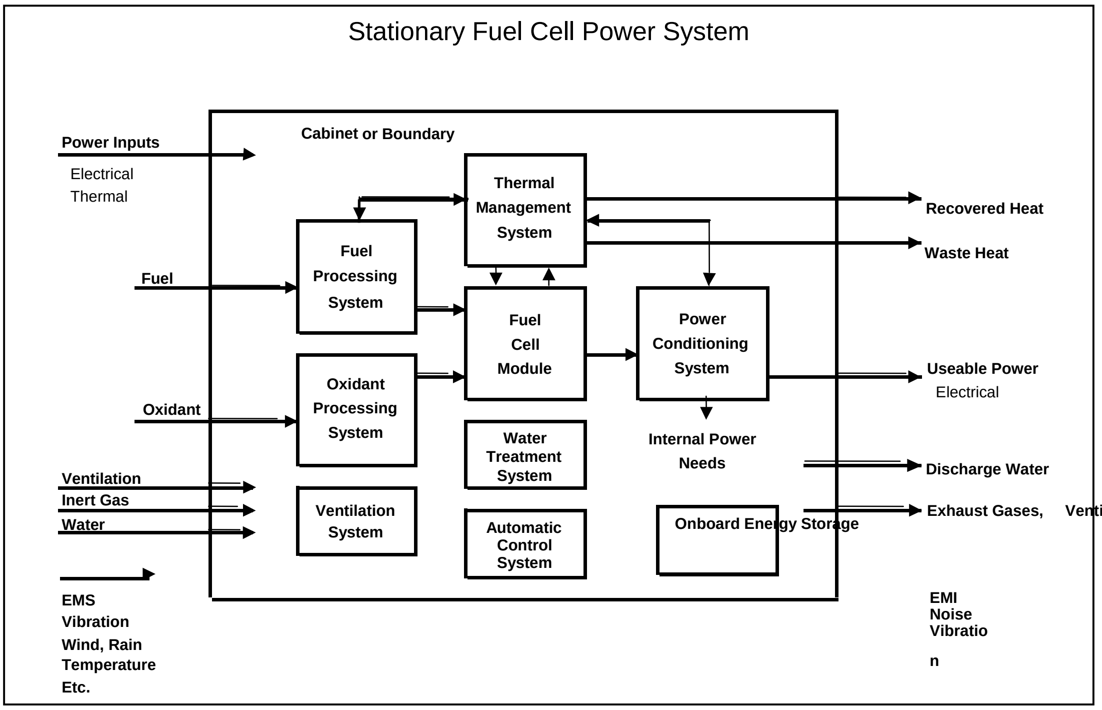


Figure 1. Stationary Fuel Cell Power Systems

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 produced 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 -** The 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 -** An assembly of cells, separators, cooling plates, manifolds and a supporting structure that electrochemically coverts, typically, hydrogen rich gas and air reactants to dc 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

1.6 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.

1.7 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 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.

1.8 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

This standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication applies.

IEC 60034 Rotating electrical machines

IEC 60034-1 Rotating electrical machines - Part 1: Rating and performance

IEC 60034-5 Rotating electrical machines - Part 5: Classification of degrees of protection provided by enclosures of rotating electrical machines

IEC 60068-2-18 Environmental Testing - Part 2 – 18: Tests – Test R and Guidance: Water

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

IEC 60146 Semiconductor convertors

IEC 60146-1-1 Semiconductor convertors - General requirements and line commutated convertors Part 1-1: Specifications of basic requirements

IEC 60204-1 Electrical Equipment of Industrial Machines - Part 1: General requirements

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

IEC 60335-2-41 Household and similar electrical appliances - Safety - Part 2-41: Particular requirements for pumps

IEC 60335-2-51 Household and similar electrical appliances - Safety - Part 2-41: Particular requirements for pumps

IEC 60364-4-41 Electrical protection of buildings - Part 4: Protection for safety - Chapter 41: Protection against electric shock

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 60439-1 Low voltage switchgear and control gear assemblies - Part 1: Type-tested and partially type-tested assemblies

IEC 60529 Degrees of protection provided by enclosures

IEC 60704-3 Test Code for the Determination of Airborne Acoustical Noise Emitted by Household and Similar Electrical Appliances Part 3: Procedure for Determining and Verifying Declared Noise Emission Values First Edition; CENELEC EN 60704-3

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

IEC 60730-2-9 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 Information technology equipment - Safety - Part 1: General requirements

IEC 61000-Series: Electromagnetic compatibility (EMC)

IEC 61025 Fault tree analysis (FTA)

IEC 61131-1 Programmable controllers – Part 1: General information

IEC 61131-2 Programmable controllers – Part 2: Equipment required and tests

IEC 61140 Protection against electric shock - Common aspects for installation and equipment

IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems

IEC 61511 Functional Safety: Safety Instrumented for the Process Industry Sector - Part 3: Guidelines in the Application of Hazard and Risk Analysis

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 62086-2 Electrical apparatus for explosive gas atmospheres - Electrical resistance trace heating - Part 2: Application guide for design, installation and maintenance

IEC 62282-1 Fuel cell technologies - Part 1: Terminology

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 plants - Tests methods for the performance

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

ISO 3864 Safety colors and safety signs

ISO 4413 Hydraulic fluid power - General rules relating to systems

ISO 4414 Pneumatic fluid power - General rules relating to systems

ISO 4898 Labeling and marking of products

ISO 5388 Stationary air compressors

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 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 16110 Hydrogen generators using fuel processing technologies - Part 1: Safety

ISO TS 16528 Boilers and pressure vessels - Registration of codes and standards to promote international recognition

3. Terms and Definitions

3.1 ACCESSIBLE.

1. Operator access area. An 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. The terms "access" and "accessible", unless qualified, relate to operator access area as defined above.
2. Service access area. An area, other than an operator access area, where it is necessary for service persons to have access with the equipment switched on.

3.2 CIRCUIT, ELV. A *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]. Extra Low Voltage Circuit abbreviated is ELV Circuit.

3.3 CIRCUIT, LIMITED CURRENT. A 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. A circuit which is directly connected to the AC mains supply. It includes, for example, the means for connection to the AC mains supply, the primary windings of transformers, motors and other loading devices [IEC 60950].

3.5 CIRCUIT, SAFETY-CONTROL. A 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, SECONDARY. A 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].

3.7 CIRCUIT, SELV. A *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]. Safety Extra Low Voltage Circuit abbreviated is SELV Circuit.

3.8 CIRCUIT, TNV. A 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, clause 1.2.8.8 for specific limits]. Telecommunications Network Voltage Circuit abbreviated is TNV Circuit.

3.9 CLASS I EQUIPMENT. Equipment where protection against electric shock is achieved by:

a. using basic insulation, and also
b. providing a means of connection to the protective earthing conductor in the building wiring 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. The maximum operational pressure, which the fuel cell systems or portions of it are designed for.

3.11 EFFLUENT. The products of combustion plus the excess air being discharged from gas utilization equipment (also see Flue Gases).

3.12 ELECTRICAL EQUIPMENT. See EQUIPMENT, ELECTRICAL.

3.13 ELV CIRCUIT. See CIRCUIT, ELV.

3.14 EQUIPMENT, ELECTRICAL. A 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 LOCK-OUT TIME, FLAME FAILURE.

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 FUEL GAS CONTROLS. See CONTROLS, FUEL GAS.

3.18 GAS VENT. A 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 (also see Vent).

3.19 HAZARDOUS LOCATION. See LOCATION, HAZARDOUS.

3.20 HAZARDOUS VOLTAGE. See VOLTAGE, HAZARDOUS.

3.21 HEAT EXCHANGER. A vessel in which heat is transferred from one medium to another.

3.22 IGNITER. A device which utilizes electrical energy to ignite gas at a pilot burner or main burner.

3.23 IGNITION, AUTOMATIC. Ignition of gas at the burner when the gas controlling device is turned on, including reignition if the flames on the burner have been extinguished by means other than by the closing of the gas controlling device.

3.24 IGNITION DEVICE.

1. A device for igniting gas at a burner. It may be a pilot or an igniter.
2. Direct. An igniter utilized to ignite gas at a main burner.

3.25 IGNITION SYSTEM, AUTOMATIC. A system designed to ignite and reignite a main burner. Such systems shall:

1. Prove the presence of either the ignition source or main burner flame, or both,
2. Automatically ignite gas at the main burner or at the pilot burner so that the pilot can ignite the main burner, and
3. 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.

3.26 IGNITION SYSTEM TIMINGS.

1. Flame-Establishing Period. The 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.
2. Ignition Activation Period. The period of time between energizing the main gas valve and deactivation of the ignition means prior to the lockout time.
3. Lockout Time. The period of time between 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.
4. Maximum Time. The maximum allowable time for the specified function of any device.
5. Purge Time. The period of time intended to allow for the dissipation of any unburned gas or residual products of combustion.
    a. Pre-purge Time. The purge time which occurs at the beginning of a burner operating cycle prior to initiating ignition.
    b. Post-purge Time. The purge time which occurs at the end of a burner operating cycle.
6. Recycle Time. The 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.

3.27 INSULATION.

1. Basic. Insulation to provide basic protection against electric shock.
2. Double. Insulation comprising both basic insulation and supplementary insulation.
3. Functional. Insulation that is necessary only for the correct functioning of the equipment.
4. Reinforced. A single insulation system which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this standard.

Notes:

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

b. The term "insulation system" dos not imply that the insulation has to be in one homogenous piece. It may comprise several layers which cannot be tested as supplementary insulation or basic installation.

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

3.29 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.

3.30 LABELED. 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 labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.31 LIMITED CURRENT CIRCUIT. See CIRCUIT, LIMITED.CURRENT.

3.32 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.

3.33 LOAD, NORMAL. The 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.

3.34 LOCK-OUT TIME, FLAME FAILURE. The period of time between the signal indicating absence of flame and lock-out

3.35 MAIN BURNER. A 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.

3.36 MANIFOLD. A conduit which supplies gas to or collects it from the fuel cell or the fuel cell stack..

3.37 MATERIALS.

1. Combustible. As 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, shall mean materials made of or surfaced with wood, compressed paper, plant fibers, 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.
2. Noncombustible. For the purpose 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.

3.38 MAXIMUM OPERATING PRESSURE. See OPERATING PRESSURE, MAXIMUM.

3.39 NORMAL LOAD, See LOAD, NORMAL.

3.40 NORMAL OPERATING CONDITIONS. Normal operating conditions are the operation of the fuel cell power system und 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, and
- Rate of change of power output (electrical and thermal) within the nominal ranges defined in the manufacturer’s specification.

Tolerances to the given nominal values shall be in accordance to ISO 16110-1, clause 5.3.

- Unless otherwise stated, the entire fuel cell system shall be operated within 2 percent of the rated input voltage and frequency; and
- Within 5 percent of the rated fuel consumption when operated at rated output conditions, as specified by the manufacturer.
- Tolerances for the other values are to be specified by the manufacturer.

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

OPERATING PRESSURE, MAXIMUM. The maximum pressure, specified in gage pressure by the manufacturer, of a component or system at which it is designed to operate continuously.
Note: Includes all normal operation; both steady state and transient.

3.41 PASSIVE STATE. A 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 per 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).

3.42 PILOT. A small gas flame used to ignite the gas at the main burner.

1. Continuous. A pilot that burns without turndown throughout the entire time the burner is in service, whether the main burner is firing or not.
2. Expanding. A 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.
3. Intermittent. A 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.
4. Interrupted. A 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.
5. Proved. A pilot flame supervised by a primary safety control.

3.43 PIPING. As applied to this standard, either pipe or tubing, or both.

1. Pipe. Rigid conduit of iron, steel, copper, brass or aluminum.
2. Tubing. Semi-rigid conduit of steel, copper or aluminum.

3.44 PIPING SYSTEM. All piping, valves and fittings used to connect gas utilization equipment to the point of delivery.

3.45 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.

3.46 PORT. Any opening in a burner head through which gas or gas-air mixture is discharged for ignition.

3.47 POWER SYSTEM. A packaged, self-contained, automatically-operated assembly of integrated systems for generating useful electrical energy and recoverable thermal energy.

3.48 PRESSURE (PRESSURIZED) VESSEL. See VESSEL, PRESSURE.

3.49 PRIMARY CIRCUIT. See CIRCUIT, PRIMARY.

3.50 PURGE. To free a gas conduit of air, gas or a mixture of air and gas.

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

3.52 REGULATOR, DRAFT. A device which functions to maintain a desired draft in the equipment by automatically reducing the draft to the desired value.

3.53 SECONDARY CIRCUIT. See CIRCUIT, SECONDARY.

3.54 SELV CIRCUIT. See CIRCUIT, SELV.

3.55 SPECIFIC GRAVITY. The 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.

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

3.57 TNV CIRCUIT, See CIRCUIT, TNV.

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

3.59 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.

3.60 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.

3.61 VENT TERMINAL (VENT CAP). The fitting at the end of the vent pipe that directs the flue products into the outside atmosphere.

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

3.63 VENTING SYSTEM. The 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.

3.64 VOLTAGE, HAZARDOUS. A 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].

3.65 WORKING PRESSURE, ALLOWABLE. The maximum gauge pressure at which a part or system may be operated in accordance with the provisions of this standard. It is the pressure used in determining the setting of pressure-limiting/relieving devices installed to protect the part or system from accidental over-pressuring.

4. Safety Requirements and Protective Measures

4.1 General safety strategy

4.1.1 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 as per ISO 14121, IEC 61882, 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 (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 store energy (e.g. 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 outside the Fuel Cell System, when such energy is released nearly instantaneously, or
- passively control (e.g. 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 (e.g. 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 Appendix 1.

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 as per IEC 60812, IEC 61025, or equivalent.

4.1.3 Behavior at normal and abnormal operating conditions

The FUEL CELL SYSTEM shall be manufactured in 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 addressed using Section 4.1 “General Safety Strategy”.

4.2 Physical environment and operating conditions

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 4.2.1 to 4.2.7.

4.2.1 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.

4.2.2 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
- to the altitude above sea level up to which the fuel cell power system shall be capable of operating correctly,
- to the range of air temperatures and humidity within which the fuel cell power system shall be capable of operating correctly,
- to the seismic zone where it may be sited.

4.2.3 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 (e.g. pipeline natural gas). The manufacturer shall specify in the user manual the composition limits and supply characteristics of the fuels to be used in the fuel cell power system.

4.2.4 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.

4.2.5 Vibrations, shock and bump

Undesirable effects of vibrations, 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 4.2.2).

4.2.6 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 °C to +55 °C and for short periods not exceeding 24 h at up to +70 °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 (e.g. adequate stability, special supports, etc.).

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

Shipping labels and bar codes should meet requirements described in ISO 15394 (Packaging-Bar code and two-dimensional symbols for shipping, transport and receiving labels)

4.2.7 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, e.g. welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable within the scheduled lifetime of the equipment and for all test conditions; in particular:

- they shall retain their mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) 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 (e.g. galvanic corrosion), the effects of ultraviolet radiation, and to the degradation effects of hydrogen on a material’s mechanical performance. Guidance to account for the degradation effects of hydrogen on a material’s mechanical performance can be found in ISO TR 15916 and Appendix 2.

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, e.g. additional thickness, or by appropriate protection, e.g. 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 6.4.5, to type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement.

4.4 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 or equivalent 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 as per Table 4.1 or the manufacturer shall fix guards or protective devices in such a way as to prevent risk of contact that could lead to accidents.

Part	Temperature Rise (°K)
External enclosure of motor-operated appliances, except handles held in normal use	60
Surfaces of handles, knobs, grips and similar parts which are continuously held in normal use	
- of metal	30
- of porcelain	40
- of moulded material (plastic), rubber or wood	50
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

Table 4.1 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) Walls, Floor and Ceiling Temperatures
The temperatures on walls, floor and ceiling adjacent to a stationary fuel cell power system shall not exceed 50^{0}C above ambient temperature under the test conditions of section 5.15(b).

