

American National Standard/
CSA America Standard For
Portable Fuel Cell Power Systems

11/13/2015 23:08:58 MST

First Edition-2004



Approved
October 22, 2004
American National Standards Institute, Inc.

Copyright © 2004

CSA America, Inc.

Permission is granted to republish material herein in laws or ordinances, and in regulations, administrative orders, or similar documents issued by public authorities. Those desiring permission for other republication should consult CSA America, Inc., 8501 East Pleasant Valley Road, Cleveland, Ohio 44131.

American National Standards Institute

The American National Standards Institute (ANSI), Inc. is the nationally recognized coordinator of voluntary standards development in the United States through which voluntary organizations, representing virtually every technical discipline and every facet of trade and commerce, organized labor and consumer interests, establish and improve the some 10,000 national consensus standards currently approved as American National Standards.

ANSI provides that the interests of the public may have appropriate participation and representation in standardization activity, and cooperates with departments and agencies of U.S. Federal, state and local governments in achieving compatibility between government codes and standards and the voluntary standards of industry and commerce.

ANSI represents the interests of the United States in international nontreaty organizations such as

the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The Institute maintains close ties with regional organizations such as the Pacific Area Standards Congress (PASC) and the Pan American Standards Commission (COPANT). As such, ANSI coordinates the activities involved in the U.S. participation in these groups.

ANSI approval of standards is intended to verify that the principles of openness and due process have been followed in the approval procedure and that a consensus of those directly and materially affected by the standards has been achieved. ANSI coordination is intended to assist the voluntary system to ensure that national standards needs are identified and met with a set of standards that are without conflict or unnecessary duplication in their requirements.

Responsibility of approving American National Standards rests with the

***American National Standards Institute, Inc.
25 West 43rd Street, Fourth Floor
New York, NY
10036***



Documents
Document Sharing Hub

Preface

This publication represents a basic standard for safe operation, substantial and durable construction, and acceptable performance of Portable Fuel Cell Power Systems. It is the result of years of experience in the manufacture, testing, installation, maintenance, inspection and research on appliances designed for the utilization of gas. There are risks of injury to persons inherent in appliances that, if completely eliminated, would defeat the utility of the appliance. The provisions in this Standard are intended to help reduce such risks while retaining the normal function of the appliance.

Nothing in this standard is to be considered in any way as indicating a measure of quality beyond compliance with the provisions it contains. It is designed to allow compliance of Portable Fuel Cell Power Systems, the safety, construction and performance of which may exceed the various provisions specified herein. In its preparation, recognition has been given to possibilities of improvement through ingenuity of design. As technical advances take place, revisions may become necessary. When they are believed desirable, recommendations or suggestions should be forwarded to CSA America Inc., Standards Department, 8501 East Pleasant Valley Road, Cleveland, Ohio 44131. A proposal form is provided in the back of this document.

Safe and satisfactory operation of a Portable Fuel Cell Power System depends to a great extent upon its proper installation, use and maintenance. It should be installed in accordance with the *National Fuel Gas Code, ANSI Z223.1/NFPA 54*; manufacturers' installation instructions and local municipal codes.

Users of this American National Standard are advised that the devices, products and activities within its scope may be subject to regulation at the Federal, state or local level. Users are strongly urged to investigate this possibility through appropriate channels. In the event of a conflict with this standard, the Federal, state or local regulations should be followed.

THIS STANDARD IS INTENDED TO BE USED BY THE MANUFACTURING SECTOR AND BY THOSE APPLYING THE EQUIPMENT AND BY THOSE RESPONSIBLE FOR ITS PROPER INSTALLATION. IT IS THE RESPONSIBILITY OF THESE USERS TO DETERMINE THAT IN EACH CASE THIS STANDARD IS SUITABLE FOR AND APPLICABLE TO THE SPECIFIC USE THEY INTEND.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute, Inc., require that action be taken to reaffirm, revise or withdraw this standard no later than five (5) years from the date of approval. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute, Inc., 25 West 43rd Street, Fourth Floor, New York, N.Y. 10036, (212) 642-4900.

EFFECTIVE DATE: An organization using this standard for product evaluation as a part of its certification program will normally establish the date by which all products certified by that organization should comply with this standard.

History Of The Development Of Standards For Portable Fuel Cell Power Systems

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

In 2001 CSA International prepared its first draft of CSA International Requirement 3.01 U.S. for Portable Fuel Cell Power Systems. Simultaneously and in a parallel effort to the completion of Requirement 3.01, CSA America, Inc. decided to further develop the draft CSA International requirement as an American National Standard under American National Standards Institute (ANSI) accreditation as CSA America FC 3.

CSA America formed a Canvass of Fuel Cell Technologies industry experts. An 'Initiation of Canvass' announcement was published in the April 6, 2001 issue of ANSI Standards Action.

In August 2001 CSA International issued its draft of CSA International Requirement 3.01 U.S. for Portable Fuel Cell Power Systems for review and comment to manufacturers of portable fuel cell power systems.

In October 2001 an invitation was issued by CSA America to establish a Canvass for standards on fuel cells. During this same time, a Portable Fuel Cell Technical Advisory Committee (TAC) was formed by CSA America to prepare the draft CSA America FC 3 standard for Canvass balloting.

The CSA America Portable Fuel Cell TAC first met in December 2001 to review proposed changes to the November 2001 draft of CSA International Requirement 3.01 U.S. for Portable Fuel Cell Power Systems.

In April 2002, the CSA America Portable Fuel Cell TAC met again to review new proposed changes to the draft CSA America FC 3 standard resulting from work assignments issued at the first TAC meeting.

In June 2002, CSA International published CSA International Requirement 3.01 U.S. for Portable Fuel Cell Power Systems

A Canvass ballot was distributed on February 14, 2003 with a public review issued in ANSI Standards on March 14, 2003. Additional technical comments needing resolution were received from fuel cell industry experts from the February 2003 Canvass. The CSA America Portable Fuel Cell TAC held a series of teleconference meetings throughout 2003 to resolve the comments resulting from the February 2003 Canvass ballot.

A second Canvass ballot was distributed on December 7, 2003 with a public review issued in ANSI Standards Action on December 26, 2003, which resulted in approval of the document.

The first edition of the American National Standard for Portable Fuel Cell Power Systems, was approved by the American National Standards Institute Inc., on October 22, 2004.

The designation and year of this new standard is as follows:

ANSI / CSA America FC 3 - 2004

CSA America Portable Fuel Cell Canvass

Jeff Grant
Ballard Power Systems, Inc.

Randy Dey
CCS Global Group, Inc.

Sam Quang
ChevronTexaco Corp.

Greg Chirdon
CSA International

David Sutula
Gas Appliance Manufacturers
Association, Inc.

John Bossert
Hazloc, Inc.

Huseyin Ayman
Hydrogenics Corporation

Mario Sandoval
HydrogenSource

Robert Shepherd
IAPMO Representative

Bruce Downing
MagPower Systems, Inc.

Gregory Dolan
Methanol Institute

Jack Schwarzenbach
Metallic Power, Inc.

Adam Briggs
Millennium Cell

James Moir
MTI Micro Fuel Cells, Inc.

Karen Hall
National Hydrogen Association

John Fisher
ReliOn, Inc.

Don Snyder
Underwriters Laboratories, Inc.