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 0% 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 (e.g. dust, salt, smoke, and corrosive gases) are present in the physical environment.

4.4.15 Any areas requiring access for production, adjustment and maintenance operations shall be designed and equipped to allow safe entry or access.

4.4.16 The fuel cell power system enclosure shall be designed to safely contain any anticipated hazardous liquid leaks. 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 TS 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 Section 4.3 and shall meet applicable requirements of Section 4.4. Such vessels, and their related joints and fittings, shall be designed and constructed with adequate strength and leakage resistance to prevent unintended releases.

4.5.2 Piping systems

Metallic, non-metallic, rigid and flexible piping and its associated joints and fittings shall conform to the applicable sections of ISO 15649.

Piping systems designed for internal gage 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 Section 4.3 and shall meet applicable requirements of Section 4.4. Such pipes, and their related joints and fittings, shall be designed and constructed with adequate strength 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 Section 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 start-up, 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 product’s technical documentation.

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 fueled 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 may be provided with a vent system to convey products of combustion from fuel utilization equipment to the outside atmosphere. 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 Section 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) If the effluent in the vent pipe system is susceptible to forming condensate, the vent pipe system for a fuel cell power system shall not leak.

h) 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 manufacturers' installation instructions.

i) 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 manufacturers' or distributors' part number or appropriate documentation which correlates to the locked pressure setting.

j) Parts of a pressure switch in contact with exhaust gas condensate shall be corrosion resistant to exhaust gas condensate at the normal operating temperatures.

k) The fuel cell power system shall be capable of starting up and shall not shutdown when the vent system is exposed to a 116 Pa static pressure or 134.5 Pa velocity pressure (54 km/h wind velocity) as per tests in Section 5.14.

l) 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 Material where gas goes through shall keep 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-percent 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 paragraph (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
- to limit the extent of dilution boundaries to within the fuel compartment.

d) Methods to maintain normal internal releases below 25-percent LEL (LFL for hydrogen), except in dilution boundaries, include:

(1) Controlled oxidation of normal internal releases

This may be accomplished by the provision of a continuous and reliable ignition and oxidant sources that ensures the combustion of the released gases (an example are component surface temperatures at or above 120% of the autoignition temperature measured in Kelvin) or the utilization of catalytic oxidation units.

The manufacturer shall ensure that the maximum credible release, when reacted produces pressures and temperatures that can be contained within the fuel compartment and tolerated by the components exposed to such conditions.

(2) Air dilution of normal internal releases

This may be accomplished by the provision of mechanical ventilation to dilute with air the concentration of normal releases to less than 25-percent LEL (LFL for hydrogen), except within dilution boundaries. In all cases the minimum ventilation rate shall be consistent with the allowable leakage rate test as per Section 5.4.

Ventilated fuel compartments shall be designed to operate at negative pressure relative to other types of compartments in the fuel cell power system and its surroundings (induced or exhaust ventilation) as per 60079-16. Proper operation of the ventilation system shall be confirmed by measuring either flow or pressure. Failure of ventilation shall cause a shutdown of the process equipment.

Alternatively, fuel compartments of fuel cell power systems need not be ventilated at negative pressures if adequate means are provided to limit the concentration of flammable gas below 25% LFL under all conditions of use except within dilution boundaries or as described in part (h) (abnormal releases).

Fuel compartments that rely on ventilation for protection against accumulation of flammable atmospheres shall be purged with at least 4 volume or purged such that the atmosphere will be brought below 25% of the LFL. The purging will take place prior to the energization of any devices that are not suitable for the area classification per paragraph (b) above. Purging is not required if the atmosphere within the compartment and associated ducts can be demonstrated by design to be non-hazardous. All devices, which must be energized prior to purging or in order to accomplish purging, shall meet the requirements specified in paragraph (e).

e) Within areas classified as hazardous as per paragraph (b), except for units that use the protection method described in (d1), the manufacturer shall eliminate ignition sources by ensuring that:

- the installed electrical equipment is suitable for the area classification as per IEC 60079-0 and other applicable parts of the IEC 60079 standards.
- the installed electrical resistance trace heating, if available, complies with IEC 62086-1.
- the surface temperatures do not exceed 80-percent of the auto-ignition temperature, expressed in degrees Celsius, of the flammable gas or vapour. See IEC 60079-20 for guidance regarding auto-ignition temperatures of various flammable fluids,
- the potential for static discharge has been eliminated by proper bonding and grounding as per IEC 60204-1, and by proper material selection.
- 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.

f) Compartments that contain electrical or mechanical equipment shall be maintained at positive pressure relative to adjacent compartments with sources of flammable gas or vapour as per IEC 60079-2, unless the equipment meet the requirements specified in paragraph (e).

g) The fuel cell power system shall be provided with passive and active means, or a combination thereof, to maintain abnormal internal releases below 25-percent LEL (LFL for hydrogen), except in dilution boundaries.

Sudden and catastrophic failures need not to be considered a release scenario in this analysis when protection against such failures has already been contemplated in the vessel and piping design (see also Section 4.5).

Passive means include, but are not limited to, the mechanical limitation of releases of flammable gases or vapours to a maximum value by using pipe orifices and similar methods of flow restriction or joints permanently secured and so constructed that they limit the release rate to a predictable maximum value.

Active means may include flow measurements and controls or the provision of safety devices such as combustible gas sensors. These means shall meet the requirements specified in Section 4.9 and shall cause a fuel cell power system shutdown upon occurrence of conditions under which the concentration of any flammable gas in the ventilation exhaust exceeds 25-percent of the LEL of that gas (LFL for hydrogen).

h) The fuel cell power system shall be designed for the safe dispersal of the ventilation and process exhaust streams. In particular, for indoor installations the ventilation and process exhaust shall be designed for connection to a flue or venting system as per Section 4.5.2.1.

i) Non-metallic tubing carrying hydrogen gas may accumulate electro-static charge along its exterior surface. Discharges from the external surface of this tube may be sufficient to ignite a flammable mixture of gas or vapour in the surrounding environment. When used in Zone 1 or Zone 2 locations, measures to eliminate electro-static discharges shall be taken. This may be achieved by specifying a tube material with sufficient conductivity, or by limiting gas flow velocity to values below which electro-static charge does not accumulate. Tubing that relies on a protective system to eliminate electrostatic discharge (i.e. a grounding wire or braid), shall not be used in a Zone 0 location.

   Note: Metal braid coverings, or conductive wires within the non-metallic tubing wall may increase the chance of electrostatic discharge if those conductors become disconnected from their bonding conductor. In Zone 1 and 2 areas, such conductors shall be mechanically secured with positive means.

4.6.2 Prevention of fire and explosion hazards in burners

a) Fuel cell power systems shall be designed such that the unsafe build up of flammable or explosive gases in burners (start, main and auxiliary burners of a reformer section, tail gas burners) is avoided.

b) The main burner shall be fitted with a pilot or a device for direct ignition.

c) The direct ignition device shall be controlled automatically and shall not cause deterioration of the burner. Direct ignition devices shall be positively positioned with respect to the main burner ports. Means shall be provided to prevent incorrect assembly or reversible mounting of any direct ignition device in relation to the burner being served.

d) Pilots shall be controlled automatically and direct ignition shall light any pilot fuel. Pilots shall be designed and fitted in such a way that they are located correctly in relation to the burners that they ignite. When a pilot is an integral part of the start burner, it need be evaluated only under the construction and performance specifications of this standard.

e) Automatic electrical burner control systems shall comply with requirements specified in Section 4.9.2.

f) The main burner or pilot flame, or both, shall be supervised by a flame detector. If a main burner is ignited by a pilot, the presence of flame at the pilot shall be detected before gas is released to the main burner. A system having an interrupted pilot shall provide supervision of the main burner flame following the main burner flame-establishing period.

g) Pilot flame supervision shall be only at a point where the pilot will effectively ignite fuel at the main burner even when the fuel supply to the pilot is reduced so the flame is just sufficient to actuate the primary safety control.

h) If the heat input of a pilot does not exceed 0.250 kW, there is no requirement for the flame establishing period.

i) If the heat input of a pilot exceeds 0.250 kW, or in case of direct ignition of the main burner, the flame establishing period is determined by the manufacturer so that in accordance with the delayed ignition test (Section 5.8.1) no health or safety hazard for the user or damage to the fuel cell power system occurs.

j) Each pilot or direct main burner ignition attempt begins with the opening of the fuel valves and ends with the closing of the fuel valves. The spark shall continue at least until ignition occurs or until the end of the flame establishing period.

k) Pilot or direct main burner ignition shall be attempted a maximum of 3 times, each time followed by purging.

An absence of flame at the end of the 3rd attempt shall result in, at least, a lockout.

l) In case of flame failure, the system shall cause at least re-ignition, recycling or lockout.

m) The pilot or main burner flame failure lock-out time shall not exceed 3 seconds.

n) If re-ignition takes place, under the test conditions of 5.13.1, the direct ignition device shall be re-energized within a maximum time of 1s after the disappearance of a flame signal. In this case the flame establishing period is the same as is used for ignition and starts when the ignition device is energized. An absence of flame at the end of the flame establishing period shall result in, at least, a lockout.

o) If recycling takes place, under the test conditions of 5.13.1, this shall be preceded by an interruption of the gas supply and purging; the ignition sequence shall restart from the beginning. In this case the flame establishing period is the same as is used for ignition and starts when the ignition device is energized. Recycling shall be attempted a maximum of 3 times, each time followed by purging. An absence of flame at the end of the 3rd attempt shall result in, at least, a lockout.

p) A burner circuit shall be arranged to prevent feedback by a motor, capacitor or similar device from energizing a fuel valve or ignition device after a control functions to shut off the main burner.

q) When for safety reasons a passive state is required prior to startup or after shutdown, means shall be provided to automatically purge a burner housing or enclosure of any flammable gas mixture before the trial for ignition at the start and in-between recycling trials. This purge shall provide a minimum of four air changes in the combustion chamber.

r) Ignition system components shall be installed so the operation of these devices and main burner ignition will not be affected by falling particles during normal operation.

s) When primary air under pressure is mixed with the fuel supply, effective means shall be provided to prevent air from passing back into the fuel line, or fuel into the air supply. The fuel and air supply shall be suitably controlled to prove air flow prior to ignition and to prevent fuel from entering each reformer burner until the air supply is available and, in the event of air fan failure, to shut off the fuel supply.

t) Linkage for operating the fuel and air controls, if used, shall be designed to reliably maintain the correct fuel/air ratio and to resist accidental breakage and disengagement.

u) Upon shutdown, hazardous gases in the process system shall be safely contained or disposed.

v) The manufacturer shall provide the fuel cell power system with adequate means to prevent the crossing of air into fuel or combustible process gas lines or of fuel or combustible process gas into air lines.

w) The fuel cell power system under a blocked outlet condition, shall not produce a concentration of carbon monoxide in excess of 300 ppm in an air-free sample of the effluents as per test in Section 5.16.2. Additionally, the fuel cell power system shall not produce a carbon monoxide concentration in excess of 300 ppm in air-free sample of the effluents when the air supply inlet is blocked as per test in Section 5.16.3.

For indoor fuel cell systems, blockage of the air supply or exhaust discharge shall not result in an effluent concentration in excess of the limits specified in Section 5.16.2 and Section 5.16.3.

4.6.3 Prevention of fire and explosion hazards in catalytic fuel oxidation systems (catalytic burners)

a) Within fuel cell power system components carrying fluids, in which flammable or explosive gas volumes are intentionally produced to conduct a controlled catalytic fuel oxidation reaction (e.g. catalytic partial oxidation, catalytic combustion), the manufacturer shall avoid the unsafe build up of flammable or explosive gases.

b) When for safety reasons a passive state is required prior to startup or after shutdown, means shall be provided to purge the catalytic fuel oxidation system components. The purging system may utilize a medium specified by the manufacturer such as but not limited to nitrogen, air or steam. The extent of purging is determined by considering flow characteristics, system dynamics and geometry.

c) Where air is mixed with fuel, the manufacturer shall provide adequate means to prevent that air flows back into the fuel line, or fuel into the air supply.

(1) For air-rich systems.

The fuel and air supply shall be suitably controlled to prove air prior to reaction initiation, and to prevent fuel from entering the reactor until the air supply is available.

(2) For fuel-rich systems.

The fuel and air supply shall be suitably controlled to prove fuel prior to reaction initiation, and to prevent air from entering the reactor until the fuel is available.

d) Linkage for operating the fuel and air controls, if used, shall be designed to reliably maintain the correct fuel-air ratio and to resist accidental breakage and disengagement.

e) The reaction initiation time shall be determined by considering the response time of the system control devices and the time required to build up the maximum allowable quantity of flammable or explosive mixture that can safely be contained in the system based on flow rates, fuel-air mixture flammability, and system dynamics and geometry.

f) If the catalytic reaction is not established within the reaction initiation time, the system shall automatically shut off the fuel supply, or for fuel-rich operations, the supply of all reactants.

g) The temperature of the catalyst shall be monitored either directly or indirectly. The reaction fails if the temperature or rate of temperature change of the catalyst fall outside an acceptable range. Then the system shall automatically shut off the fuel supply, or for fuel-rich operations, supply of all reactants. The reaction failure lock-out time shall not exceed 3 seconds.

h) If a mixture of fuel and air could potentially build up inside the fuel cell power system following either the failure of a reaction to start within the reaction initiation time; or the extinction of a reaction; or decrease or increase of the reaction rate to unsafe levels, the manufacturer shall ensure that the maximum quantity of flammable mixture that could credibly accumulate, if combusted, produces pressures and temperatures that can be contained within the components exposed to such conditions.

i) Upon shutdown, hazardous gases in the process system shall be safely contained or disposed.

j) Where air and fuel streams are put in close contact as part of the thermal management system, the manufacturer shall provide the fuel cell power system with adequate means to prevent that health or safety risks arise from the crossing of air into fuel lines or of fuel into air lines.

4.7 Electrical safety

The output voltage of a fuel cell power system shall not exceed nominal 600 VAC or 600 VDC.

4.7.1 Protection against electric shock and energy hazards

Electrical terms and definitions used in this standard are the same as those given in IEC 60950-1, Clause 1.2.

IEC 60950-1 sections 2.1.1.2, 2.1.1.4, 2.1.1.5, 2.1.1.6, 2.1.1.7 apply together with the following.

Any electrical disconnect devices provided to shut power down for the safety of service personnel shall be provided with a means for physically locking-out the disconnect lever to prevent inadvertent reconnection before servicing has been completed.

The provisions of 2.10 of IEC 60950-1 apply to clearances, creepage distances and distances through insulation.

60950-1, section 3 applies to wiring connection and supply.

4.7.1.1 Operator Access

This standard specifies two categories of requirements for protection against electric shock from energized parts.

The operator is permitted to have access to:

a) bare parts in SELV circuits

b) bare parts in limited current circuits

c) insulation of wiring in ELV circuits under the conditions specified in 60950-1 section 2.1.1.3

The operator shall be prevented from having access to

a) bare parts of circuits at ELV or hazardous voltages

b) operational or basic insulation of such parts except under the conditions specified in subsequent sections

c) unearthed conductive parts separated from parts at ELV or at hazardous voltages by operational or basic insulation only

4.7.1.2 Access to ELV wiring

IEC 60950-1 section 2.1.1.3 applies together with consideration for the maximum unsynchronized voltages that may appear across the line and inverter terminals.

4.7.1.3 Discharge of capacitors in the primary circuit

IEC 60950-1 section 2.1.1.7 applies together with consideration for capacitance stored in the load as well as internal circuitry.

4.7.1.4 Emergency switching device

The fuel cell generator shall be provided with an integral single emergency switching device, or terminals for connection of a remote emergency-switching device, which prevents further supply to the load in any mode of operation. If reliance is placed on additional disconnection of supplies in the building wiring, the installation instructions shall so state.

Plug connected fuel cell generators do not require an emergency switching device if the plug can perform the same function.

4.7.2 Components

The following apply to electrical components within the equipment.

Where safety is involved, components shall comply either with the requirements of this standard or with the safety aspects of the relevant IEC component standards.

A component which is to be connected to an SELV circuit and also to an ELV circuit or to a part at hazardous voltage shall comply with the requirements for SELV circuits. An example of such a component is a relay with different supplies connected to different elements (coils and contacts).

Evaluation and testing of components

- a component that has been demonstrated to comply with a standard harmonized with the relevant IEC component standard shall be checked for correct application and use in accordance with its rating. It shall be subjected to the applicable tests of this standard as part of the equipment with the exception of those tests which are part of the relevant IEC component standard;

- a component that has not been demonstrated to comply with a relevant standard as above shall be checked for correct application and use in accordance with its specified rating. It shall be subjected to the applicable tests of this standard, as part of the equipment, and to the applicable tests of the component standard, under the conditions occurring in the equipment; NOTE- The applicable test for compliance with a component standard is, in general, carried out separately.

- where no relevant IEC component standard exists, or where components are used in circuits not in accordance with their specified ratings, the components shall be tested under the conditions occurring in the equipment. The number of samples required for test is, in general, the same as required by an equivalent standard.

Thermal controls shall meet the requirements of 1.5.3 of IEC 60950-1

Transformers shall comply with the requirements of 1.5.4 of IEC 60950-1

Capacitors connected across line power shall comply with 1.5.5 of IEC 60950-1

Components that bridge double or reinforced insulation

- Bridging capacitors
  It is permitted to bridge DOUBLE INSULATION or REINFORCED INSULATION by:

  - a single capacitor complying with IEC 60384-14:1993, subclass Y1; or

  - a single capacitor complying with IEC 60384-14:1993, subclass Y2, where the equipment RATED VOLTAGE is less than 150 V with respect to neutral or earth; or two capacitors in series, each complying with IEC 60384-14:1993, subclass Y2 or Y4.

- A Y1 capacitor, or a Y2 capacitor used in accordance with the above second dash, is considered to have REINFORCED INSULATION. Where two capacitors are used in series, they shall each be rated for the total WORKING VOLTAGE across the pair and shall have the same nominal capacitance value.

- Bridging resistors
  It is permitted to bridge DOUBLE INSULATION or REINFORCED INSULATION by two resistors in series. The resistors shall each comply with the requirements of 2.10.3 and 2.10.4 for BASIC INSULATION or SUPPLEMENTARY INSULATION, as applicable, between their terminations for the total WORKING VOLTAGE across the pair and shall have the same nominal resistance value.

- Accessible parts
  Where accessible conductive parts or circuits are separated from other parts by DOUBLE INSULATION or REINFORCED INSULATION that is bridged by components in accordance with 1.5.7.2 or 1.5.7.3, the accessible parts or circuits shall comply with the requirements for LIMITED CURRENT CIRCUITS in 2.4. These requirements shall apply after electric strength testing of the insulation has been carried out.

- Components in equipment for IT power distribution systems

  For equipment to be connected to IT power distribution systems, components connected between line and earth shall be capable of withstanding the stress due to the line-to-line voltage. However, capacitors rated for the applicable line-to-neutral voltage are permitted in such applications if they comply with IEC 60384-14:1993, subclass Y1, Y2 or Y4.

4.7.3 Input current

The steady state input current of the equipment shall not exceed the RATED CURRENT by more than 10% under NORMAL LOAD.

NOTE- See also 1.4.10.

Compliance is checked by measuring the input current of the equipment at NORMAL LOAD under the following conditions:

- NORMAL LOAD for systems that utilize an external mains power source to idle, start, or maintain operation of the power system, is considered to be the maximum load that is connected to the mains.

- where an equipment has more than one RATED VOLTAGE, the input current is measured at each RATED VOLTAGE;

- where an equipment has one or more RATED VOLTAGE RANGES, the input current is measured at each end of each RATED VOLTAGE RANGE. Where a single value of RATED CURRENT is marked (see 1.7.1), it is compared with the higher value of input current measured in the associated voltage range. Where two values of RATED CURRENT are marked, separated by a hyphen, they are compared with the two values measured in the associated voltage range.

In each case, the readings are taken when the input current has stabilized. If the current varies during the normal operating cycle, the steady-state current is taken as the mean indication of the value, measured on a recording r.m.s. ammeter, during a representative period.

4.7.4 Insulation

IEC 60950-1 sections 2.2.3.1, 2.2.3.2 and 2.2.3.3 apply. IEC 62282-2 applies with respect to the fuel cell stack construction.

4.7.5 Limited current circuits and limited power circuits

IEC 60950-1 sections 2.4.1, 2.4.2 , 2.4.3 and 2.5 apply.

4.7.6 Provisions for protective earthing

IEC 60950-1 sections 2.6 apply, along with the following portions of this section.

4.7.6.1 Protective earthing

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 protective earthing terminal within the equipment.
This requirement does not apply to accessible conductive parts that are separated from parts at hazardous voltage by:

- Earthed metal parts, or
- Solid insulation or an air gap, or a combination of the two, meeting the requirements for double insulation or reinforced insulation. In this case the parts involved shall be so fixed and so rigid that the minimum distances are maintained during the application of force as required by the tests of IEC 60950-1 sections 2.10 and 4.2.3

4.7.6.2 Bonding

For Class I pluggable equipment Type A, the fuel cell generator shall provide sufficient terminals, earthed socket-outlets or other means to permit, in the final installed system configuration, equipotential earth bonding to the fuel cell generator from other Class I equipment. This requirement includes external battery cabinets, irrespective of whether the fuel cell generator’s primary protective conductor is disconnected from its source. Any special bonding instructions shall be stated in the user’s instructions.

4.7.7 AC and DC power isolation

IEC 60950-1 sections 2.6.2, 2.6.3, 2.6.4, 2.6.5 are applicable, together with the following.

4.7.7.1 Disconnect devices

Disconnection devices shall be provided to disconnect the fuel cell generator from the a.c. supplies for servicing by qualified personnel. The means of isolation can be located either in the service access area or external to the equipment.

4.7.7.2 Three-phase equipment

For three phase fuel cell generators, the disconnect device(s) shall disconnect simultaneously all phase conductors of the supply.

If a disconnect device interrupts the neutral conductor, it shall simultaneously interrupt all phase conductors (see IEC 60950-1, section 1.7.2).

4.7.7.3 Switch as a disconnect

Where the disconnect device is a switch incorporated into the equipment, its “ON” and “OFF” positions shall be marked in accordance with IEC 60950-1 section 1.7.8.

If the operating means of the disconnection device is operated vertically rather than rotationally or horizontally, the “UP” position of the operating means shall be in the “ON” position.

4.7.7.4 Multiple power sources

Where a permanently connected unit receives power from more than one external source, there shall be a prominent marking at each disconnect device giving adequate instructions for the removal of all power from the unit.

4.7.7.5 Ungrounded conductors

For both internal and external d.c. supplies, disconnect devices or means of isolation, shall open all ungrounded conductors of the dc supply.

4.7.8 Over-current and earth fault protection

IEC 60950-1 sections 2.7.3, 2.7.4, 2.7.5, 2.7.6 apply along with the following.

4.7.8.1 General

Protection against excess currents, short circuits and earth faults in input and output circuits shall be provided, either as an integral part of the equipment or as part of the building installation.

4.7.8.2 Battery circuit protection

Where a d.c. supply is installed inside the fuel cell generator, the d.c. supply shall be provided with a protective device located adjacent to the d.c. connecting means before any component which may fail short-circuited, such as capacitors, semi-conductors, or similar components.

Where the d.c. supplies are external to the fuel cell generator, the rating of the over-current protective device shall be indicated in the instruction manual and shall take into account the current rating of the conductors to be connected between the fuel cell generator and the d.c. supply.

4.7.8.3 Rating of protective device

The rating of the over-current protective device located internally shall be such that it protects against the conditions given in IEC 60950-1 section 5.3.1.

4.8 Electromagnetic compatibility (EMC)

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

IEC 61000-3-2	Electromagnetic compatibility (EMC) Part 3-2: Limits for harmonic currents emissions (equipment input current up to 16 A per phase)
IEC 61000-3-3	Electromagnetic compatibility (EMC) Part 3-3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current up to 16 A.
IEC 61000-3-4	Electromagnetic compatibility (EMC) Part 3-4: Limits – Limitation of emission of harmonic currents emissions 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 fluctuations and flicker in low-voltage supply systems for equipment with rated current greater then 16 A.
IEC 61000-6-1	Electromagnetic compatibility – Part 6-1: Generic standards – Immunity for residential, commercial and light industrial environments
IEC 61000-6-2	Electromagnetic compatibility – Part 6-2: Generic standard – Immunity for industrial environments
IEC 61000-6-3	Electromagnetic compatibility – Part 6-3: Generic standards – Emission standard for residential, commercial and light industrial environments
IEC 61000-6-4	Electromagnetic compatibility – Part 6-4: Generic standard – Emission standard for industrial environments

4.9 Control systems and protective/safety components

4.9.1 General requirements

4.9.1.1 The safety and reliability analysis as specified in 4.1.2 shall provide the basis to set the protection parameters of the safety circuit.

4.9.1.2 The fuel cell power system shall be designed such that the single failure of a component does not cascade into a hazardous condition. Means to prevent cascade failures include but are not limited to:

- protective devices in the fuel cell power system (e.g. interlocking guards, trip devices);
- protective interlocking of the electrical circuit;
- use of proven techniques and components;
- provision of partial or complete redundancy or diversity
- provision for functional tests.

Guidance for the design of electrical, electronic and programmable controls can be found in IEC 61061 (Safety of machinery- Functional safety of electrical, electronic and programmable control systems) or IEC 61511-1 (Functional safety - Safety instrumented systems for the process industry sector - Part 1: Framework, definitions, system, hardware and software requirements)

4.9.2 Control systems

Automatic electrical and electronic controls of fuel cell power systems shall be designed and constructed so that they are safe and reliable. Residential, commercial and light industrial fuel cell power systems shall conform to IEC 60730-1.

Automatic electrical burner control systems shall comply with IEC 60730-2-5.

Automatic electrical control systems for catalytic oxidation reactors shall comply as applicable with IEC 60730-2-5. Specific requirements are provided in 4.6.3.

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

In particular, the following requirements apply:

4.9.2.1 Start

The start of an operation shall be possible only when all the safeguards are in place and are functional.

Suitable interlocks shall be provided to secure correct sequential starting.

It shall be possible for automated plant functioning in automatic mode to be restarted after a stoppage once the safety conditions have been fulfilled. It shall also be possible to restart the fuel cell power system by intentional actuation of a control provided for the purpose, provided such restarting is verifiably non-hazardous.

This requirement does not apply to the restarting of the fuel cell power system resulting from the normal sequence of an automatic cycle.

4.9.2.2 Shutdowns

As determined by the reliability assessment indicated in 4.1.2 and the functional requirements of the fuel cell power system shall be provided with the following shutdowns:

- Safety shutdowns

  A safety shutdown is, for air-rich operation, the de-energization of the main fuel flow means, or for fuel-rich operation, the de-energization of both the process air flow and the main fuel flow means, as the result of the action of a limiter, a cut-out or the detection of an internal fault of the system.

- Controlled shutdown

  A controlled shutdown is, for air-rich operation, the de-energization of the main fuel flow means, or for fuel-rich operation, the de-energization of both the process air flow and the main fuel flow means, as the result of the opening of a control loop by a control device such as a thermostat. The system returns to the start position.

4.9.2.2.1 Safety shutdowns

a.) General:

Safety shutdowns shall be incorporated as part of the fuel cell power system in order to avert actual or impending danger that cannot be corrected by controls. These functions shall:

- stop the dangerous condition without creating additional hazards;
- trigger or permit the triggering of certain safeguard actions where necessary;
- override all other functions and operations in all modes;

- prevent reset from initiating a restart; and
- be fitted with restart lock-outs such that a new start command may take effect on normal operation only after the restart lock-outs have been intentionally reset.

b.) Emergency stop:

Manual safety shutdowns (i.e. emergency stops), if required by the safety and reliability analysis in 4.1.2, shall have clearly identifiable, clearly visible and quickly accessible controls such as buttons, in accordance with ISO 13850 (see also 4.9.5).

c.) Control functions in the event of control systems failure:

In case of fault in the control system logic, or failure of or damage to the control system hardware:

- the fuel cell power system shall not be prevented from stopping once the stop command has been given,
- automatic or manual stopping of the moving parts shall be unimpeded,
- the protection devices shall remain fully effective, and
- the fuel cell power system shall not restart unexpectedly,

When a protective device or interlock causes a safety shutdown of the generator, that condition shall be signaled to the logic of the control system. The reset of the shutdown function shall not initiate any hazardous condition.

Control/monitoring systems that can operate safely in the hazardous situation may be left energized to provide system information.

4.9.2.2.2 Controlled shutdown

Upset conditions that can be safely controlled or that do not pose immediate danger may be corrected with a controlled shutdown. A controlled shutdown may remove all power to the equipment, or may leave power
available to the generator actuators.

4.9.2.3 Permissives

Permissives shall be implemented consistent with requirements established from the safety and reliability analysis described in 4.1.2. A "permissive" is defined as a condition within a logic sequence that must be satisfied before the sequence is allowed to proceed to the next phase.

4.9.2.4 Complex installations

When the fuel cell power system is designed to work together with other equipment, the fuel cell power system stop controls, including the emergency stop, shall be provided with means, such as signal interfaces, to enable the coordinated shutdown with equipment upstream and/or downstream, as applicable, of the fuel cell power system if continued operation can be dangerous.

4.9.2.5 Operating modes

a. There shall be two primary operating modes: On and Off.

During the On-mode the fuel cell power system components shall be active and operating as necessary to supply power. The following conditions are also considered on-modes:

- Standby State (zero net power output)

- Automatic start enabled (power left available to the power system actuators)

In the Off-mode, all power to the fuel cell power system shall be cut and the unit shall be inactive, or some power to prevent deterioration of the components shall be supplied only to the fuel cell power system and the unit shall be inactive.

b. There shall be two primary transitions: start-up and shutdown

Start-up is the automatic transition from OFF to On and shall be initiated from an external signal. Shutdown is the automatic transition from On to OFF. It may be initiated either via an external signal, or internal signal in response to out of limits conditions to the fuel cell power system controller.

c. Secondary operating modes and transitions may be provided as necessary, such as to allow for different power output rates or for adjustment, maintenance, or inspection activities.

d. Mode selection

If the fuel cell power system has been designed and built to allow for its use in several control or operating modes presenting different safety levels (e.g. to allow for adjustment, maintenance, inspection, etc.), it shall be capable of mode selection that can be secured in each position. Each position of the selector shall correspond to a single operating or control mode and shall be fitted with restart lockouts. A new start command may take effect on normal operation only after the restart lockouts have been intentionally reset. Mode selection shall be allowed by any securable means, such as a positioning knob, key lock, or software command, to prevent unintentional change to a different mode that may lead to a hazardous condition. The selector may be designed to restrict user access to certain fuel cell power system operating modes (e.g. access codes for certain numerically controlled functions, etc.).

The mode selected shall override all other control systems with the exception of the safety shutdowns.

4.9.2.6 Remote monitoring and control systems

Fuel cell power systems that can be operated remotely shall have a local, labeled switch or other means to disconnect the generator from remote signals that may be used while a local operator performs inspection or maintenance. Remote monitoring and control systems shall:

a. Be allowed on fuel cell power systems only where remote control will not lead to an unsafe condition;

b. Not override locally set manual controls; and

c. Not override protective safety controls.