Anthony Al Vasys
Consultant, U.S. DoE

Robert Wichert
US Fuel Cell Council

William Collins
UTC Fuel Cells

CSA America Portable Fuel Cell Canvass

CSA America Portable Fuel Cell Technical Advisory Committee

Robert Wichert (Chairman)

Kenneth Bunk
Eugene Bushmelov
Janet Buyer
John Cervený
Gregory Chirdon
Serge Comtois
Randy Dey
John Donahue
Bruce Downing
John Fisher
Jeff Grant
Craig Holmes
Harry Jones
Thomas Lavka
Steve Leutbecher
Brian Lock
Robert Pendergrass
Bill Pledger
Sam Quang
Matt Romanow
Greg Rush
Mario Sandoval
Richard Shaw
Larry Shockling
Andrew Skok
Todd Strothers
David Sutula

CSA America, Inc. 2004

Contents

Page

Part I: Construction

1.1	Scope	1
1.2	General Construction	2
1.3	Materials.....	5
1.4	Electrical Components and Equipment.....	6
1.5	Enclosures.....	8
1.6	Mechanical Assembly	12
1.7	Cord-Connected Portable Fuel Cell Power System.....	13
1.8	Current-Carrying Parts	14
1.9	Internal Wiring.....	15
1.10	Electrical Insulation	16
1.11	Transformers.....	16
1.12	Motors.....	17
1.13	Capacitors	17
1.14	Suppressors	18
1.15	Fuses and Fuseholders.....	18
1.16	Overload Relays	18
1.17	Switches and Controllers.....	19
1.18	Printed Circuit Boards	19
1.19	Spacings	20
1.20	Separation of Circuits.....	22
1.21	Protection of Control, Battery, and Output Power Circuits	23
1.22	Protection of Receptacles	23
1.23	Battery Supplies	23
1.24	Grounding and Bonding.....	25
1.25	Static Transfer Switches	26
1.26	Heaters and Vessels (If Part of the Portable Fuel Cell Power Systems).....	27
1.27	Protection of the Potable Water Supply.....	28
1.28	Piping Systems.....	28
1.29	Fuel Controls and Equipment.....	30
1.30	Air/Fluid-Handling Equipment.....	31
1.31	Air/Fluid-Moving Equipment.....	32
1.32	Inverters	34
1.33	Uninterruptible AC Power Supplies (UPS).....	34
1.34	Safety Analysis	34
1.35	Instructions.....	35
1.36	Marking.....	40

Part II: Performance

2.1	Ultimate Strength	47
2.2	Leakage Test For Liquid Fueled Systems	48
2.3	Flammable Gas Concentration Test (Normal Operation)	49
2.4	Protection Parameters.....	50
2.5	Surface and Component Temperatures.....	50
2.6	Electrical Requirements	51
2.7	Rain and Wind Tests	52

Contents (Continued)

	Page
2.8 Sequences of Tests.....	53
2.9 Test Conditions.....	53
2.10 Temperature (Normal).....	54
2.11 Leakage Current	55
2.12 Dielectric Strength	57
2.13 Abnormal Operation.....	58
2.14 Protection (Battery Supply Circuits).....	59
2.15 Overload (Control Devices).....	60
2.16 Endurance (Control Devices).....	60
2.17 Compression (Metal Enclosures)	61
2.18 Deflection (Metal Enclosures).....	61
2.19 Flaming Oil (Perforated Panels)	61
2.20 Printed Circuit Board Coatings.....	62
2.21 Securement of Components	63
2.22 Strain Relief.....	63
2.23 Insulating Material	63
2.24 Capacitor Discharge (Energy and Shock Hazards)	63
2.25 Tank Pressure Test	63
2.26 Mounting Bracket Vertical Loading Test	64
2.27 Stability	64
2.28 Adhesion and Legibility of Marking Materials	65
2.29 Flammable Gas Accumulation	66
2.30 Oxygen Depletion	67
2.31 Carbon Monoxide Emissions - Closed Room	68
2.32 Emission of Effluents - Open Room.....	69
2.33 Burner Operating Characteristics.....	69
2.34 Automatic Ignition Systems.....	70
2.35 Drop Test	71
2.36 Lifting Means.....	72

Tables.

Table I	Minimum Corrosion Protection of Ferrous Materials Used In the Construction of Fuel Cell Power Systems For Outdoor Installation	74
Table II	Thickness of Sheet Metal For Enclosures Carbon Steel or Stainless Steel.....	75
Table III	Thickness of Sheet Metal For Enclosures - Aluminum, Copper, or Brass	76
Table IV	Minimum Thickness of Cast Metal Enclosures For Live Parts	77
Table V	Acceptable Perforated Metal Plates, mm	77
Table VI	Insulation Thickness of Factory Wiring Exposed In Engine or Fan Compartment.....	78
Table VII	Minimum Spacings For Power Supplies For Use In Other Than Controlled Environments.....	79
Table VIII	Minimum Spacings For Power Supplies For Use In a Controlled Environment	79
Table IX	Conductor Spacings On Printed Circuit Boards For Use In Other Than Controlled Environments	80
Table X	Conductor Spacings On Printed Circuit Boards For Use In Controlled Environments.....	81

Contents (Continued)

	Page
Table XI Protection of Battery Supplies	82
Table XII Maximum Allowable Rise Above Room Temperature For Various Component Parts.....	83
Table XIII Maximum Allowable Motor Winding Temperatures, °F (°C)	84

Figures.

Figure 1. Articulated Probe	86
Figure 2. Top Cover Designs.....	87
Figure 3. Openings in Vertical Sides.....	87
Figure 4. Openings in Vertical Sides.....	88
Figure 5. Location and Extent of Barrier	89
Figure 6. Ground and Neutral Wiring For Two Source Systems	90
Figure 7. Temperature-Measuring Probe.....	91
Figure 8. Arrangement of Spray Heads and Associated Piping For Simulated Rainstorm Test	92
Figure 9. Spray Head Assembly and Details of Construction.....	92
Figure 10. Leakage Current Measurement Circuits.....	93
Figure 11. Leakage Current Test Circuits.....	94
Figure 12. Mounting Bracket Vertical Loading Test	94
 Exhibit A. List of Referenced Standards	 95

Part III: Quality Assurance Plan	103
---	------------

Part IV: Definitions	105
-----------------------------------	------------

Appendices:

Table of Conversion Factors	107
Temperature Scales and Conversions	108
Multiples and Submultiples of Basic Units	108

Portable Fuel Cell Power Systems

Part I: Construction

1.1 Scope

- 1.1.1** This Standard applies to ac and dc type portable fuel cell power systems, with a rated output voltage not exceeding 600 V, for commercial, industrial, and residential indoor and outdoor use in non-hazardous locations, in accordance with the Rules of the *National Electric Code, ANSI/NFPA 70*.
- 1.1.2** This Standard does not apply to portable fuel cell power systems that are
- Permanently connected (stationary) to either fuel or electric supply;
 - Designed to export power to the grid;
 - Replacement fuel cell power units for appliances; or
 - Fuel cell systems for propulsion.
- 1.1.3** Fuels considered within the scope of this standard are:
- Natural Gas;
 - Liquefied Petroleum / Propane Gases;
 - Liquid Alcohols e.g. Methanol, Ethanol;
 - Gasoline;
 - Diesel;
 - Kerosene;
 - Hydrogen;
 - Chemical Hydrides; and
 - Metallic.
- 1.1.4** The overall design of a portable fuel cell 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 - meters and processes incoming fuel supply for use within the portable fuel cell power system.

- b. Air Processing System - meters, conditions, processes and may pressurize (blowers or turbochargers) incoming air supply for use within the portable fuel cell power system.
- c. Thermal Management System - provides cooling and heat rejection to maintain thermal equilibrium within the portable fuel cell power system and may provide for recovery of excess heat and assist in heating the portable fuel cell power system during startup.
- d. Electrical System - conditions output power of the fuel cell to meet the specifications of the output system.
- e. Automatic Control System - the assembly of sensors, actuators valves, switches, and control logic components that maintains the portable fuel cell power system control parameters within manufacturer specified limits without manual intervention.
- f. Fuel Cell Module - an assembly of cells, separators and cooling plates, manifolds and a supporting structure that electrochemically converts fuel and oxidant to direct electrical current, heat, water and other byproducts.