4.9.3 Protective/Safety Components

a. Suitable protective devices and combinations thereof comprise:

- safety devices

- where appropriate, adequate monitoring devices such as indicators and/or alarms which enable adequate action to be taken either automatically or manually to keep the fuel cell power system within the allowable limits.

b. Safety devices shall:

- be so designed and constructed as to be reliable and suitable for their intended duty and take into account the maintenance and testing requirements of the devices, where applicable,

- have their safety functions independent of other possible functions,

- comply with appropriate design principles in order to obtain suitable and reliable protection. These principles include, in particular, fail-safe modes, redundancy, diversity and self-diagnosis.

c. Dangerous overloading of equipment shall be prevented at the design stage by means of integrated measurement, regulation and control devices, such as over-current cut-off switches, temperature limiters, differential pressure switches, flowmeters, time-lag relays, over-speed monitors and/or similar types of monitoring devices.

d. Safety devices with a measuring function shall be designed and constructed so that they can cope with foreseeable operating requirements and special conditions of use. Where necessary, it shall be possible to check the reading accuracy and serviceability of devices. These devices shall incorporate a safety factor that ensures that the alarm threshold lies far enough outside the limits to be registered, taking into account, in particular, the operating conditions of the installation and possible aberrations in the measuring system.

e. Pressure limiting devices, such as pressure switches, shall be provided as per IEC 60730-2-6.

f. Temperature monitoring devices shall have an adequately safe response time, consistent with the measurement function, as per IEC 60730-2-9.

g. Gas sensors relied upon for safety shall comply with IEC 61779-4 and be selected, installed, calibrated, used and maintained in accordance with IEC 61779-6.

h. All parts of fuel cell power systems which are set or adjusted at the stage of manufacture, and which should not be manipulated by the user or the installer, shall be appropriately protected.

i. Levers and other controlling and setting devices shall be clearly marked and given appropriate instructions so as to prevent any error in handling. Their design shall be such as to preclude accidental manipulation.

4.10 Pneumatic and hydraulic powered equipment

Pneumatic and hydraulic equipment of fuel cell power systems shall be designed as per ISO 4414 and ISO 4413.

4.11 Valves

4.11.1 Shut-off valves

a. Shut-off valves shall be provided for all equipment and systems where containment or blockage of the process fluid flow is necessary during shutdown, testing, maintenance, upset or emergency conditions.

b. Shut-off valves shall be rated for the service pressure, temperature and fluid characteristics.

c. Actuators mounted on shut-off valves shall be temperature-rated to withstand heat conducted from the valve body.

d. Electrically, hydraulically or pneumatically operated shut-off valves shall be of a type that will move to a failsafe position upon loss of actuation energy.

4.11.2 Supply fuel valves

Supply fuel valves shall meet the following requirements:

a. All fuel supplied to the fuel cell power system shall pass through at least two automatic valves, in series, each of which serves as an operating valve and a safety shutoff valve.

b. Any fuel supplied directly to fuel-fired equipment, such as a startup boiler or a reformer start burner, shall also pass through at least two automatic valves, in series, each of which serves as an operating valve and a safety shutoff valve. These valves may or may not be contained in a single control body.

c. Electrically operated supply fuel valves shall meet the requirements of IEC 60730-2-17 or IEC 60730-2-19 as applicable.

d. When fuel gases are recycled from appliances using the fuel cell power system output gas, the connection may be exempt from employing shutoff valves if demonstrated to be safe as per the safety and reliability analysis of 4.1.2.

4.12 Rotating equipment

4.12.1 General requirements

a. Rotating equipment shall be designed for the pressures, temperatures and fluids to which they may be subjected under normal operating conditions.

b. Fluid inlet and outlet lines shall be adequately protected from damage due to vibration.

c. Shaft seals shall be compatible with the pumped fluids and the operating temperatures and pressures expected in normal and abnormal operation and during normal and emergency shutdowns.

d. Shaft seals shall be designed such that hazardous fluid leakage is avoided. If shaft seals will leak hazardous fluids, the manufacturer shall provide hazardous fluid containment or dilution means as necessary to avoid risks to health or safety.

e. Motors, bearings, and seals shall be suitable for the expected duty cycles.

4.12.2 Compressors

4.12.2.1 Where appropriate, packaged compressors shall conform to one of the following standards:

Standard Number Application
ISO 5388:1981 Stationary air compressors
ISO 10439:2002 Petroleum, chemical and gas service industries – Centrifugal compressors
ISO 10442:2002 Petroleum, chemical and gas service industries -- Packaged, integrally geared centrifugal air compressors
ISO 13707:2000 Petroleum and natural gas industries -- Reciprocating compressors
ISO 10440-1:2000 Petroleum and natural gas industries -- Rotary-type positive displacement compressors -- Part 1: Process compressors (oil-free)
ISO 10440-2:2001 Petroleum and natural gas industries -- Rotary-type positive-displacement compressors -- Part 2: Packaged air compressors (oil-free)
ISO 13631:2002 Petroleum and natural gas industries -- Packaged reciprocating gas compressors

4.12.2.2 Unless determined unnecessary by the safety and reliability analysis, compressors, or compressor systems, shall be provided with the following:

a. Pressure relief devices that limit each stage pressure to the maximum operating pressure for the compression cylinder and piping associated with that stage of compression.

b. An automatic shutdown control for high discharge and low suction pressure.

c. Where required to re-start the compressor after shutdown, an unloading device that captures and recycles blow down gas for re-use, and/or safe venting.

d. Vibration isolation from the inlet pipe to the compressor suction line.

e. A pressure limiting device to avoid over pressurization at the inlet.

4.12.2.3 Compressors excluded from the scope of the standards referenced in 4.12.2.1 due to small capacity or low discharge pressure need only to comply with the requirements specified in 4.12.2.2.

Packaged low discharge pressure compressors (fans and blowers) shall be guarded as per ISO 12499 (see also Section 4.4.4).

4.12.3 Pumps

4.12.3.1 Packaged electric pumps for process liquids shall conform to ISO 13709-2 or ISO 14847.

Packaged electric pumps for water shall conform to IEC 60335-2-41 or IEC 60335-2-51 as applicable.

4.12.3.2 Electric pumps, or electric pump systems, shall be provided with the following:

a. Pressure relief devices that limit both inlet and outlet pressure to less than the design pressure of the piping. If the shut-off head of the electric pump is less than the pressure rating of the piping, relief valves are not required. Relief valve releases shall be routed to a safe place.

b. An automatic shutdown control for high discharge pressure.

c. Suction and discharge lines shall be adequately protected from damage due to vibration.

4.12.3.3 Pumps excluded from the scope of the standards referenced in 4.12.3.1 due to small capacity or low discharge pressure need only to comply with the requirements specified in 4.12.3.2.

4.13 Cabinets

4.13.1 Fuel cell power system cabinets shall have sufficient strength, rigidity, durability, resistance to corrosion and other physical properties to support and protect all fuel cell power system components and piping; and to meet the requirements of storage, transport, installation, and final location conditions.

4.13.2 Fuel cell power system cabinets intended for use indoors or under conditions of weather-protected outdoor locations shall be designed and tested as to meet a minimum IP22 rating as per IEC 60529.

4.13.3 The fuel cell power system for use under conditions of non weather-protected outdoor locations shall start and operate normally, without damage or malfunctioning of any part that would create a hazardous condition when subjected to a simulated rain test per IEC 60529, Test Condition 14.2.4a.

4.13.4 Ventilation openings shall be designed so that they will not become obstructed during normal operation either by dust, snow or vegetation in accordance with the expected application.

4.13.5 All materials used to construct cabinets, including joints, vents, and gaskets of doors shall be capable of withstanding the physical, chemical and thermal conditions that are reasonably foreseeable throughout the fuel cell power system life.

4.13.6 Access panels, covers or insulation that need to be removed for normal servicing and accessibility shall be designed such that repeated removal and replacement will not cause damage or impair insulating value.

4.13.7 Access panels, covers or insulation that need to be removed for normal servicing and accessibility shall not be interchangeable if that interchange may lead to an unsafe condition.

4.13.8 Any access panel, cover or door that is intended to protect equipment from entry by users or untrained personnel shall have means for retaining it in place and shall require the use of a tool, key or similar mechanical means to open. For residential units, this shall include all access panels, covers, or doors.

4.13.9 All parts of fuel cell power systems that are set or adjusted at the stage of manufacture and that should not be manipulated by the user or the installer shall be adequately protected.

4.13.10 Means shall be provided to drain collected liquids and to pipe them to the exterior for disposal or redirect them to processes associated with the fuel cell power system.

4.13.11 Where personnel can fully enter the cabinet, the cabinet shall be considered a confined space and adequate guidelines shall be provided in the product's technical documentation.

4.14 Thermal insulating materials

Insulation systems employed in the fuel cell power system shall be designed to attain:

- chemical compatibility with the metals being insulated, the atmosphere and temperatures to which the systems will be exposed, and the various components of the insulation system itself,
- protection of insulation systems from expected thermal and mechanical abuse (including damage by atmospheric conditions),
- fire safety, by avoiding to increase temperatures around heat producing objects to the extent that these become sufficiently hot to ignite materials in contact with them,
- future accessibility of piping, fittings, etc. for maintenance purposes.

In particular, thermal insulating materials and their internal bonding or adhesive attachment means mounted on components of the fuel cell power system shall:

- be mechanically or adhesively retained in place and shall be protected against displacement or damage from anticipated loads and service operation,
- withstand all air velocities, temperatures and fluids to which they may be subjected in normal operation.

If necessary to avoid hazards to health and safety, the manufacturer shall specify in the maintenance manual the thermal insulation system inspection and safety requirements.

4.15 Utilities

a. The fuel cell power system shall be designed and constructed such that in case of loss of utility supply, i.e. interruption of electrical supply, feed water, cooling water, instrument air, etc., the system shut-downs safely without:

1. the creation of any health or safety hazards;

2. permanent distortion or damage to the system;

b. Where the fuel cell power system requires water to operate, it shall be provided through a connection to an on-site water supply in accordance with the applicable regional and national plumbing codes and standards, or through self-contained water source; or shown to produce water in sufficient quantities during operation.

c. If applicable, means shall be provided to prevent backflow of steam into the water treatment system of the fuel cell power system. A suitable check valve or equivalent device meets the intent of this provision.

4.16 Installation and maintenance

4.16.1 Installation

The manufacturer shall provide instructions for the proper installation, adjustment, operation, and maintenance of the fuel cell power systems.

Errors, likely to be made when fitting or refitting certain parts which could be a source of risk shall be made impossible by the design of such parts or, failing this, by information given on the parts themselves and/or the housings. The same information shall be given on moving parts and/or their housings where the direction of movement shall be known to avoid a risk. Any further information that may be necessary shall be given in the instructions.

Where a faulty connection can be the source of risk, incorrect fluid connections, including electrical conductors, shall be made impossible by the design or, failing this, by information given on the pipes, cables, etc. and/or connector blocks.

Where the fuel cell power system requires water to operate it shall be provided: through a connection to an on-site water supply in accordance with the applicable Plumbing Code; through self-contained water source; or shown to produce water in sufficient quantities during operation.

4.16.2 Maintenance

a. Adjustment, lubrication and maintenance points shall be located outside zones in which a person is exposed to risk of injury or damage to health; or maintenance instructions shall be provided in the product’s maintenance manual specified in 7.4.5 as necessary to avoid risks to health or safety.

b. It shall be possible to carry out adjustment, maintenance, repair, cleaning and servicing operations while the fuel cell power system is at a standstill. When adjustment, maintenance, repair, cleaning and servicing must be conducted while the fuel cell power system is operating, means shall be provided to do this safely.

c. Automated fuel cell power system components that have to be changed frequently shall be capable of being removed and replaced in safety. Access to the components shall enable these tasks to be carried out with the necessary technical means (tools, measuring instruments, etc.) in accordance with the product’s technical documentation.

d. Where for protection of health or safety instructions or diagrams are to be adhered to the fuel cell power system, they shall be displayed using a permanent method, resistant to or protected from the environmental conditions of use.

5 Type Tests

A design examined for compliance with this standard shall be a representative production sample of the fuel cell power system.

Each new design shall be subjected to the type tests. Components, making up the system, that have been pre-certified do not need to be re-tested when applied within their rating and listing requirements. For example, a fuel cell stack that has been certified to IEC 62282-2 need not be subjected to the over-potential or over-pressure tests in this section.

The Type Tests shall prepare the data basis for a type approval of a stationary fuel cell power plant type according to applicable national and international regulations.

5.1 General requirements

Type tests shall be performed in a test environment simulating the fuel cell application, which the fuel cell system is designed for, in order to obtain the required operating conditions. In particular, the test environment for the type tests shall provide interfaces at Boundary Limits according to the designed application of the plant. It is recommended to perform the Type Tests in the order as described below. The Type Test under Abnormal Conditions may be destructive.

5.1.1 Operating parameters for tests

5.1.1.1 Except where specific test conditions are stated elsewhere in the standard and where it is clear that there is a significant impact on the results of the test, the tests shall be carried out under the most unfavorable combination within the manufacturer's operating specifications of the following parameters:

- supply voltage;
- supply frequency;
- operating temperature;
- physical location of equipment and position of movable parts;
- operating mode;
- adjustment of thermostats, regulating devices or similar controls in operator access areas, which are:
  - adjustable without the use of a tool; or
  - adjustable using a means, such as a key or a tool, deliberately provided for the operator.

5.1.1.2 Except where otherwise stated in the particular clauses, measurements shall be carried out with the maximum uncertainties indicated below:

1) Atmospheric pressure (mbar or Pa)	± 5 mbar;
2) Combustion chamber and test flue pressure	± 5 % full scale or 0,05 mbar; (mbar or Pa)
3) Gas pressure (bar, Pa)	± 2 % full scale;
4) Water-side pressure loss (bar, mbar, Pa)	± 5 %;
5) Water rate (l/h, m^3/h)	± 1 %;
6) Gas rate (m^3/h (n))	± 1 %;
7) Air rate (m^3/h (n))	± 2 %;
8) Time (h)	
- up to 1 h	± 0,2 s

- beyond 1 h ± 0,1 %;

9) Auxiliary electrical energy/performance kWh or kW ± 2 %;

10) Temperatures: °C or K

- Ambient ± 1 K;
- Water ± 2 K;
- Combustion products ± 5 K;
- Gas ± 0,5 K at T < 1*00 °C*

  ± 2% of reading in °C, $100<T<300$ *°C*

  ± 5% of reading in °C, $T>300$ *°C; agreed*
- Surface ± 5 K;

11) CO, CO_2 and O_2 for the calculation of flue losses ± 6 % of reading;

12) Gas calorific value kWh/m^3 (n) ± 1 %;

13) Gas density kg/m^3(n) ± 0,5 %;

14) Mass kg ± 0,05 %;

15) Torque Nm ± 10 %;

16) Force N ± 10 %,

17) Current A ± 1 %,

18) Voltage V ± 1%

19) Electrical Power W, kW ± 2%

The full range of the measuring apparatus is chosen to be suitable for maximum anticipated value.

For the determination of the leakage rate a method is used which gives such accuracy that the error in its determination does not exceed 2% of related volume per hour.

The measurement uncertainties indicated concern individual measurements. For measurements requiring a combination of individual measurements (e.g. efficiency measurements), the lower uncertainties associated with individual measurements may be necessary to limit the total uncertainty.

5.1.1.3 Normal operating voltages

For the purpose of determining operating voltages see IEC 60950-1, clause 1.4.80.

5.2 Test fuels

5.2.1 A fuel cell power system intended for use with natural gas shall have the tests specified herein conducted with a gas whose composition and supply pressures reflects that of commercially available natural gas. If required by the country of destination, the tests shall also be conducted with limit gases.

5.2.2 A fuel cell power system intended for use with liquefied petroleum gases shall have the tests specified herein conducted with a gas whose composition and supply pressures reflects that of commercially available liquefied petroleum gas. If required by the country of destination, the tests shall also be conducted with limit gases.

5.2.3 A fuel cell power system intended for use with other type of fuel(s) (see paragraph 1. Scope) shall be tested with a test fuel(s) of composition and supply characteristics representative of the fuel(s).

5.3 Basic test arrangements

In conducting the tests the entire fuel cell power system, including any air filters, start-up devices, venting or exhaust systems and all field furnished equipment shall be installed and operated in accordance with the manufacturer's instructions.

Unless otherwise stated, the entire fuel cell power system shall be operated:

a) at the inlet supply pressure as defined in 5.2;

b) within ±5 percent of the rated output power and frequency; and ±10% ouput power

c) within ±5 percent of the rated fuel consumption when operated at rated conditions, and ±10% as specified by the manufacturer

d) at reference conditions specified as follows:

Reference temperature : t0 = 288.15 K (15°C)

Reference pressure : p0 = 101.325 kPa

Testing shall commence when the fuel cell power system components are at equilibrium temperature, unless otherwise specified.

5.4 Leakage Tests

The procedures of this section shall be performed twice, prior to and following the conduction of all non-destructive tests specified in 5.6 through 5.16.

5.4.1 Gas Leakage Tests

All portions of the fuel cell power system that contain flammable gas mixtures shall not leak externally in excess of the limit specified below when tested with appropriate gases or vapors (e.g. the nominal operating gases, clean dry air or inert gas as specified by the manufacturer) that correlate with the expected constituents during operation and shutdown.

Prior to conduct of this test, it shall be established which flammable gas-conveying parts are subject to the same internal pressure during normal operation of the 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 fuel cell power system by any convenient means.

Fuel cell modules shall be tested as described in IEC 62282-2, *Fuel Cell Modules*. Fuel cell modules designed without anode/cathode seals and operated above their fuel auto-ignition temperature are not addressed in IEC 62282-2 leakage tests; therefore, their containment vessel shall be tested as described below.

A suitable pressurizing system, capable of supplying the gaseous medium at the required test pressure, and a suitable flow-measuring device, capable of measuring the leakage rate with an accuracy of 2 percent, shall be connected to the inlet of a test section. The flow-measuring device shall be located between the pressuring system and the test section to be pressurized. The outlet of the test section shall be sealed by any convenient means. All functional parts shall be caused to assume their open position so that the required test pressure is exerted on all parts of the test section.

The gaseous medium shall be gradually admitted to the test section so that a uniform gauge pressure of not less than 1.1 times the maximum operating pressure of that test section is attained gradually in approximately one minute. This pressure then shall be maintained for one minute, at which time any leakage, as indicated by the flow-measuring device, shall be noted.

An acceptable leakage rate is a total measured rate, from all test areas, that can not result in an area concentration greater than 25 percent of the fuel's flammability limit (LFL). For outdoor fuel cell power systems leaking to the environment (e.g. no cabinet), an acceptable leakage rate is a total measured rate, from all test sections, not higher than 1 percent by volume of the gas flow.

If mechanical ventilation is used to compensate for fuel leakage, the allowable leakage rate is determined by the formula:

$$L = 0.01 \times (V/R)$$

where

L = Allowable leakage rate, in cubic meters per hour, for each part or all parts respectively:

$R = (TGSG/FGSG)^{1/2}$ where TGSG=test gas specific gravity
FGSG=fuel gas specific gravity

or

$R = (\mu_{test}/\mu_{fuel})$ where μ_{test} = test gas absolute viscosity
μ_{fuel} = fuel gas absolute viscosity

Note: The R value that results in the lower allowable leakage rate shall be reported.

V = Minimum ventilation rate, in cubic meters per hour of air.

A correction factor may be used when fuel gas of less than 100 percent flammables is used;

$$L = 0.01 \times (V/R) \times (1/C)$$

where

C = Concentration of combustibles.

5.4.2 Liquid Leakage Tests

This test method is used for evaluating test sections that contain combustible and/or hazardous liquids, e.g. liquid fuels, toxic coolants.

The test fluid shall be the design liquid. If the manufacturer considers that testing with the design liquid is impractical, then the test liquid shall be water. If there is the possibility of damage due to freezing or to adverse effects of water on the piping system, another suitable non-toxic liquid may be used. If the liquid is flammable, its flash point shall be at least 50 C and consideration shall be given to the test environment.

Metallic Sections: The hydrostatic test pressure at any point on a test section made of metallic components shall be as follows:

a. not less than 1.5 times the maximum operating pressure
b. for design temperature above the test temperature, the minimum test pressure shall be calculated by the following equation, except that the value S_T/S shall not exceed 6.5

$$P_T = 1.5\,(PS_T)/S$$

where:

P_T = minimum test gauge pressure

P = internal maximum operating gauge pressure

S_T = stress value at test temperature from Table A-1 of ANSI/ASME B31.3 (as per ISO 15649)

S = stress value at design temperature from Table A-1 of ANSI/ASME B31.3 (as per ISO 15649)

Non-metallic Sections: The hydrostatic test pressure at any point in a test section made of non-metallic components shall be a follows:

a. not less than 1.5 times the maximum operating pressure, but shall not exceed 1.5 times the maximum rated pressure of the lowest rated component in the system

b. for design temperature above the test temperature, the minimum test pressure shall be calculated by the equation above

where:

S_T = stress value at test temperature from Table B-1 of ANSI/ASME B31.3 (as per ISO 15649)

S = stress value at design temperature from Table B-1 of ANSI/ASME B31.3 (as per ISO 15649)

(Refer to ANSI B31.3 Sections 345.4 and A345.4 for details.)

Notes:

1. If the test pressure would produce a nominal pressure stress or longitudinal stress in excess of yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at high temperature.
2. A preliminary test using air at more than 170 kPa gauge pressure may be made prior to hydrostatic testing to locate major leaks.
3. Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.
4. Where the test pressure of the piping exceeds the vessel test pressure and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure provided the manufacturer agrees and the vessel test pressure is not less than 77 percent of the piping test pressure calculated in accordance with the formula above.

All external surfaces of the parts that convey liquids shall be made visible to check for leakage. If certain parts cannot be made visible, provisions shall be made to capture and route leakage to a point of visibility. If leak routing cannot be achieved then an alternate leak check will need to be devised by the manufacturer.

Prior to test performance, it shall be determined which liquid carting parts are subject to the same internal pressure during normal operation of the 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 power system by any convenient means.

The test apparatus shall be filled with the liquid medium and connected to a suitable hydraulic system, including a pressure-measuring devise, capable of sustaining the required test pressure. Care should be taken to vent air from the test section during liquid fill.

The test pressure shall be gradually increased so that a uniform gauge pressure is attained. This pressure shall be maintained for at least one hour, or longer as necessary to complete the leak checks, while inspecting all external surfaces of the system for any sign of leakage. If a leak routing system is employed, the test pressure shall be held for a minimum of three hours.

No liquid leakage is allowed. Any visible evidence of leakage is cause for failing the test.

5.5 Strength Tests

All portions of the fuel cell power system that convey potentially flammable mixtures of gases, and all portions of the fuel cell power system that convey liquids shall perform strength tests according to the following:

1. portion that fall within the scope of National Pressure Standards, shall be tested according to those standards.
2. fuel cell modules shall be tested or have already been tested as specified in IEC 62282-2 *Fuel Cell Modules.*
3. all other portions shall be tested as follows:

Liquid Sections: Parts that convey a liquid shall withstand, without rupture, fracture, deformation or other physical damage, an internal static pressure of not less than 1.5 times their maximum operating pressure.

Prior to conduct of this test, it shall be established which liquid-conveying parts are subject to the same internal pressure during normal operation of the 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 fuel cell power system by ant convenient means. Any nonhazardous 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 operating pressure is attained. This pressure then shall be maintained for 30 minutes during which time no rupture, fracture, deformation or other physical damage shall occur.

Gas Sections: Parts, including joints and connections, that convey a flammable gas shall withstand, without rupture, fracture, deformation or other physical damage the following pressures:

1. for test sections subject to a maximum working pressure of 3.45 kPa, an internal static pressure of 5 times their maximum operating pressure
2. for test sections subject to a maximum working pressure over 3.45 kPa, but not exceeding the minimum pressure of the scope of the National Pressure Standard, the test pressure to be used shall be no less than 1.5 times the maximum operating pressure.

Prior to conduct of this test, it shall be established which gas-conveying parts are subjected to the same internal pressure during normal operation of the 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 fuel cell power system by ant convenient means. Any nonhazardous 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 air from the test section.

When liquid cannot be tolerated as a test medium, clean dry air or any inert gas, such as nitrogen or helium, may be used in lieu of the liquid medium. A suitable pressurization 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, when a liquid medium is used, shall be gradually increased or the gaseous medium, when used, shall be gradually admitted to the test section so that a uniform gauge pressure as specified above is attained in approximately one minute. The pressure shall be maintained for one minute during which time no rupture, fracture, deformation or other physical damage shall occur.

5.6 Normal operation type test

Verify name plate values using IEC 62282-3-2 procedures

5.7 Electrical overload test

The Fuel Cell System shall be capable to withstand an electrical overload. Where a manufacturer specifies a current higher than the rated current for a certain period, the Fuel Cell System shall be thermally stabilized at rated current, then the current shall be increased to the defined value and held constant for the defined time, both specified by the manufacturer.

There shall be no flame, risk of shock, rupture, fracture, permanent deformation or other physical damage to the system.

If no higher current is allowed by the manufacturer, the test cannot be performed.

5.8 Dielectric requirements and simulated abnormal conditions

5.8.1 Earth Leakage

Leakage currents from the ac portions of a fuel cell power system shall meet the requirements of IEC 60950-1, clause 5.1.

5.8.2 Electric Strength

Solid dielectrics shall meet the requirements of IEC 60950-1, clause 5.2. The solid insulation shall be pre-heated to a temperature representative of normal operation, unless such a temperature rise does not substantively affect the breakdown voltage.

Note: Liquid dielectrics, such as those used for coolants, are not intended to be included in this test.

The fuel cell stack may be isolated for this test.

5.8.3 Abnormal Conditions

The following clauses from IEC 60950-1 are applicable:

Protection against overload and abnormal operation : Clause 5.3.1

Motors : 5.3.2
Transformers : 5.3.3
Functional insulation : 5.3.4
Electromechanical Components : 5.3.5
Simulation of faults : 5.3.6
Unattended equipment : 5.3.7
Compliance criteria : 5.3.8

5.9 Shut-Down Parameters

Compliance with this section shall be established for each anomaly using a simulated test procedure or 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 fuel cell power system for any of the critical anomalies resulting from the reliability analysis described in 4.9.1.

5.10 Burner operating characteristics tests

The procedures of this section are applicable to fuel cell power systems equipped with any fuel-fired boiler or heating device, e.g. the start burner of the reformer section, and shall be performed with the burner both hot and cold for the following conditions:

a) at the test pressures and using test gases as defined in 5.2,

b) at the maximum and minimum fuel supply pressures specified by the manufacturer, if different from those pressures defined in Section 5.10a,

c) when operating at 85-percent and 110-percent of the rated igniter input voltage. When provided with voltage variation protection within this range, the system shall be tested at the specified limits. In addition, the voltage variation protection shall be verified as per Section 5.9.

5.10.1 General testing

The automatic ignition system shall effect ignition of burner fuel immediately after the fuel reaches the burner port(s). A continuous pilot, when provided, shall not extinguish when the burner fuel gas is turned “on” or “off”. This provision does not apply to an intermittent or interrupted type pilot when the burner fuel is turned “off”.

During the test it shall be verified that:

a) the burner fuel ignites effectively without delayed ignition, flashback, undue noise or equipment damage,

b) the burner flames extinguish without flashback and undue noise,

c) the burner flames do not flash outside the combustion chamber

d) the burner does not deposit carbon, and

e) there is no gas escaping or backflow at the burner’s primary air openings.

5.10.2 Limit testing

The test is carried out without altering the adjustment of the burner and ignition burner. The pressure at the fuel inlet is reduced to 70 % of the normal pressure. Under these supply conditions, it is checked that the burner is safely operating, and that the CO emissions remain below the level required in Section of 4.4.11. This test is repeated at the minimum heat input permitted by the controls, if ignition is possible under these conditions.

5.11 Automatic control of burners and catalytic oxidation reactors

The procedures of this section are associated with the start of all components intended to conduct a controlled oxidation reaction, e.g. combustion (start burner of a reformer section), catalytic partial oxidation and catalytic combustion.

The manufacturer may opt to conduct ignition tests (sections 1.3 thru 1.7) on a fuel cell power system sub-assembly, rather than on a completely built unit, provided the sub-assembly contains all the parts (for example, the igniter and main burner, the manufacturer’s specified igniter location, combustion chamber and, if applicable, the combustion/exhaust fan dedicated to the combustion chamber) that may have an effect on the test results.

5.11.1 Automatic ignition control burners

The automatic ignition control of fuel cell power system burners shall be tested as per the following tests:

5.11.1.1 Effective ignition

The igniter shall light the main burner fuel immediately after fuel reaches the main burner ports. With the fuel cell power system maintained at rated voltage, the igniter shall be activated and ignition observed. Flames shall not flash outside of the fuel cell power system, nor shall there be any damage to the fuel cell power system. A sufficient number of ignition attempts shall be made, and in each instance ignition shall occur immediately after fuel reaches the main burner ports.

5.11.1.2. Ignition - voltage variation

Undervoltage

The voltage to the fuel cell power system shall be adjusted to 85-percent of the rating plate voltage or the specified voltage when provided with voltage variation protection within 85-percent of the rating plate voltage. Under this condition, the igniter shall light the main burner fuel within the main flame establishing period. The CO emissions shall be measured to verify compliance with the requirement of section 4.4.11. Flames shall not flash outside the fuel cell power system, nor shall there be any damage to the fuel cell power system. A sufficient number of ignition attempts shall be made, and in each instance ignition shall occur within the designated time.

Overvoltage

The voltage to the fuel cell power system shall be adjusted to 110-percent of the rating plate voltage or the specified voltage when provided with voltage variation protection within 110-percent of the rating plate voltage. Under this condition, the igniter shall light the main burner fuel within the main flame establishing period. The CO emissions shall be measured to verify compliance with the requirement of section 4.4.11 Flames shall not flash outside the fuel cell power system, nor shall there be any damage to the fuel cell power system. A sufficient number of ignition attempts shall be made, and in each instance ignition shall occur within the designated time.

5.11.1.3 Flame establishing period

The flame establishing period shall be checked when the fuel cell power system is being operated as specified in Section 5.3. The time from energizing the main fuel flow to the time of proof of the ignition device or burner flame, as applicable, shall not exceed the appropriate flame-establishing period as specified in Section 4.6.2.

5.11.1.4. Flame failure lock-out time

The fuel cell power system shall operate at its rated fuel consumption rate until thermal equilibrium is achieved. The flame failure lock-out time is measured between the moment when the pilot (if equipped) and main burner are intentionally extinguished by shutting off the fuel and the moment when, after admission of the fuel is restored, it ceases by the action of the safety device. The safety device shall de-energize all fuel safety shutoff valves within the flame failure lock-out time specified in section 4.6.2. With the burner alight, flame failure is simulated by disconnection of the flame detector, and the time is measured that elapses between this moment and that when the flame supervision device effectively shuts off the fuel supply. For the purposes of this test, the control manufacturer's specified maximum flame failure lock-out time shall be used.

5.11.1.5. Recycling/Spark restoration

With a recycling ignition system, the recycle time shall be checked with the fuel cell power system being adjusted to its rated fuel consumption rate. The recycle time is the period of time between shut off of the fuel supply following loss of flame and reactivation of the igniter. When spark restoration occurs, it shall be verified that after flame failure the igniter effectively re-lit the fuel within the flame establishing period.