1.1.5 These requirements are not intended to prevent the design and construction of a portable fuel cell power system not specifically prescribed in this standard, provided that such alternative has been considered in testing and listing the portable fuel cell power system. In considering alternative designs or construction the materials or methods used shall be evaluated as to their ability to yield equivalent performance to that prescribed by this standard.

1.2 General Construction

1.2.1 General Requirements

- a. All parts and all substances used shall be:
 - 1. Suitable for the expected range of usage temperatures and pressures; and
 - 2. Resistant to expected reactions, processes, and other usage conditions.
- b. Component parts shall be found to comply with requirements suitable for the application.
- c. All parts that require regular or routine maintenance or servicing, as defined in 1.35.1-k. such as inspection, lubrication, cleaning, replacement or similar function shall be reasonably accessible.
- d. Heat transfer surface joints shall be substantially continuous and of a type to provide permanent joining of parts. Joints used in positive pressure zones shall be tightly closed and shall not depend upon cement or other sealing material for their strength or tightness. Joints in positive pressure zones shall be either welded, brazed, threaded, lock-seamed, machined and bolted, or be designed with a rigid flanged construction joint. Rigid flanged construction joints shall be tightly bolted together

with enclosed gaskets or shall utilize a rigid pressed machined slip connection or equivalent design.

A machined slip joint shall neither be constructed entirely of sheet metal nor depend upon friction of the joint itself for strength. Such a joint shall be constructed so that making and breaking the connection will not alter the effectiveness of the joint.

- e. Adequate protection shall be provided against accidental contact with all moving parts.
- f. All parts that may be contacted during normal usage, adjustment or servicing shall be free from sharp projections or edges.
- g. Means shall be provided to purge those systems of the portable fuel cell power system where, for safety reasons, it requires a passive state after shutdown or prior to initialization as specified by the manufacturer. A suitable purge system, utilizing a medium specified by the manufacturer such as but not limited to nitrogen, or air or steam in a non-hazardous situation within the intended use, meets the intent of this provision. Purging can be accomplished with fuel flow if supported by safety analysis and the unit passes the shutdown flammable gas accumulation test in 2.29.7.

1.2.2 Flammable Atmospheres

The integrated systems of the portable fuel cell power system shall be constructed so as to prevent the ignition of flammable atmospheres within the portable fuel cell power system that might cause a safety hazard.

a. Surface Temperatures

Surface temperatures of components used in classified areas shall not exceed 80% of the ignition temperature, measured in °C, of the specific gas or vapor in the atmosphere where the components are used.

For reference, the following ignition temperatures apply:

Methanol	--	385°C
Methane	--	537 °C
Ethanol	--	363 °C
Gasoline	--	280 - 471°C
Hydrogen	--	520 °C
Propane	--	450 °C

b. Normal Operation

The extent of a flammable region within system enclosure created or produced under normal operation shall fall below 25 percent of the Lower Flammability Limit (LFL). Where mechanical ventilation is used, a means to confirm operation, and interlock shall be provided to safely shut down the generator upon failure of the ventilation system. Compliance with this requirement is demonstrated in 2.3, Flammable Gas Concentration Test (Normal Operation).

c. Abnormal Operation

The extent of a flammable region within the system enclosure created by a limited internal release shall be addressed using a minimum of one of the following techniques.

1. The dilution boundary within the portable fuel cell power system produced under normal operation or by a limited internal release shall be classified using *Recommended Practice for the Classification of Flammable Liquids, Gases or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, NFPA 497* or *IEC 60079-10 Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas*. All equipment within this dilution boundary shall be suitable for the classification including the potential for static discharge, surface temperatures, and the flame suppression of catalytic reactors. Guidance can be found in:
 - (a) *Electrical Apparatus for Explosive Gas Atmospheres - Part 0: General Requirements, UL 60079-0,*
 - (b) Article 500-4 of the *National Electrical Code, ANSI / NFPA 70,* and
 - (c) *Electrical apparatus for explosive gas atmospheres - Part 0: General requirements IEC 60079-0.*
2. A reliable means shall prevent the accumulation of flammable fuel above 25 percent of the lower flammability limit (LFL) within the portable fuel cell power system. Where detection is used, the system must be compliant with 1.4.7, and the control circuit and logic must be compliant with the requirements outlined in 1.34, Safety Analysis. Localized volumes within the generator may momentarily exceed 25 percent LFL of the fuel, however, this transient condition must not pose a safety hazard to the surrounding environment.
 - (a) Where flammable gas sensor is provided to comply with 1.2.2-c2, it shall be located downstream of the stack ventilation discharge.
 - (b) The reliable means shall be set to shut off the generator system to ensure the discharge air stream flammable gas concentration(s) does(do) not exceed 50 percent of the LFL(s) at the ventilation outlet. Compliance is demonstrated through 2.29, Flammable Gas Accumulation Test.
 - (c) The portable generator shall remain inoperable upon flammable gas sensor activation. Only the manufacturer's authorized personnel shall perform service and re-activation after flammable gas sensor activation.

1.2.3 Fuel Supply

- a. This standard does not cover requirements of pressurized or non-pressurized fuel supply containers upstream of the appliance gaseous or liquid fuel supply connector that are not integral to the portable fuel cell power system.
- b. Cylinders containing hazardous compressed gases shall comply with the requirements of the *ASME Boiler and Pressure Vessel Code, Section VIII or Title 49 of the*

US Code of Federal Regulations, Title 49 CFR, Hazardous Materials Regulations, Chapter 1, Subchapter C, Part 178 - Specifications for Packagings.

- c. Means shall be provided to secure fuel containers from becoming dislodged while in use or stored on the portable fuel cell power system. Lateral movement shall not exceed 25.4 mm at the retention means and the cylinder or any portion thereof shall not become dislodged from its retention means when a lateral force equal to the full weight of the cylinder is applied in any direction at the center of the vertical height of the cylinder.
- d. Removable compressed gas fuel containers shall be equipped with a cylinder valve compliant with the applicable requirements in *CGA V-9, Standard for Compressed Gas Cylinder Valves* and include a connection fixture that will not allow the flow of gas until a positive seal has been achieved.
- e. Unpressurized vessels, such as tanks and similar containers, shall be of stainless steel, cast iron, aluminum, plastic, reinforced plastic, ceramic, or other material specifically suited to the application for which the tank or container is intended.

1.3 Materials

1.3.1 A design examined for compliance with this standard shall be a representative production sample of the portable fuel cell power system constructed entirely of new, unused parts and materials.

1.3.2 Ferrous materials used in the construction of the outside casing, and in an outside cabinet which is the sole enclosure of current-carrying parts, shall be protected against corrosion by one of the coatings appropriate to the thickness of the part as outlined in Table I, Minimum Corrosion Protection of Ferrous Materials Used in the Construction of Portable Fuel Cell Power Systems, and the notes applicable thereto, or by other metallic or nonmetallic coatings or materials which have been shown to give equivalent protection.

Nonferrous cabinets, enclosures and outside portions of casings may be employed without special corrosion protection.

Parts constructed of rubber and rubber-like (elastomeric) materials shall be judged with respect to their suitability for the particular application. The acceptability of such materials shall be based on the classification system and associated terminology specified in the *Standard Classification System for Rubber Products in Automotive Applications, ASTM D2000, Standard Terminology Relating to Rubber, ASTM D1566*, and the *Standard Practice for Rubber and Rubber Latices-Nomenclature, ASTM D1418*.