Flames shall not flash outside the fuel cell power system, nor shall there be any damage to the fuel cell power system. With the burner alight, flame failure is simulated by disconnection of the flame detector.

Observe the time that elapses between flame outage to when the flame detector acts to shutdown fuel flow. Also, observe the time that elapses between the moment when the fuel flow stops to when the igniter re-energizes. For the purposes of this test, the control manufacturer's specified maximum flame failure lock-out time and minimum recycle time shall be used.

5.11.1.6. Pilot flame reduction

A pilot, when provided, shall effect safe ignition of fuel at the burner when the pilot fuel supply is reduced to an amount just sufficient to keep the safety shutoff valve open or just above the point of flame extinction, whichever represents the higher pilot fuel rate. Flames shall not flash outside the fuel cell power system, nor shall there be any damage to the fuel cell power system.

For purposes of this test, the control manufacturer's specified maximum flame failure lock-out time shall be used.

This test shall be initiated from both a cold start and immediately after the fuel cell power system has been shutoff after equilibrium condition.

5.11.1.7. Delayed ignition

For a fuel cell power system that is arranged for ignition of the main burner directly by an electric igniter, delay of ignition of the fuel shall not result in flashback of flame to the outside of the fuel cell power system or any damage to the fuel cell power system and the connected vent system. For purposes of this test, the control manufacturer's specified maximum trial for ignition period for the automatic fuel ignition system shall be used. For systems that deactivate the igniter prior to the end of the trial for ignition period, the test shall be conducted using the control manufacturer's specified maximum ignition activation period timing.

With the fuel cell power system at room temperature, the fuel cell power system shall be placed into operation at normal heat input rate with the ignition means temporarily circumvented for varying intervals of time up to the control manufacturer's maximum specified trial for ignition period or maximum specified ignition activation period, whichever is shorter. For multi-try systems, attempts to ignite shall be made for varying intervals of time for each trial for ignition period and any time the ignition means is activated throughout the total operating sequence up to lockout. The ignition of the main burner shall be observed for each of the trials. There shall be no flame flashout or damage to the fuel cell power system. Delayed ignition testing is also used to confirm the flame establishing period provided by the manufacturer.

5.11.1.8 Ignition system components temperature test

Thermocouples or equivalent temperature measuring devices shall be suitably attached to applicable points of each ignition system component. The fuel cell power system shall be operated at rated fuel consumption rate until equilibrium condition is obtained. Temperatures of the components shall then be obtained. The temperatures obtained shall not exceed those for which the components are listed.

5.11.1.9 Pre-purge

This test is applicable to systems that require purge as per Section 4.6.2q.

According to the option chosen by the manufacturer, the pre-purge volume or the pre-purge time are determined as follows:

a) Pre-purge volume

   1) The rate is measured at the outlet of the combustion products evacuation duct, at ambient temperature. (Measured as nominal flow)
   2) The fuel cell power system is at ambient temperature and not operating. The fan is supplied with electricity under actual pre-purge conditions.

3) The rate, measured with a limit of error of +/- 5-percent, is corrected to reference conditions.

4) The manufacturer states the volume of the combustion circuit.

b) Pre-purge time

1) The fuel cell power system is at ambient temperature and not operating.

The time between the fan starting and the ignition device being energized is determined.

It is checked that the requirements of 4.6.3 are satisfied.

5.11.2 Automated control of catalytic oxidation reactors

a) The time of initiation of fuel flow to proof of the reaction initiation shall not exceed the reaction initiation time specified in 4.6.3

Method of test

The fuel cell power system shall be operated as specified by the manufacturer until conditions for reaction initiation are attained. Then, the fuel supply for air-rich operation, or for fuel-rich operation, the supply of air, shall be opened. The system response time shall begin at that point of time and shall end when the reactor monitoring devices signal as specified by the manufacturer that the reaction has been successfully initiated. The reaction initiation time shall not exceed the value specified in 4.6.3.

b) In the event of reaction extinction or reaction rate decrease or increase to unsafe levels, the primary safety control shall de-energize the fuel safety shutoff valve for air-rich operation, or for fuel-rich operation, the air safety shutoff valve followed suit by the de-energizing of the fuel safety shutoff valve, within the reaction failure lock-out time specified in 4.6.3.

Method of test

The fuel cell power system shall be operated as specified in 5.3 until equilibrium conditions are attained. Then, the fuel supply for air-rich operation, or for fuel-rich operation, the supply of air, shall be shut off. With the catalytic reactor alight, reaction failure is simulated by disconnection of the device monitoring the reaction temperature. The time measured between this moment and the time when the system control shuts off the fuel supply for air rich operation, or the supply of all reactants for fuel-rich operation, shall not exceed the reaction failure lock-out time specified in 4.6.3.

5.12 Exhaust gas temperature test

When the fuel cell power system is provided with a venting system (see 4.12), 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

Method of test

The exhaust gas temperature shall be measured by a thermocouple or similar devices. A sufficient number should be used to establish the average temperature within the exhaust streams while considering size and symmetry of the venting systems.

The fuel cell power system shall be installed and operated as specified in the applicable provisions of 5.3. When equilibrium conditions are attained, the average temperature of the exhaust gases shall be determined as specified above. The temperature obtained shall not exceed the temperature for which the venting system material has been determined to be acceptable.

5.13 Surface and component temperatures

a) The fuel cell power system shall be installed and operated as specified in 5.3. When equilibrium conditions are attained, temperatures shall be determined as per procedure indicated in 5.1.

The maximum temperature of any surface that may be contacted by personnel performing regular and routine service while the fuel cell power system is in operation shall not exceed the limits specified in 4.4.9.

The maximum temperature of any remaining surface that may be exposed to flammable gas or vapor above 25% of the lower flammability limit shall not exceed the 80% of self ignition temperature (°C) with the exception of internal surfaces which are intended to operate at temperatures above the self ignition temperatures of the combustible gases.

The maximum temperature of electrical equipment and wiring shall not exceed the temperature to which the components are rated.

b) Wall, Floor and Ceiling Temperatures

This test is only for stationary power systems intended for installation on or near combustible surfaces.

The fuel cell system is placed on the test panels made of wood.

The manufacturer shall specify the distance between the fuel cell system and the back and sidewalls, ceiling (and closet door, if applicable) of the test panels.

The fuel cell system is placed on the test panels having the following specifications:

Dull black-painted plywood approximately 20mm thick is used for the test panels.

Temperature rises are determined by means of thermocouples.

Thermocouples used for determining the temperature rise of the surface of walls, ceiling and floor of the test corner are attached to the back of small blackened disks of copper or brass,. The front of the disk is flush with the surface of the boards.

As far as possible, the fuel cell system is positioned so that the thermocouples detect the highest temperatures.

The fuel cell 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 whether the requirements of section 4.4.9(b) are met.

5.14 Wind tests

Wind tests are only applicable for fuel cell systems intended for installation outdoor or indoor units having horizontal air inlets and exhaust to the outdoors.

5.14.1 Wind Source Calibration Procedure for Winds Directed Perpendicular to the Wall

The wind source calibration configuration shall consist of the center of the wind source being directed perpendicular to the center of a test wall equipped with 4 ports located around a vent terminal which is installed in the center of the test wall, in accordance with the manufacturer's installation instructions (see Appendix 3, Figure: Test Wall with Static Pressure Ports and Vent Terminal Locations). The ports shall be manifolded to obtain a single average static pressure reading. With the wind source directed against the wall, the average static pressure reading as measured by a manometer referenced at the fuel cell power system combustion air opening shall form the basis for calibrating the wind source using the following relationships:

Nominal km/h	Average Static Pressure (Pa)
16	10
54	116

Additionally, the wind source calibrated at 54 km/h shall not generate a velocity pressure exceeding 12 Pa [16km/h] at a distance of 305 mm perpendicular to the test wall and in line with the ports

5.14.2 Verification of operation of outdoor fuel cell power systems under wind conditions

The procedures of this section apply only to fuel cell power systems intended for outdoor installation or components of fuel cell power systems intended for outdoor installation.

Cabinets of fuel cell power systems intended for outdoor installation or enclosures of components of hydrogen generators intended for outdoor installation shall be subject to and pass a wind test as per the following method:

Method of test

The fuel cell power system shall start and operate normally, without damage or malfunctioning of any part and without creating a hazardous or unsafe condition, when exposed to winds having nominal velocities up to and including 54 km/h.

A wind, produced by a fan/blower of sufficient capacity to develop a draft having a velocity up to and including 54 km/h, shall be directed against an outer surface of the fuel cell power system at the point(s) deemed most critical by the testing agency. The fan/blower shall be located so a uniform wind, covering the entire projected area of the outer surface, is directed horizontally toward the fuel cell power system at the specified velocity measured in a vertical plane 50 cm from the windward surface of the fuel cell power system.

With the fuel cell power system subjected to a wind having a nominal velocity of 16 km/h, the pilot, when provided, shall be capable of being ignited.

With the fuel cell power system subjected to a wind having a nominal velocity of 54 km/h, the burner gas shall ignite from the ignition device without excessive delay and the burner and pilot flames shall not extinguish. The pilot, when provided, shall be operated alone, as well as simultaneously with the burner.

At the discretion of the conformity assessment organization, additional tests may be conducted with winds of specified and unspecified velocities directed from other direction(s).

5.14.3 Verification of operation of indoor fuel cell power systems vented horizontally through an outside wall

Method of Test

These tests shall be conducted at normal inlet test pressure.

a) The fuel cell power system shall meet the requirement of Section 4.5.3(l) when testing with a wind direction other than perpendicular to the wall, except that the wind produced by the wind source shall have a nominal velocity of 54 km/h (134.5 Pa free-stream velocity pressure) measured with the wind parallel to the wall with a Pitot tube at three locations positioned on a plane perpendicular to the wall and also bisecting the vent system. The three locations shall be at distances of 305 mm horizontally and vertically from the extremities of the vent system]. See Appendix 4.

After the calibration of the wind source parallel to the wall the wind source or test wall shall be rotated to direct the wind from other angles at the discretion of the test agency.

b) For wind directed perpendicularly to the wall, either of the following test methods shall apply.

1. The following test method shall be applied at the maximum vent length specified. Remove only the vent terminal from the horizontal vent, when a vent terminal is used. Equip the vent pipe with a piezo ring 305 mm from the outlet of the horizontal vent [See Appendix 5, Figure: Piezo Ring and Details of Typical Construction]. Connect the piezo ring to a differential pressure gage that can be read directly to within 1.24 Pa pressure. The manometer reference pressure connection shall be extended to a point adjacent to the fuel cell combustion air supply opening.

   Start fuel cell power system operation. Restrict the end of the vent until the pressure at the piezo ring reaches 116 Pa. Stop fuel cell power system operations. Turn on gas supply to the fuel cell power system. With the restriction still in place, start the fuel cell power system operation from a cold start. While under the above condition, the fuel cell power system shall not shut down. After steady-state conditions are attained readjust the restriction to maintain 116 Pa. While operating under the above condition, the fuel cell power system shall not shut down during a 10-minute period. While maintaining the vent pressure of 116 Pa the fuel cell power system shall be turned on and off by the automatic controls, and the fuel cell power system shall start up without excessive delay.

2. The following test method shall be applied at the maximum vent length specified. The wind produced by the wind source shall have a nominal velocity of 54 km/h calibrated as specified in Section 5.16.1.

   The fuel cell power system shall start when exposed to a 54 km/h wind and continue to operate.

5.14.4 CO emissions under wind - indoor units:

For fuel cell power systems installed indoors and utilizing an exterior wall vent air inlet, the CO emissions shall be checked when a wind ranging from zero to 54 km/h is exerted against the vent-air intake terminal(s). The wind is applied from any horizontal direction with respect to the vent-air terminals. The vent-air intake system is exposed to a 54km/h wind velocity [Freesteam velocity pressure of 134.5 Pa measured with a Pitot tube at three locations on a plane perpendicular to the wall and also bisecting the vent-air intake system. The three locations shall be at distances of 305 mm horizontally and vertically from the extremities of vent-air intake system]. The fuel cell power system shall operate at nominal input rate until a constant exhaust gas temperature is achieved. During the application of this range of wind velocities, the CO emissions are measured to verify compliance with the requirement of Section 4.4.11.

After the calibration of the wind source parallel to the wall the wind source or test wall shall be rotated to direct the wind from other angles at the discretion of the conformity assessment organization.

5.14.5 CO emissions under wind - outdoor units

For fuel cell power system installed outdoors, the CO emissions shall be checked when the unit is exposed to a wind ranging from zero to 54 km/h. A wind, produced by a blower of sufficient capacity to develop a draft having a velocity up to and including 54 km/h, shall be directed against an outer surface of the hydrogen generator at the points deemed most critical by the conformity assessment organization. The blower shall be located so a uniform wind, covering the entire projected area of the outer surface, is directed horizontally toward the fuel cell power system at the specified velocity measured in a vertical plane 0.5m from the windward surface of the fuel cell power system. The fuel cell power system shall operate at nominal input rate until a constant exhaust gas temperature is achieved. During the application of this range of velocities, the CO emissions are measured.

5.15 Rain test

Rain test is applicable for outdoors units only. The rain test shall be performed as defined in IEC 60529 for the manufacturer's declared IP rating.

5.16 CO emissions

Carbon Monoxide emissions to the room or exhausted outside shall not be in excess of 300 ppm in an air-free sample of the effluents as per tests in Sections 5.16.1, 5.16.2 and 5.16.3.

5.16.1 Blocked exhaust outlet

The CO emissions shall be checked with the fuel cell power system's exhaust outlet blocked to any degree up to and including complete closure. The fuel cell power system shall be operated at nominal fuel input rate for at least 15 minutes. When the fuel cell power system incorporates a control to automatically shut off the main fuel supply under blocked outlet conditions, the area of the exhaust outlet shall be gradually decreased to the lowest point at which the control will remain in its open position.

5.16.2 Blocked air supply

a) With the fuel cell power system at ambient temperature and the air supply duct completely blocked, the air supply duct is opened gradually. The blockage at which the burner is able to ignite is determined. At this blockage and once thermal equilibrium has been achieved, the CO emissions are measured.

b) The fuel cell power system shall be operated at nominal heat input rate for at least 15 minutes. The air intake duct is progressively blocked. The CO emissions shall then be measured.

5.16.3 Voltage variation

This test is performed on fuel cell power systems that rely on mechanical fan. The fuel cell power system shall be operated at steady state. Then the following tests shall be conducted:

a) The voltage at the fan terminals is progressively reduced. It is checked that the gas supply is shut off before the CO concentration of the combustion products exceeds the requirement of Section 5.16.

b) With the fuel cell power system at ambient temperature, the voltage at the fan terminals is progressively increased from zero. The voltage at which the burner ignites is determined. At this voltage, the CO emissions are measured to verify compliance with the requirement of Section 5.161.

5.17 Leakage tests (Repeat)

The Fuel Cell System shall be re-tested for leakage at the same testing conditions as specified in Clause 5.4 “Leakage tests”.

6. Routine Tests

Routine Tests shall be performed on all production units. They shall be performed in a test environment simulating the application of the fuel cell system, which the fuel cell system is designed for, in order to obtain the required operating conditions. In particular, the test environment for the Routine Tests shall

provide interfaces at BOUNDARY LIMITS according to the designed application of the fuel cell plant. It is recommended to perform the Routine Tests in the order as described below.
In case of performing the Routine Tests in direct conjunction with the initial start-up and conditioning procedure of the fuel cell system, it is connected to the conditioning facility and is under operational conditions as specified by the manufacturer.

The following Routine Tests shall be performed on all fuel cell power systems:

Gas Leakage Test

The Gas Leakage Test shall be performed as described under Clause 5.4.

Normal Operation Test

As described under Clause 5.5

Dielectric Strength Test

As described under Clause 5.9

Coolant Leakage Test (*Liquid Coolant Only)*

As described under Clause 5.4.1

The following tests shall be performed based on a sampling plan:

Burner Operation Test

Emissions Test

7. Marking, Labeling and Packaging

7.1 General requirements

The fuel cell power system shall be marked in compliance with the applicable sections of ISO 4898: 1994/Add 2: 1998 Labeling and marking of products.

7.2 Fuel cell power system marking

Each fuel cell power system shall bear a data plate or combination of adjacent labels located so as to be easily read when the fuel cell power system is in a normally installed position.

The marking shall clearly state any restrictions on use, in particular the restriction whereby the fuel cell power system shall be installed only in areas where there is sufficient ventilation.

The data plate/label(s) shall include the following information:

a) Manufacturer's name (with trademark), and location;

b) Manufacturer’s Model number or trade name;

c) Serial number of the fuel cell power system and year of manufacture;

d) Fuel Cell Type;

e) Electrical Input, as applicable (Voltage/Type of current/Frequency/Phase /Power Consumption;

f) Electrical Output (Voltage/Type of current/Frequency/Phase /Rated Power/Power Factor; KVA;

g) Fuel type and quality to be used by the fuel cell power system;

h) Range of fuel supply pressure;

i) Fuel consumption at rated power (kW);

j) Range of ambient temperatures (minimum and maximum) within which the fuel cell power system is intended to operate in degrees Celsius;

k) outdoor or indoor use;

l) Heating circuit (if applicable): Rated heat output (kW), Max Flow, Pressure, Temperature;

m) Grid Interactivity: Stand Alone/grid parallel bi-directional/grid parallel uni-directional, as applicable (output or input only);

n) Warnings for alerting personnel to the potential for personal injury or equipment damage and requirements to follow installation and operation instruction;

o) Number that refers to this International Standard;

p) Symbol of the organization making examination for compliance to this standard.

If the fuel cell power system is rated under hazardous area classification as per IEC 60079-10, it shall be marked accordingly.

7.3 Marking of components

All types of valves, transmitters, motors, pumps, and fans shall be identified to match the fuel cell power system drawings.

Warning signs shall be appropriately placed to identify electrical hazards, contents from drain valves, hot components and mechanical hazards. Preference should be given to the use of standard symbols given in ISO 3864:1984 Safety colors and safety signs.

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 should be given to the use of standard symbols given in IEC 60417 and ISO 7000.

7.4 Technical documentation

7.4.1 General

The manufacturer shall provide with each fuel cell power system the information necessary for safe installation, operation, and servicing of the fuel cell power system and shall in particular draw attention to any restrictions on use. The information shall be provided in form of technical documents such as drawings, diagrams, charts, tables and instructions and these shall be on suitable data medium and language.

Part of the technical information might be provided only to qualified personnel, in which case the manufacturer shall specify criteria for qualification of personnel.

The information provided with the fuel cell power system shall include:

- a clear, comprehensive description of the equipment, installation and mounting, and the connection to electrical supply(ies);
- electrical supply(ies) requirements;
- physical environment and operating conditions (fuel and water supply characteristics, etc.) as per 4.2
- electric circuit diagrams
- information (where appropriate) on:
  a) handling, transportation and storage;
  b) software programming;
  c) sequence of operations;
  d) frequency of inspection;
  e) frequency and method of functional testing;
  f) guidance on the adjustment, maintenance, and repair, particularly of the protective devices and circuits; and
  g) parts list and recommended spare parts list.
- A description (including interconnection diagrams) of the safeguards, interlocking functions, and interlocking of guards for potentially hazardous situations.
- A description of the safeguarding and of the means provided where it is necessary to suspend the safeguarding (e.g. for manual programming, program verification)

7.4.2 Installation manual

The installation manual shall provide the installer all the information necessary for the preliminary work of setting-up the machine.

In particular, an interconnection diagram or table shall be provided. That diagram or table shall give full information about all external connections (e.g. electrical supply, fuel supply, water supply, control signals, exhaust venting, ventilation connections, etc.).

These installation instructions shall provide guidelines on: location and design of the fuel cell power system foundation; ventilation requirements; protection from weather hazards; recommended height in relation to the base flood elevation; security enclosure; acceptable distances from combustible materials, vegetation, sidewalks, public ways, roads, and railroad tracks; and protection from vehicular impact.

In addition to the above, the installation manual shall specify:

- The manufacturer's or distributor's name and location, and the model number of the fuel cell power system,
- The minimum and maximum fuel supply pressures and the method of determining these pressures,
- Adequate clearances around air supply, ventilation and exhaust openings,

- Adequate clearances for maintenance, servicing and proper operation,
- Adequate clearances to combustible materials,
- A sediment trap or filter must be provided upstream of the fuel controls, when applicable, and
- If appropriate, special instructions for extended dormant periods.

7.4.3 User's information manual

For fuel cell power systems to be installed for residential use, the system supplier shall provide to the residence owner a user's information manual, together with any appropriate additional information to facilitate maintenance (e.g. addresses of the importer, repairer, etc.).

The user's information manuals shall be typed or typeset and formatted to provide easy-to-follow procedures. Illustrations should be used to identify fuel cell components, dimensions and clearances, assembled components, and connection points as needed to make the instructions clear. Illustrations should also be used to identify the location of 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.

The user's information manual shall be affixed to the fuel cell in a pocket or attached by a clip which is part of the fuel cell or shall be supplied in an envelope(s) marked with instructions (1) to the installer to affix them on or adjacent to the fuel cell, and/or (2) to the consumer to retain them for future reference. 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 following safety information, as applicable:

a. 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 following safety precautions boxed as shown:

For Odorized Gas Fueled Systems:

WARNING:

FIRE OR EXPLOSION HAZARD

Failure to follow safety warnings exactly could result in serious injury, death or property damage.

– **Do not store or use gasoline or other flammable vapors and liquids in the vicinity of this or any other appliance.**

– **WHAT TO DO IF YOU SMELL GAS**

- **Do not try to light any appliance.**
- **Do not touch any electrical switch; do not use any phone in the area.**
- **Leave the area immediately.**
- **Immediately call your gas supplier. Follow the gas supplier's instructions.**
- **If you cannot reach your gas supplier, call the fire department.**

– **Installation and service must be performed by a qualified installer, service agency or the gas supplier.**

For Odorant-Free Gas Fueled Systems:

⚠ WARNING:

FIRE OR EXPLOSION HAZARD

Failure to follow safety warnings exactly could result in serious injury, death or property damage.

- **Do not store or use gasoline or other flammable vapors and liquids in the vicinity of this or any other appliance.**
- **Installation and service must be performed by a qualified installer, service agency or the gas supplier.**

For Liquid Fueled Systems:

WARNING:

FIRE OR EXPLOSION HAZARD

Failure to follow safety warnings exactly could result in serious injury, death or property damage.

– **Do not store or use gasoline or other flammable vapors and liquids in the vicinity of this or any other appliance.**

– **WHAT TO DO IF YOU SEE LIQUID LEAKAGE**

- **Do not try to light any appliance.**
- **Do not touch any electrical switch; do not use any phone in the area.**
- **Leave the area immediately.**
- **Immediately call your fuel supplier. Follow the fuel supplier's instructions.**
- **If you cannot reach your fuel supplier, call the fire department.**

– **Installation and service must be performed by a qualified installer, service agency or the fuel supplier.**

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

b. Safety Section:

A safety section shall be included near the front of the manual to present fuel cell users with a listing of potential hazards and safety related instructions for a particular fuel cell. Statement of at least the following shall be included in the safety section with references to specific section or page of the manual.

1. Directions that the area surrounding the fuel cell must be kept clear and free of combustible materials, gasoline and other flammable vapors and liquids.

2. Where requiring air for combustion or ventilation, instructions not to block or obstruct air openings on the fuel cell, air openings communicating with the area in which the fuel cell is installed, and the required spacings around the fuel cell that provide clearances to secure and discharge required air.

3. Instructions for starting and shutting down the fuel cell. These instructions shall pictorially illustrate and locate all user interface components.

4. The following statement: "Do not use this fuel cell if any part has been under water. A flood-damaged fuel cell is potentially dangerous. Attempts to use the fuel cell can result in fire or explosion. A qualified service agency should be contacted to inspect the fuel cell and to replace all gas controls, control system parts, electrical parts that have been wet.

5. 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.

6. Recommended methods for periodic cleaning of necessary parts.

7. Instructions for examining the fuel cell installation to determine that:

   a. Any intake or exhaust openings associated with those items covered in 1.9, Drain, Venting and Ventilation Exhaust Systems, are clear and free of obstructions.

   b. The physical support of the fuel cell is sound without sagging cracks, gaps, etc, around the base so as to provide a seal between the support and the base.

   c. There are no obvious signs of deterioration of the fuel cell.

8. The manual shall indicate the necessity and minimum frequency for the examination in 1.18.4-b7 above by the user and shall also specify the periodic inspection of the fuel cell by a qualified service agent.

c. In-Text Safety Information:

In-text safety instructions should refer to or incorporate safety precautions from the front cover and from the safety section of the manual. Potentially hazardous situations described in the manual require that additional safety precautionary statements be created.

7.4.4 Operating manual

The operating manual shall detail proper procedures for set-up and use of the fuel cell power system. Particular attention should be given to the safety measures provided and to the improper methods of operation that are anticipated.

The operation manual shall include a section on the hazards related to the use of the fuel cell power system.

Where the operation of equipment can be programmed, detailed information on methods of programming, equipment required, program verification and additional safety procedures (where required) shall be provided.

The instructions shall give information concerning airborne noise emissions by the fuel cell power system, either the actual value or a value established on the basis of measurements made on identical fuel cell power system:

If the manufacturer foresees that the fuel cell power system will be used in a potentially explosive atmosphere, the instructions shall give all the necessary information.

In the case of the fuel cell power system which may also be intended for use by non-professional operators, the wording and layout of the instructions for use, whilst respecting the other essential requirements mentioned above, shall take into account the level of general education and acumen that can reasonably be expected from such operators.

7.4.5 Maintenance manual

The maintenance manual shall detail proper procedures for adjustment, servicing, and preventive inspection, and repair. Recommendations on maintenance/servicing records should be part of the maintenance manual. Where methods for the verification of proper operation are provided (e.g. software testing programs), the use of such methods shall be detailed.

This manual shall contain clearly defined, legible and complete instructions for at least the following:

- Instructions for starting and shutting down the fuel cell power system. These instructions shall pictorially illustrate and locate all components.
- 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.
- Recommended methods for periodic cleaning of necessary parts.
- Instructions for lubrication of moving parts, including type, grade and amount of lubricant.
- Instructions for examining the fuel cell power system installation to determine that:
    a) Any intake or exhaust openings are clear and free of obstructions.
    b) There are no obvious signs of physical deterioration of the fuel cell power system or its support (i.e. base, frame, cabinet, etc.).
- Periodic examination of the venting system and all functional parts.
- A replacement parts list, including information necessary for ordering spare or replacement parts.
- Directions that the area surrounding the fuel cell power system must be kept clean and free of combustible materials, gasoline and other flammable vapors and liquids.
- The following statement: Do not use this fuel cell power system if any part has been under water. Immediately call qualified service personnel to inspect the fuel cell power system and to replace any function part which has been under water.
- Instructions and a schedule for neutralizing condensate, if appropriate.

The maintenance manual shall also provide an enumeration of all regular and routine maintenance activities to be performed on the fuel cell power system components and indicate the necessity and minimum frequency for these examinations. The maintenance manual shall specify the periodic inspection of the fuel cell power system that shall be performed by qualified service personnel.

Appendix 1. Table 5.0 Significant hazards, hazardous situations and events dealt with in this standard.

Significant hazards, hazardous situations and events	Section
Mechanical hazards due to:	
Shape (sharp surfaces)	4.4
Relative location (trip/crash hazard)	4.4
Mass and stability (potential energy of elements which may move under the effect of gravity)	4.4
Mass and velocity (kinetic energy of elements in controlled or uncontrolled motion)	4.4, 4.12
Inadequacy of mechanical strength (inadequate specification of material or geometry)	4.4, 4.5, 4.13
Fluids under pressure (overpressurization, ejection of fluids under pressure, vacuum)	4.4, 4.5
Electrical hazards due to:	
Contact of persons with live parts (direct contact)	4.7
Contact of persons with parts that have become live under faulty conditions (indirect contact)	4.7
Approach to live parts under high voltage	4.7
Electrostatic phenomena	4.6, 4.7
Electromagnetic phenomena	4.8
Heat/ chemical effects from short circuits, overloads	4.7
Projection of molten particles	4.7
Thermal hazards due to:	
Contact of persons with surfaces at extreme high temperatures	4.4
Release of high temperature fluids	4.5
Thermal fatigue	4.3, 4.5
Equipment overtemperature causing unsafe operation	4.9
Hazards generated by materials and substances:	
Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes and dusts.	4.4
Fire or explosion hazard due to leak of flammable fluids	4.6

Fire or explosion hazard due to internal build-up of flammable mixture	4.6
Hazardous situations caused by material deterioration (e.g. corrosion) or accumulation (e.g. fouling)	4.3
Asphyxiation	4.4
Reactive Materials (pyrophoric)	4.4
Hazards generated by malfunctions:	
Unsafe operation due to failures or inadequacy of software or control logic	4.9
Unsafe operation due to failures of control circuit or protective / safety components	4.9
Unsafe operation due to power outage	4.9
Hazards generated by neglecting ergonomic principles	
Hazards due to inadequate design, location or identification of manual controls	4.9
Hazards due to inadequate design or location of visual display units and warning signs	4.9
Noise	4.4
Hazards generated by erroneous human intervention	
Hazards due to deviation from correct operating	4.9, 7.4
Hazards due to errors of manufacturing/fitting/installation	4.4, 7.4
Hazards due to errors of maintenance	7.4
Vandalism	
Environmental Hazards:	
Unsafe operation in extreme hot/cold environments	4.13
Rain, flooding	4.13
Wind	4.13
Earthquake	4.4
External Fire	
Smoke	
Snow, ice load	4.13
Attack by vermin	
Pollution:	
Air pollution	4.4

Water pollution	4.4, 4.5
Soil pollution	4.4

Appendix 2. Carburisation and Material Compatibility for Hydrogen Service

(This Appendix is informative and is not part of the standard.)

A2.1 Carburisation

Conventional carburisation is a familiar problem with high-temperature alloys in steam reforming furnaces. It is caused by the inward migration of carbon, the source of which is hydrocarbon cracking, resulting in the formation of carbides within the metal matrix. The process is promoted by high temperature, typically > 800 $_{o}$C , and leads ultimately to loss of ductility.

In general carburisation of an alloy results in low ductility at ambient temperatures. Carbon pickup will increase the volume of the metal and coefficient of expansion, resulting in strong internal stresses that give rise to premature failure of equipment. Failure is usually by creep rupture and low-cycle fatigue. If carburisation is sufficiently severe it can also affect the elevated temperature creep and rupture characteristics. There seems to be differences in tolerance between the various alloys regarding this issue.

Generally the carburisation rate varies with:

Temperature – The rate roughly doubles for every 55$_{o}$C increase.

Reaction kinetics is controlled by the ratio of CO/CO_2 in the gas and by the temperature. A CO/CO_2 ratio of t results in extremely severe attack, while a ratio of 0.5 yields insignificant attack.

Strongly carburising conditions are $CO/CH_4/H_2$-flows with a low steam/carbon ratio at intermediate temperatures (usually 450 – 850$_{o}$C), and an oxide layer with flaws.

Nickel and silicon content – High values are beneficial

Protective and regenerative oxide films – Cr, Si and Al in the alloy are beneficial.

These rules are general and may not be true for all material/environment combinations due to the anomalous character of metal reactions.