Any metallic part that is exposed directly to moisture, condensate, liquid fuel etc., as well as fasteners used to attach any part that must be adjusted or removed for servicing, (1) shall be constructed of an appropriate corrosion-resistant material, or (2) shall have an appropriate corrosion-resistant coating, such as aluminum, chromium, ceramic, zinc chromate, black oxide, nickel or electro-less nickel, Teflon, or its equivalent, as necessary.

1.3.3 The acceptability of parts constructed of plastic (polymeric) materials shall be based on the classification system and associated terminology specified in the *Standard Classification System for Specifying Plastic Materials, ASTM D4000*, the *Standard Terminology for Abbreviated Terms Relating to Plastics, ASTM D1600* and the *Standard Terminology Relating to Plastics*,

ASTM D883. Polymeric materials shall also be evaluated in accordance with the Standard for Polymeric Materials - Short Term Property Evaluations ANSI/UL 746 A, the Standard for Polymeric Materials - Long Term Property Evaluation ANSI/UL 746 B, the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746 C, and the Standard for Polymeric Materials - Fabricated Parts, UL 746 D, where applicable.

Fuel connection devices constructed of copper alloys, such as brass and bronze, shall be resistant to season cracking when tested in accordance with the Standard Test Method for Ammonia Vapor Test for Determination of Susceptibility to Stress Corrosion Cracking in Copper Alloy, ASTM B 858 using a pH value of 10.0. This test shall be conducted on unplated samples.

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

1.3.5 Components and materials inside classified gas explosive atmospheres shall be so constructed or shall make use of such materials, that propagation of fire and ignition is minimized. The material flammability shall be such that a sustained fire will not be supported after electrical power and the fuel supply have been removed. This may be demonstrated through the selection of materials meeting FV 0, FV 1 or FV 2 in accordance with the Standard Series on Fire Hazard Testing, IEC 60695.

Exemptions: Membranes, or other materials within the fuel cell stack which comprise less than 10 percent of the total fuel cell stack mass, are considered to be of limited quantity and are permissible without flammability ratings.

1.3.6 Liquid fuel piping materials are required to pass the compatibility tests specified in 1.28, Piping Systems.

1.3.7 All piping materials, thread compounds, and thread tapes used for liquid fuels shall not cause degradation of the system by interaction of the fuel or compromise their function. Guidance for evaluation can be found in:

Standard for Recommended Methods for Determining Physical Properties of Polymeric Materials Exposed to Gasoline/Methanol Fuel Mixtures, SAE CRP-008,

Standard for Recommended Methods for Conducting Corrosion Tests in Gasoline/Methanol Fuel Mixtures, SAE J1747, and

Standard for Gasoline, Alcohol, and Diesel Fuel Surrogates for Materials Testing, SAE J1681.

1.4 Electrical Components and Equipment

1.4.1 Except as permitted by 1.4.3, electrical components of equipment shall comply with the applicable nationally recognized U.S. product standard, insofar as they apply.

Components not complying with an applicable Standard may be acceptable as a component part for a particular unit, providing that it is suitable for the application and it has been established that no hazard is involved.

1.4.2 Components of electronic circuits, such as resistors, capacitors, inductors, and semiconductor devices, for which there are no appropriate requirements in Part II of the applicable nationally recognized U.S. product standard, shall comply with the applicable tests in Part II of this Standard, unless specifically exempted elsewhere in this Standard.

1.4.3 No requirements are specified for components of secondary circuits that are

a. Supplied by

1. A transformer that complies with the requirements for a transformer for a Class 2 circuit, as specified in the Standard for *Specialty Transformers*, CSA C22.2 No. 66, Standard for *Specialty Transformers*, UL 506 or the Standard for *Class 2 and Class 3 Transformers* UL 1585, as appropriate;
2. An isolated portable fuel cell power system that has an over-current protective device rated 5 A maximum for open-circuit voltages of 20 V rms or less and 100/V for voltages over 20 up to 30 V rms; or
3. A combination of transformer and impedance that limits the current to 5 A, under any conditions of non-capacitive loading, as measured 1 min after energization, for open-circuit voltages of 20 V rms or less and 100/V for voltages over 20 up to 30 V rms; and

b. Not safety circuits.

1.4.4 Fuses used to limit current levels to those specified in 1.4.3-a2 shall be of a type that is non-replaceable without the use of tools (e.g. soldered-in type) if the circuits protected by the fuses extend beyond the fuel cell power enclosure. If there are no circuits extending beyond the enclosure, the fuses may be of a readily replaceable type.

1.4.5 Electrical components shall be so located or enclosed that suitable protection will be provided against accidental contact with bare live parts.

1.4.6 Components that meet the requirements of the Standard for *Safety of Information Technology Equipment* CAN/CSA-C22.2 No. 60950, the Standard for *Safety of Information Technology Equipment*, ANSI/UL 60950, the Standard for *Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use - Part I: General Requirements*, CSA C22.2 No. 1010.1, or the Safety Standard for *Electrical and Electronic Test, Measuring, Controlling and Related Equipment - General Requirements*, ANSI/ISA S82.02.01, as appropriate, may be used as component parts of a portable fuel cell power system without further investigation if it is intended for use in a controlled environment and is marked in accordance with 1.36.8.

1.4.7 Gas detectors or gas sensors, when used as protection means shall meet the applicable requirements of the Standard for *Performance Requirements - Combustible Gas Detectors*, ANSI/ISA RP 12.01.13 Part I, or if the gas mixture calibration setting is 25 percent of the lower flammability limit (LFL) or less, Underwriters Laboratories *Bulletin for Gas and Vapor Detectors and Sensors*, UL 2075.

1.5 Enclosures

1.5.1 General Requirements for Enclosures

- a. Portable fuel cell power systems shall have enclosures that shall enclose all live parts. Rack-mounted assemblies (e.g. component types) may have exposed parts where enclosed by the rack enclosure.
- b. Enclosures for electrical equipment shall be formed and assembled so that they will have the strength and rigidity necessary to resist the damage to which they may be subjected, without increasing their fire and accident hazards due to partial collapse and without reduction of spacing, loosening or displacement of parts or other serious defects.
- c. For applications where the equipment may be exposed to oil, acid fumes, moisture, dust, or other injurious materials in normal operation, the protection afforded the components enclosed shall be subject to investigation.

1.5.2 Thickness of Sheet Metal Enclosures for Live Parts

- a. Except as specified in 1.5.2-b, the thickness of sheet metal enclosures shall be not less than that specified in Table II, Thickness of Sheet Metal For Enclosures - Carbon Steel or Stainless Steel, and Table III, Thickness of Sheet Metal For Enclosures - Aluminum, Copper, or Brass.
- b. The thickness of sheet metal for enclosures at points other than where a wiring system is to be connected may be less than that specified in Table II, Thickness of Sheet Metal For Enclosures - Carbon Steel or Stainless Steel, and Table III, Thickness of Sheet Metal For Enclosures - Aluminum, Copper, or Brass, provided that the enclosure complies with 2.17, Compression (Metal Enclosures) and 2.18, Deflection (Metal Enclosures).
- c. With reference to Table II, Thickness of Sheet Metal For Enclosures - Carbon Steel or Stainless Steel, and Table III, Thickness of Sheet Metal For Enclosures - Aluminum, Copper, or Brass, a supporting frame shall consist of a structure of angles or channels or folded rigid sections of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending moments that may be applied by the enclosure surface when it is deflected. A structure that is as rigid as one built with a frame of angles or channels is considered to have equivalent reinforcing. Constructions without a supporting frame shall be considered to include:
 - 1. A single sheet with single formed flanges or formed edges;
 - 2. A single sheet that is corrugated or ribbed;
 - 3. An enclosure surface loosely attached to a frame (e.g. with spring clips); and
 - 4. An enclosure surface having an unsupported edge.