A2.2 Material Compatibility for Hydrogen Service

Components in which gaseous hydrogen or hydrogen-containing fluids are processed, as well as all parts used to seal or interconnect the same, should be sufficiently resistant to the chemical and physical action of hydrogen at the operating conditions.

A2.2.1 Metals and Metallic Materials

Users of this standard should be aware that engineering materials exposed to hydrogen in their service environment may exhibit an increased susceptibility to hydrogen assisted corrosion via different mechanisms such as hydrogen embrittlement and hydrogen attack.

Hydrogen embrittlement is defined as a process resulting in a decrease of the toughness or ductility of a metal due to the permeation of atomic hydrogen.

Hydrogen embrittlement has been recognized classically as being of two types. The first, known as internal hydrogen embrittlement, occurs when the hydrogen enters the metal matrix through material processing techniques and supersaturates the metal with hydrogen. The second type, environmental hydrogen embrittlement, results from hydrogen being absorbed by solid metals from the service environment.

Atomic hydrogen dissolved within a metal interacts with the intrinsic defects of the metal typically increasing crack propagation susceptibility and thus degrading such basic properties as ductility and fracture toughness. There are both important material and environmental variables that contribute to hydrogen-assisted fracture in metals. The material microstructure is an important consideration as second phases, which may or may not be present due to compositional and processing variations, may affect the resistance of the metal to fracture. Second phases, such as ferrite stringers in austenitic stainless steels, may also have a specific orientation leading to profound anisotropic response in the materials. In general, metals can also be processed to have a wide range of strengths, and the resistance to hydrogen-assisted fracture is known to decrease as the strength of the alloy is increased.

The environmental variables affecting hydrogen-assisted fracture include pressure of hydrogen, temperature, chemical environment and strain rate. In general, the susceptibility to hydrogen-assisted fracture increases as hydrogen pressure increases. The effect of temperature, however, is not as systematic. Some metals such as austenitic stainless steels exhibit a local maximum in hydrogen-assisted fracture susceptibility as a function of temperature. Although not well understood, trace gases mixed with the hydrogen gas can also affect hydrogen-assisted fracture. Moisture, for example, may be detrimental to aluminum alloys since wet oxidation produces high-fugacity hydrogen, while in some steels moisture is believed to improve resistance to hydrogen-assisted fracture by producing surface films that serve as kinetic barriers to hydrogen uptake. A socalled inverse strain rate effect is generally observed in the presence of hydrogen; in other words, metals are less susceptible to hydrogen-assisted fracture at high strain rates.

At temperatures close to ambient this phenomenon can affect metals with body centered cubic crystal lattice structure, e.g. ferritic steels. In the absence of residual stress or external loading, environmental hydrogen embrittlement is manifested in various forms, such as blistering, internal cracking, hydride formation, and reduced ductility. With a tensile stress or stress-intensity factor exceeding a specific threshold, the atomic hydrogen interacts with the metal to induce sub-critical crack growth leading to fracture.

Hydrogen embrittlement can occur during elevated-temperature thermal treatments and in service during electroplating, contact with maintenance chemicals, corrosion reactions, cathodic protection, and operating in high-pressure, high temperature hydrogen.

At temperatures above 473°C, many low-alloyed structural steels may suffer from hydrogen attack. This is a non-reversible degradation of the steel microstructure caused by a chemical reaction between diffusing hydrogen and the carbide particles in the steels that results in the nucleation, growth and merging of methane bubbles along grain boundaries to form fissures.

Hydride embrittlement occurs in metals such as titanium and zirconium and is the process of forming thermodynamically stable and relatively brittle hydride phases within the structure.

Clad welding and welds between dissimilar materials often involve high alloy materials. During operation at temperatures over 250°C hydrogen diffuses in the fusion line between the high alloy weld and the unalloyed/ low alloy base material. During shutdown, the material temperature drops. The reduced solubility and diffusibility of hydrogen breaks the weld by disbonding.

The following are some general recommendations for managing the risk of hydrogen embrittlement.

- Select raw materials with a low susceptibility to hydrogen embrittlement by controlling chemistry (e.g. use of carbide stabilizers), microstructure (e.g. use of austenitic stainless steels), and mechanical properties (e.g. restriction of hardness, preferably below 225 HV, and minimization of residual stresses through heat treatment). Use test methods specified in ISO/DIS 11114-4 to select metallic materials resistant to hydrogen embrittlement. The API Publication 941 shows the limitations of various types of steel as a function of hydrogen pressure and temperature. The susceptibility to hydrogen embrittlement of some commonly used metals is summarized in ISO/PDTR 15916.

- Clad welds and welds between dissimilar materials used in hydrogen service should be ultrasonically tested at regular intervals and after uncontrolled shutdowns in which the equipment may have cooled rapidly.

- Minimize the level of applied stress and exposure to fatigue situations.

- When plating parts, manage anode/cathode surface area and efficiency, resulting in proper control of applied current densities. High current densities increase hydrogen charging.

- Clean the metals in non-cathodic alkaline solutions and in inhibited acid solutions.
- Use abrasive cleaners for materials having a hardness of 40 HRC or above.
- Use process control checks, when necessary, to mitigate risk of hydrogen embrittlement during manufacturing.

A2.2.2 Polymers, Elastomers, and other non-metallic materials
Most polymers can be considered suitable for gaseous hydrogen service. Due account should be given to the fact that hydrogen diffuses through these materials much easier than through metals. Polytetrafluoroethylene (PTFE or Teflon®) and Polychlorotrifluoroethylene (PCTFE or Kel-F®) are generally suitable for hydrogen service. Suitability of other materials should be verified. Guidance can be found in ISO/PDTR 15916 and the NASA document NSS 1740.16. See also ANSI/AGA 3.1-1995 for guidance with regard to gaskets, diaphragms, and other non-metallic parts.

Further guidance on hydrogen assisted corrosion and control techniques may be found through the following standards and organizations:

American Society for Testing and Materials

ASTM **B577-93** 01-Apr-1993
Standard Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper

ASTM **B839-94** 01-Nov-1994
Standard Test Method for Residual Embrittlement in Metallic Coated, Externally Threaded Articles, Fasteners, and Rod-Inclined Wedge Method

ASTM **B849-94** 01-Nov-1994
Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement

ASTM **B850-98** 01-Nov-1998
Standard Guide for Post-Coating Treatments Steel for Reducing the Risk of Hydrogen Embrittlement

ASTM E1681-99 10-Apr-1999
Standard Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials

ASTM **F1459-93** 01-Nov-1993
Standard Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement

ASTM **F1624-00** 01-Aug-2000
Standard Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique

ASTM **F1940-01** 01-Nov-2001
Standard Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners

ASTM **F2078-01** 01-Nov-2001
Standard Termninology Relating to Hydrogen Embrittlement Testing

ASTM **F326-96** 01-Nov-1996
Standard Test Method for Electronic Measurement for Hydrogen Embrittlement from Cadmium-Electroplating Processes

ASTM **F519-97** 01-Nov-1997
Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments

ASTM **G129-00** 01-Aug-2000
Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking

ASTM **G142-98** 01-Nov-1998
Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both

ASTM **G146-01** 01-Feb-2001
Standard Practice for Evaluation of Disbonding of Bimetallic Stainless Alloy/Steel Plate for Use in High-Pressure, High-Temperature Refinery Hydrogen Service

ASTM **G148-97** 01-Nov-1997
Standard Practice for Evaluation of Hydrogen Uptake, Permeation, and Transport in Metals by an Electrochemical Technique

The National Association of Corrosion Engineers

NACE TM0177-96 23-Dec-1996
Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking in Hydrogen Sulfide (H2S) Environments

NACE TM0284-96 30-Mar-1996
Standard Test Method - Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking

The American Petroleum Institute

API **RP 941** 01-Jan-1997

Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants.

API **934** 01-Dec-2000
Materials and Fabrication Requirements for 2-1/4Cr-1Mo & 3Cr-1Mo Steel Heavy Wall Pressure Vessels for High Temperature, High Pressure Hydrogen Service

American Welding Society

ANSI/AWS A4.3-93 01-Jan-1993
Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding

The American Society of Mechanical Engineers

ASME Boiler and Pressure Vessel Code

ASME/ANSI B31.3 Chemical plant and petroleum refinery piping

ASME/ANSI B31.1 Power piping.

Society of Automotive Engineers

SAE/AMS 2451/4 01-Jul-1998
Plating, Brush, Cadmium - Corrosion Protective, Low Hydrogen Embrittlement

SAE/AMS 2759/9 01-Nov-1996
Hydrogen Embrittlement Relief (Baking) of Steel Parts

SAE/USCAR 5 01-Nov-1998
Avoidance of Hydrogen Embrittlement of Steel

International Standards Organization

ISO **15330** 01-Oct-1999
Fasteners -- Preloading test for the detection of hydrogen embrittlement -- Parallel bearing surface method

ISO **15724** 01-Jan-2001
Metallic and other inorganic coatings - Electrochemical measurement of diffusible hydrogen in steels - Barnacle electrode method

ISO **2626** 01-Oct-1973
Copper - Hydrogen embrittlement test

ISO **3690** 01-Mar-2000
Welding and allied processes -- Determination of hydrogen content in ferritic steel arc weld metal

ISO **3690 /Amd1** 01-Jan-1983
Amendment 1 - Welding - Determination of Hydrogen in Deposited Weld Metal Arising from the Use of Covered Electrodes for Welding Mild and Low Alloy Steels

ISO **7539-6** 1989
Corrosion of metals and alloys—Stress corrosion testing – Part 6: Preparation and use of pre-cracked specimens

ISO **9587** 01-Oct-1999
Metallic and other inorganic coatings -- Pretreatments of iron or steel to reduce the risk of hydrogen embrittlement

ISO **9588** 01-Oct-1999
Metallic and other inorganic coatings -- Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement

ISO **PDTR 15916** 09-May-2002
Basic considerations for the safety of hydrogen systems

ISO/DIS **11114-4** 2004-07-15
Transportable gas cylinders—Compatibility of cylinders and valve materials with gas contents – Part 4: Test methods for hydrogen compatibility with metals

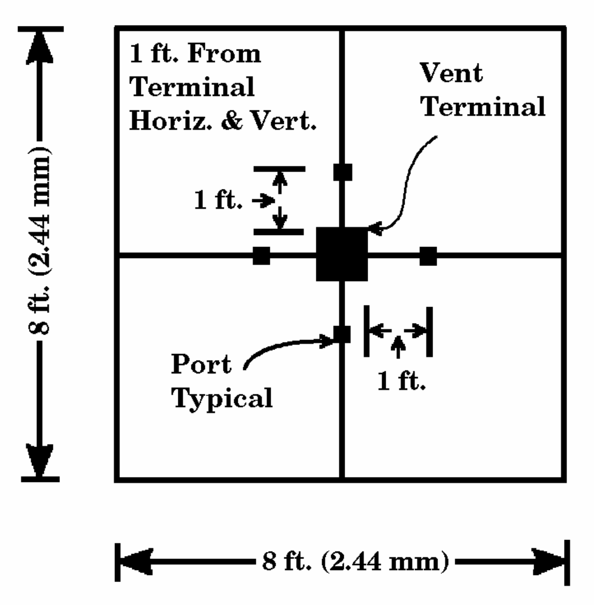
European Standards

BS 7886 01-Jan-1997
Method of Measurement of Hydrogen Permeation and the Determination of Hydrogen Uptake and Transport in Metals by an Electrochemical Technique

DIN **8572-1** 01-Mar-1981
Determination of Diffusible Hydrogen in Weld Metal - Manual Arc Welding

DIN **8572-2** 01-Mar-1981
Determination of Diffusible Hydrogen in Weld Metal - Submerged Arc Welding

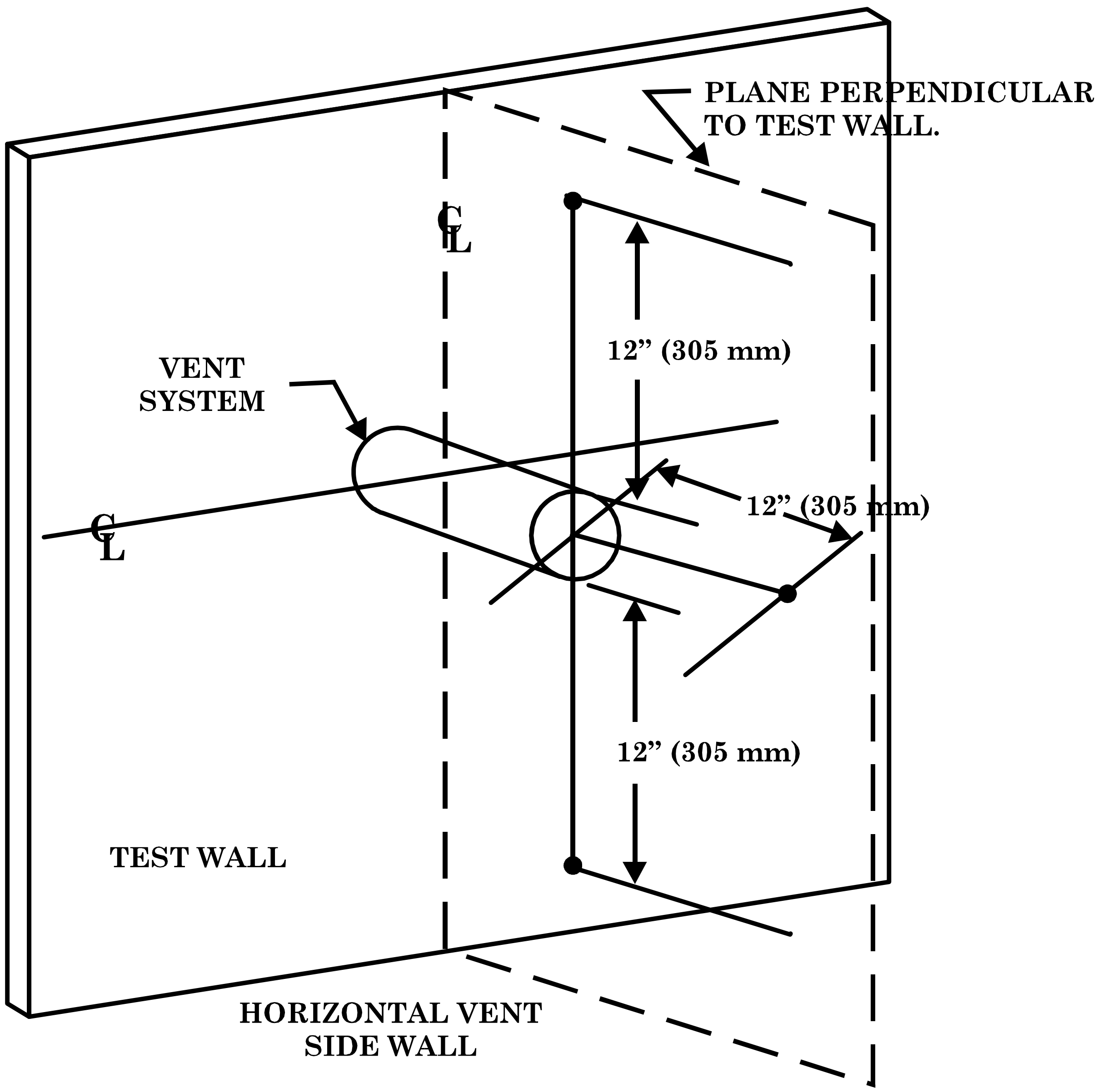
Appendix 3. Figure: Test wall with static pressure ports and vent terminal locations



Points Designate Static Pressure
Ports Located 1 Foot (305 mm)
Horizontally and Vertically from the
Extremities of the Vent Terminal

Vent Terminal Located in Center of Test Wall and in
Accordance With Manufacturers Installation
Instructions

Appendix 4: Figure: Vent test wall



Appendix 5: Figure: Piezo ring and details of typical construction