1.5.3 Thickness of Cast Metal Enclosures For Live Parts

The minimum thickness of metal for cast enclosures shall comply with Table IV, Minimum Thickness of Cast Metal Enclosures For Live Parts.

1.5.4 Polymeric enclosures of portable fuel cell power systems shall comply with the appropriate requirements for enclosures in the Standard for *Polymeric Materials - Use in Electrical Equipment Evaluations*, UL 746C. For purposes of applying these requirements, the portable fuel cell power system shall be categorized as either a "portable appliance" or "stationary equipment" in accordance with the definitions for these designs as noted in UL 746C.

1.5.5 Decorative Trim

Polymeric compounds which are used as decorative trim or features of the enclosure, and are specifically not part of the fire or electrical enclosure(s) of the product, may be classified as HB or less flammable. Small decorative parts, push buttons, etc, under 0.035 oz (1g) or 0.061 in³ (1cm³) shall not be required to have a flammability rating.

1.5.6 Openings in Enclosures

- a. The enclosure shall have no openings through which the articulated probe (see Figure 1, Articulated Probe, can be inserted so as to touch moving parts (e.g. fan blades), or any un-insulated live parts (including film-coated wire) operating at a voltage of more than 42.4 V peak to any other part or to ground.
- b. The probe of Figure 1 shall be inserted to any depth that the opening will permit, using an applied force of not greater than 1 lb (4.4 N). The probe shall be rotated or angled before, during, and after insertion through the opening to any necessary position, using any possible configuration. If necessary, the configuration shall be changed after insertion through the opening.
- c. Openings in the top of an enclosure that are directly over uninsulated live parts involving a risk of shock or energy hazard shall not exceed 0.20 in (5 mm) in any dimension unless the construction is such that straight access to those uninsulated live parts is prevented. See Figure 2, Top Cover Designs, for examples of top cover designs that prevent straight access. This requirement shall not apply to a portable fuel cell power system over 6 ft (1.8 m) high.
- d. Openings in the vertical sides of an enclosure of a portable fuel cell power system shall not allow intrusion of objects or material that would cause injury to persons or malfunction of equipment that would result in a shock or energy hazard. Openings shall:
 1. Be provided with louvers that are shaped to deflect outwards an external vertically falling object (see Figure 3, Openings in Vertical Sides, for examples); or
 2. Be so located that an object upon entering the enclosure, is unlikely to fall on uninsulated live parts, resulting in a shock or energy hazard (see Figure 4, Openings in Vertical Sides).
- e. A portable fuel cell power system having an enclosure with openings that are located directly beneath live parts shall be provided with a barrier or bottom panel,

complying with 1.5.6-g located beneath such live parts, so as to prevent molten or flaming particles from falling on the surface on or over which the portable fuel cell power system is mounted.

- f. If a portion of a vertical side panel falls within the area D of the required bottom enclosure as traced out by the 5 degrees (0.09 rad) angle in Figure 5, Location and Extent of Barrier, that portion of the vertical panel shall be evaluated as a bottom enclosure.
- g. If a barrier is provided to comply with 1.5.6-e, the barrier shall:
 - 1. Be made of metal or nonmetallic material complying with the flame test of 2.19, Flaming Oil, Perforated Panels;
 - 2. Not contain perforations or openings except as specified in Items 1.5.6g.4 and 1.5.6g.5 below,
 - 3. Be so located and be of such extent as to conform to Figure 5, Location and Extent of Barrier, and the notes appended thereto; and
 - 4. Have one of the following constructions, if made of perforated metal:
 - (a) A metal screen, or the equivalent, that has a mesh not greater than 0.08 x 0.08 in (2 x 2 mm) (14 x 14 mesh per in) and wire with a minimum diameter of 0.018 in (0.46) mm; or
 - (b) A panel in accordance with Table V, Acceptable Perforated Metal Plates; or
 - (c) A perforated metal panel that complies with the flaming oil test of 2.19, Flaming Oil, Perforated Panels; and
 - 5. Be permitted to have openings not larger than 0.001 in² (6.4 mm²) if the barrier is located under areas containing only materials classified, at least V-1 in accordance with the Standard for *Evaluation of Properties of Polymeric Materials*, CSA C22.2 No. 0.17, or the Standard for *Tests for Flammability of Plastic Materials for Parts in Devices or Appliances*, UL 94, as appropriate. Openings that are not square can be provided if they do not have an area greater than 0.062 in² (40 mm²).

A mesh or screen described in 1.5.5-g4a cannot be used to form the side of an enclosure.
- h. The diameter of the wires of a metal screen used for other than the bottom of an enclosure shall be not less than:
 - 1. 0.05 in (1.2 mm) when the screen openings are 0.5 in² (320 mm²) or less in area; and
 - 2. 0.079 in (2 mm) for larger screen openings.
- i. Sheet metal employed for expanded metal mesh and perforated sheet metal used for other than the bottom of an enclosure shall have an uncoated thickness of not less than:

1. 0.05 in (1.2 mm) if the mesh openings or perforations are 0.5 in² (320 mm²) or less in area; and
 2. 0.079 in (2 mm) for larger openings.
- j. Glass covering openings shall be reliably secured in place so that the glass cannot be readily displaced, and shall provide mechanical protection for the enclosed parts (See 1.5.4.).
- k. Material other than glass employed as a sole covering over an opening forming part of the enclosure and relied upon to prevent contact with bare live parts shall be of adequate mechanical strength and shall comply with the requirements of the flame test specified in 2.19, Flaming Oil, Perforated Panels. (Also see 1.5.4.)
- l. Components that have a flammability classification of, at least, HB as specified in the Standard for *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94*, and that form part of the enclosure need not comply with 1.5.4 under any one of the following conditions:
1. The component covers an opening that has no dimension greater than 1 in (25.4 mm);
 2. The component covers an opening that has no dimension greater than 3.94 in (100 mm), and there is no source of fire hazard closer than 3.94 in (100 mm) from the surface of the enclosure; or
 3. There is a barrier or a device that forms a barrier having a flammability classification of, at least, V-O as specified in the Standard for *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94*, between the component and a source of fire hazard.
- m. The minimum dimension of any cabinet opening(s) provided for the entrance of process or ventilation air shall not be less than $\frac{1}{4}$ in (6.4 mm).

1.5.7 Doors, Covers, and Guards

- a. Doors and covers of enclosures shall be provided with means for securing them firmly in place. If bare live parts that may cause electric shock or mechanical hazards are exposed by the opening of such doors or covers as determined by the use of the probe (Figure 1, Articulated Probe), means requiring the use of a tool shall be provided to hold such doors or covers closed.
- b. If it is necessary to open a door to perform operational maintenance, the door shall be hinged or secured in an equivalent manner, and all moving parts that involves a risk of injury and parts that present a shock or energy hazard shall be located or guarded so that the operator is protected from accidental contact while performing such maintenance. Any barriers or guards that are provided to comply with this requirement shall be secured in place so that the use of a tool or other deliberate action is required for their removal.
- c. When a hinged door is required by 1.5.7-b, means shall be provided to keep the door closed.

- d. Any uninsulated live part at which a shock or energy hazard may exist and any moving part that involves a risk of injury shall be located, guarded, or enclosed so as to prevent unintentional contact by service personnel adjusting or resetting controls, or the like, or performing mechanical service functions that may be performed with the system energized (e.g. lubricating a motor, adjusting the setting of a control, resetting a trip mechanism or operating a manual switch).
- e. A component that may require examination, resetting, adjustment, servicing, or maintenance while energized shall be so located and mounted with respect to other components and with respect to grounded metal parts that it is accessible for electrical service functions without subjecting service personnel to a possible shock or energy hazard or injury by adjacent moving parts. Access to a component shall not be impeded by other components including wiring.
- f. When determining compliance with 1.5.7-e, misalignment of a screwdriver or similar tool with the adjustment means shall be taken into account. Protection against inadvertent contact with adjacent uninsulated hazardous live parts shall be provided by:
 - 1. Location of the adjustment means away from uninsulated hazardous live parts; or
 - 2. A guard to reduce the likelihood of the tool contacting uninsulated hazardous live parts.
- g. A live heat sink for a solid-state component (e.g. one mounted on a printed circuit board), a live relay frame, and the like, that could be a shock or energy hazard and that may be mistaken for an unenergized part, shall be guarded to reduce the risk of unintentional contact by service personnel or be marked in accordance with 1.36.9.
- h. Moving parts that can cause injury to service personnel and that must be in motion during service operations shall be so located or protected that unintentional contact with the moving parts is not likely.

1.5.8 Special-Purpose Enclosures

- a. Special-purpose enclosures for nonhazardous locations shall comply with the requirements of the Standard for *Special Purpose Enclosures*, CAN/CSA-C22.2 No. 94, or the Standard for Enclosures for *Electrical Equipment*, ANSI/UL 50, as appropriate.
- b. When a supplementary housing is used to comply with 1.5.7-a, the temperature rise of the enclosed equipment shall be investigated.

1.6 Mechanical Assembly

- 1.6.1** A component shall be secured to the base or surface so that it will be prevented from rotating or shifting in position as the result of normal stresses, if such movement might result in a reduction of spacings below the minimum acceptable values (see 1.19, Spacings).
- 1.6.2** Electrical components such as switches that are subjected to turning moments in normal operation or servicing shall be fastened securely and prevented from turning by means other than friction between surfaces, if turning could result in reduction of the spacings specified

in 1.19, Spacings, or in an infringement of other requirements of this Standard. A lockwasher shall not be considered acceptable for devices that require turning moments for their operation.

1.7 Cord-Connected Portable Fuel Cell Power System

- 1.7.1** Portable fuel cell power system intended to be cord-connected at the input shall be provided with a suitable length of flexible cord having an additional conductor for grounding non-current-carrying conductive parts. The cord shall have an ampacity at least equal to the marked input in amperes (see 1.33.2) and shall be of the hard-usage type, damp/wet (Table 400.4 NEC) except as required by other clauses of this Standard; and The flexible cord shall be Type S, SO, SOO, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJOO, SJT, SJTO, SJTOO, ST, STO, or STOO. Products intended for use out of doors shall include one of the flexible cord type designations noted above but with the suffix "W."
- 1.7.2** The supply cord shall terminate in a suitable attachment plug that conforms to the Standard for *General Use Receptacles, Attachment Plugs and Similar Wiring Devices, CSA C22.2 No. 42*, or the Standard for *Attachment Plugs and Receptacles, ANSI/UL 498*, as appropriate, and has a:
- a. Voltage rating suitable for the voltage marked on the portable fuel cell power system; and
 - b. Current rating of not less than
 - 1. 125 percent of the marked input current; or
 - 2. 100 percent of the marked input current if the input current decreases to 80 percent of the marked value after the first 3 h of operation starting with a discharged battery.
- 1.7.3** It shall not be possible for a flexible cord to be pushed through the cord-entry hole, if such displacement is liable to:
- a. Subject the cord to mechanical injury;
 - b. Expose the cord to a temperature higher than that for which the cord is recognized; or
 - c. Reduce the spacings (such as from bare live parts to a metal strain relief clamp) below the values specified in 1.19, Spacings.
- 1.7.4** Strain relief shall be provided so that stress on a supply cord, as determined by the test specified in 2.22, Strain Relief, or twisting of the cord will not be transmitted to the connections inside the portable fuel cell power system.
- 1.7.5** At the point at which a supply cord passes through an opening in a wall, barrier, or the overall enclosure, there shall be a bushing or the equivalent that is secured in place and that has a smooth, well-rounded surface against which the cord may bear.

- 1.7.6** A bushing of the same material as that molded integrally with the supply cord shall be acceptable if the built-up section is not less than 0.063 in (1.6 mm) thick at the point at which the cord passes through the enclosure.
- 1.7.7** A cord-connected portable fuel cell power system having an input or output rating of 208 V single phase may be provided with an attachment plug for a supply cord rated 250 V or cord connector (socket) for an output cord rated 250 V provided that
- There is no evidence of a shock or fire hazard when the portable fuel cell power system is tested at 240 V in accordance with 2.13.9;
 - The supply cord is marked in accordance with 1.36.18; and
 - An output receptacle or cord connector is marked in accordance with 1.36.19.
- 1.7.8** Notwithstanding 1.7.7-b, no marking is required on the supply cord if:
- The portable fuel cell power system complies with the requirements of the rating test of 2.9.3, 2.10, Temperature (Normal) and 2.11, Leakage Current, and the backfeed protection test as specified in the Standard for *General Use Power Supplies*, CSA C22.2, No. 107.1, or the Standard for *Uninterruptible Power Supply Equipment*, ANSI/UL 1778, as appropriate; and
 - The output voltage of the portable fuel cell power system does not exceed its output voltage rating by more than 10 percent while energized from a 240 V source of supply.

1.8 Current-Carrying Parts

- 1.8.1** Current-carrying parts shall have adequate mechanical strength and current-carrying capacity for the service, and shall be nonferrous or stainless steel.
- 1.8.2** Bare live parts (including conductors) shall be secured to their bases or mounting surfaces so that they will be prevented from turning or shifting so as to reduce the spacings required by 1.19, Spacings. Friction between surfaces is not an acceptable means of preventing the turning of live parts, but a suitable lockwasher will be acceptable if properly applied.
- 1.8.3** The securement of contact assemblies shall be such as to ensure the continued alignment of contacts.
- 1.8.4** Misalignment of male and female connectors, insertion of a multi-pin male connector in a female connector other than one intended to receive it, and other manipulations of parts that are accessible without the use of a tool shall not result in a hazardous condition.

Note: *The intent of 1.8.4 is to address the concerns of mechanical damage, risk of fire, electric shocks, or injury to persons.*

1.9 Internal Wiring

- 1.9.1** The space within enclosures of equipment shall provide ample room for the distribution of wires and cables required for the proper wiring of the equipment to prevent overheating and damage to the insulation.
- 1.9.2** The wire connections and wires between parts of equipment shall be protected or enclosed as required by Section 110 of the *National Electrical Code, ANSI/NFPA 70*, as appropriate.
- 1.9.3** Wireways shall be smooth and entirely free from projections, burrs, and sharp edges that may cause abrasion of the insulation on the conductors.
- 1.9.4** Bare conductors shall be so supported that spacings will be maintained as required by 1.19, Spacings.
- 1.9.5** Wiring other than that of printed circuits shall consist of wire of a type or types that are suitable for the particular application when considered with respect to:
- a. Conductor size [consideration shall be given to the effects of vibration, impact, and handling for wires smaller than No. 24 AWG (0.20 mm²)];
 - b. Temperature and voltage to which the wiring is liable to be subjected;
 - c. Exposure to oil, grease, or other substance liable to have a deleterious effect on the insulation;
 - d. Exposure to moisture; and
 - e. Other conditions of service to which the wire is liable to be subjected.
- 1.9.6** All wiring joints shall be provided with insulation equivalent to that of the conductors themselves unless they are held securely and rigidly so that the spacings required by 1.19, Spacings, are maintained.
- 1.9.7** Cords and insulated conductors, either single or bunched, or cabled, when passing through openings in sheet metal walls shall be effectively protected by suitable bushings or well-rounded surfaces against which the cords or conductors may bear.
- 1.9.8** Conductors identified by green or the color combination green/yellow shall be used only for grounding or bonding connections.
- 1.9.9** When within a control, fan or similar compartment, factory wiring, involving voltage of not more than 300 volts between parts attached to the same assembly with a predetermined fixed relationship one to the other, may be done with Type SJ0, SJT or SPT-3 cord or appliance wiring material having neoprene, thermoplastic or equally durable insulation of a thickness no less than that specified in Group B of Table VI, Insulation Thickness of Factory Wiring Exposed in Engine or Fan Compartment, or Group A of Table VI when the wiring material is covered as specified in the footnote to the table, judged on temperature limitation and usage suitability as defined in Article 400 of the *National Electrical Code, ANSI/NFPA 70*, provided:

- a. The compartment normally is closed;
- b. Wiring below openings located in other than vertical surfaces is protected;
- c. Openings in vertical surfaces will not permit the entrance of a $\frac{33}{64}$ inch (1.31 cm) diameter rod where such straight rod may cause damage to the wiring; and
- d. Permitted openings are at least 2 in (5.08 cm) above the bottom of the compartment, if the compartment contains a motor.

Cords and other wiring material permitted in the preceding paragraphs shall be arranged to avoid being mechanically damaged, such as by closely following surfaces, and shall be supported.

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

1.10 Electrical Insulation

- 1.10.1** Heat-resistant, moisture-absorption-resistant insulating material, such as phenolic composition, porcelain, cold molded composition, that will withstand the most severe conditions likely to be met in service shall be used for the support of bare, live parts and for barriers used to obtain required spacings (as specified in 1.19, Spacings) and shall comply with the test specified in 2.23, Insulating Material.

- 1.10.2** Insulating material that may be subject to the influence of the arc formed by the opening of a set of contacts shall be suitable for the particular application.

1.11 Transformers

- 1.11.1** Transformers shall comply with the requirements of the Standard for *Specialty Transformers*, CSA C22.2 No. 66, the Standard for *Specialty Transformers*, UL 506, or the Standard for *Class 2 and Class 3 Transformers*, UL 1585, as appropriate.

- 1.11.2** Transformers intended for supplying power to low-voltage circuits extending beyond the enclosure of the portable fuel cell power system shall not be of the auto-transformer type.

- 1.11.3** Transformers shall be housed within:

- a. Their own enclosures;
- b. The main enclosure of the equipment; or
- c. A combination of the methods specified in Items "-a" and "-b."

1.12 Motors

- 1.12.1** Motors shall comply with the applicable requirements of the Standard for *Motors with Inherent Overheating Protection*, CSA C22.2 No. 77, or the Standard for *Motors and Generators*, CSA C22.2 No. 100, or the Standard for *Electric Motors*, UL 1004, and the *Standard for Overheating Protection for Motors*, ANSI/UL 2111, as appropriate.
- 1.12.2** Fan motors, other than those connected in secondary circuits that operate at low-voltage and are supplied by Class 2 circuits, shall be provided with either of the following:
- Inherent overheating protection complying with the requirements of the Standard for *Motors with Inherent Overheating Protection*, CSA C22.2 No. 77, or the Standard for *Overheating Protection for Motors*, ANSI/UL 2111, as appropriate; or
 - Overload protection rated or set at not more than 125 percent of the motor current rating.
- 1.12.3** Motors of fans and blowers rated more than 200 cfm (94.4 dm³/s) including the fan blade or blower itself located over bare live parts shall be secured by:
- Nuts and bolts having interference fits;
 - Bolts having compression type locknuts;
 - Nuts secured to bolts by cotter pins;
 - Rivets; or
 - Equivalent means to reduce the likelihood of the motor, blower or fan blade from vibrating loose and falling on bare live parts.

1.13 Capacitors

- 1.13.1** Capacitors shall not create a hazard when tested in accordance with 2.13, Abnormal Operation.
- 1.13.2** Capacitors shall not be affected adversely by the temperatures attained by the device under the most severe conditions of normal use.
- 1.13.3** Electrolytic or other special types of capacitors and capacitors intended for connection directly across the line shall be made the subject of investigation by the certifying agency.
- 1.13.4** Provision shall be made for the safe discharge of the energy stored in capacitors if the safety of an area to which a service worker has access for routine maintenance is dependent upon de-energization of the portable fuel cell power system, unless:
- The covers by which access is gained require the use of tools for removal; and

- b. The portable fuel cell power system is marked with clear instruction specifying the time required for a safe discharge [see 2.24, Capacitor Discharge, Energy and Shock Hazards].

In cord-connected portable fuel cell power systems, the pins of the attachment plug shall be considered as bare live parts unless there is an isolating transformer between the supply cord and the capacitors (see 2.24).

1.14 Suppressors

- 1.14.1** Suppressors used for suppressing radio interference shall comply with the requirements of the Standard for *Safety Function Incorporating Electronic Technology*, CSA C22.2 No. 0.8, or the Standard for *Transient Voltage Surge Suppressors*, UL 1449, as appropriate.
- 1.14.2** Suppressors shall be enclosed by housings of noncombustible, moisture-absorption-resistant material. If sheet steel is used, it shall be not thinner than 0.02 in (0.52 mm).
- 1.14.3** The housing required by 1.14.2 may be dispensed with if a suppressor is mounted in an enclosure that affords protection equivalent to that of the housing.

1.15 Fuses and Fuseholders

- 1.15.1** Plug fuses shall not be used in circuits exceeding 150 V to ground.
- 1.15.2** Screw-shells of plug fuse fuseholders shall be connected to the "load" side of the circuit.
- 1.15.3** Fuses and fuseholders shall have voltage and current ratings suitable for the circuit in which they are connected. Fuses shall have an interrupting rating suitable for the circuits in which they are connected.
- 1.15.4** When fuseholders are accessible to the operator either a caution in accordance with 1.36.7 shall be provided or the design shall be such that bare live parts of a fuse or fuseholder that may be a shock hazard cannot be contacted by the probe shown on Figure 1, Articulated Probe, when the fuse is completely inserted or when the fuse is tilted at any angle during insertion or removal.

Note: Accessibility is not to be considered with the fuse completely removed.
- 1.15.5** A panel-mounted in-line fuseholder shall be wired such that the line end is connected to the terminal that is the least accessible from outside the enclosure.

1.16 Overload Relays

- 1.16.1** Overload relays shall be so designed and connected as to ensure reliable and positive electrical and mechanical performance for their intended purpose under all conditions of operation.

- 1.16.2** Automatic tripping of overload relays shall be independent of manipulation of the handle.
- 1.16.3** Adjustable overload relays shall be provided with instructions for such adjustment.

1.17 Switches and Controllers

- 1.17.1** Switches shall comply with the requirements of the Standard for *Industrial Control Equipment*, CSA C22.2 No. 14, the Standard for *Special Use Switches*, CSA C22.2 No. 55, and the Standard for *General Use Snap Switches*, CSA C22.2 No. 111, (Bi-National Standard, with UL 20), or the Standard for *Industrial Control Equipment*, ANSI/UL 508, and the Standard for *Special Use Switches*, ANSI/UL 1054, as appropriate, so far as they apply.
- 1.17.2** A switch or other control device shall have a current and voltage rating not less than that of the circuit that it controls when the equipment is operated under any condition of normal service.
- 1.17.3** If the circuit controlled has a power factor of less than 75 percent, the switch or other control device shall:
- Have a horsepower rating based on the full-load ampere equivalent rating;
 - Have a current rating of not less than twice the rated input current; or
 - Withstand the overload and endurance test specified in 2.15, Overload (Control Devices), and 2.20, Printed Circuit Board Coatings.

1.18 Printed Circuit Boards

- 1.18.1** Except as specified in 1.18.2 and 1.18.4, printed circuit boards shall have a minimum flammability classification of V-2, as determined by the test specified in Standard for *Evaluation of Properties of Polymeric Materials*, CSA C22.2 No. 0.17, or the Standard for Tests for *Flammability of Plastic Materials for Parts in Devices and Appliances*, UL 94, as appropriate.
- 1.18.2** The requirements of 1.18.1 shall not apply to a printed circuit board on which components connected only in Class 2 circuits are mounted.
- 1.18.3** Printed circuit boards involving primary circuits or those located in secondary circuits where failure of the bond between the conductor and the base material could result in contact with uninsulated primary circuit parts, shall be of a type that is acceptable for the application.
- 1.18.4** Printed circuit boards used in enclosures that have openings in accordance with the requirements of 1.5.6-g5 shall have a flammability classification of at least V-1 in accordance with Standard for *Evaluation of Properties of Polymeric Materials*, CSA C22.2 No. 0.17, or the Standard for Tests for *Flammability of Plastic Materials for Parts in Devices and Appliances*, UL 94, as appropriate.

1.19 Spacings

1.19.1 Unless otherwise specified, electrical spacings shall be not less than those specified in:

- a. Table VII, Minimum Spacings For Power Supplies for Use In Other Than Controlled Environments, for a portable fuel cell power system intended for use in other than a controlled environment; and
- b. Table VIII, Minimum Spacings For Power Supplies for Use In a Controlled Environment, for a portable fuel cell power system intended for use in a controlled environment and marked in accordance with 1.36.8.

Note: *An environment equivalent to a controlled environment may be provided by means of*
a. A hermetically sealed enclosure;
b. Encapsulation;
c. A conformal coating; or
d. A gasketed tight-fitting enclosure with an internal heater or equivalent to protect against formation of condensation.

1.19.2 Electrical spacings of conductors on printed circuit boards shall be not less than those specified in:

- a. Table VII, Minimum Spacings For Power Supplies for Use In Other Than Controlled Environments, for portable fuel cell power system for use in other than a controlled environment; and
- b. Table VIII, Minimum Spacings For Power Supplies for Use In a Controlled Environment, for a portable fuel cell power system intended for use in a controlled environment.

1.19.3 Notwithstanding 1.19.2, spacings between primary traces and spacings between secondary traces on printed wiring boards may be less than specified in Table IX, Conductor Spacings on Printed Circuit Boards For Use In Other Than Controlled Environments, and Table X, Conductor Spacings on Printed Circuit Boards For Use In Controlled Environments, provided that:

- a. The spacings withstand the applicable test specified in 2.12, Dielectric Strength, when the portable fuel cell power system is intended for use in a controlled environment; or
- b. There is no evidence of a shock or fire hazard when the traces are short-circuited in accordance with 1.19.5 for portable fuel cell power system intended for use in either a controlled or other than a controlled environment.

1.19.4 For the dielectric strength test required by 1.19.3-a, power-dissipating components, electronic devices and capacitors connected between those conductors having reduced spacings shall be removed or disconnected in such a manner that the spacings and the insulation, rather than these component parts, are subjected to the full dielectric strength test voltage.

1.19.5 For the short-circuit tests, specified in 1.19.3-b, the primary or secondary traces, as applicable, shall be short-circuited, one location at a time, subject to the following conditions:

- a. Separate samples may be used for each test, in which case the applicable test of 2.12, Dielectric Strength, shall be applied at the completion of each test;
- b. More than one short-circuit test may be conducted on one sample, in which case the dielectric strength test may be conducted at the completion of all tests;
- c. There shall be no emission of flame or molten metal from the enclosure of the portable fuel cell power system or other evidence of fire hazard during any test and no breakdown of the insulation when the dielectric strength test voltage is applied;
- d. The branch circuit protection shall not open; and
- e. A wire or printed wiring board trace shall not open.

1.19.6 Electrical spacings are not specified for:

- a. Class 2 secondary circuits that are not a shock hazard; and
- b. Secondary circuits and battery circuits if the:
 - 1. Circuits are not safety circuits;
 - 2. Spacings are sufficient to withstand the applicable test of 2.12, Dielectric Strength, without breakdown;
 - 3. Secondary circuits are supplied by a transformer winding for which the output voltage does not exceed 100 V or the maximum available output at a voltage over 100 V does not exceed 200 VA; and
 - 4. Voltage of the battery and fuel cell circuit is limited to 100 V or less (e.g. by a regulating network).

1.19.7 The spacings within components such as lampholders and special-use switches shall comply with the Standard for *Attachment Plugs and Receptacles, ANSI/UL 498*, the Standard for *Lampholders, Starters, and Starter Holders for Fluorescent Lamps, UL 542*, and the Standard for *Special Use Switches, ANSI/UL 1054*, as appropriate.

1.19.8 If live parts are not rigidly supported, or if movable non-current-carrying metal parts are in proximity to bare live parts, the construction shall be such that the minimum required spacings will be maintained as determined by the test specified in 2.21, Securement of Components.

1.19.9 The spacing at wiring terminals shall be measured with appropriate wires in place and connected to the terminals as in actual service.

1.19.10 Bare current-carrying parts connected to different circuits shall be spaced from each other as though they were parts of opposite polarity, in accordance with the requirements of 2.20.1 and shall be judged on the basis of the highest voltage involved.

1.19.11 If insulating barriers are used to obtain the required spacings they shall:

- a. Comply with 1.10, Electrical Insulation;

- b. Be not less than 0.028 in (0.7 mm) thick if of electrical grade paper and if the spacings, without the barrier, would be less than half those specified;
- c. Be not less than 0.012 in (0.3 mm) thick if of electrical grade paper and if the spacings, without the barrier, would not be less than half those specified; and
- d. Be reliably held in place.

1.19.12 Insulating barriers having a thickness less than that specified in "-b" and "-c" of 1.19.11 may be used if, upon investigation, they are found to have mechanical and electrical properties adequate for all conditions of service.

1.19.13 Adhesives used to hold insulating barriers in place shall be subject to investigation to assure adequate life under conditions of normal use.

1.20 Separation of Circuits

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

- a. Be segregated by internal barriers;
- b. Be segregated from each other;
- c. Be segregated by grounded shielding;
- d. Have all conductors insulated for the highest voltage; or
- e. Have either conductor (or the group of conductors for that voltage) insulated for twice the highest voltage.

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

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

1.20.4 If an internal barrier is used to provide separation between the wiring of different circuits it shall be of adequate mechanical strength and reliably held in place and constructed in accordance with the requirements of 1.20.5 to 1.20.7.

1.20.5 Barriers of sheet metal shall have a thickness not less than that specified in Table II, Thickness of Sheet Metal For Enclosures - Carbon Steel or Stainless Steel.

1.20.6 Barriers of insulating material shall be not less than 0.028 in (0.70 mm) thick, if of electrical grade paper and, when located between conductors and bare live parts of different circuits, shall comply with 1.10, Electrical Insulation.

- 1.20.7** Openings in barriers for wires and closures for unused openings shall present a smooth surface wherever an insulated conductor may be in contact with it.

1.21 Protection of Control, Battery, and Output Power Circuits

- 1.21.1** Protection shall be provided for:

- a. Control circuits that extend from the portable fuel cell power system to a remote control panel or the like;
- b. Battery supply circuits (see Table XI, Protection of Battery Supplies); and
- c. An ac output circuit

Note: Equivalent protection may be achieved by electronic means.

- 1.21.2** The protective devices required by 1.21.1 shall be capable of interrupting the short-circuit current of the circuit in which they are used and their rating or setting shall not exceed the ampacity of the conductors to be protected, see Table XI, Protection of Battery Supplies.

- 1.21.3** For battery cabinets, the protective device required by 1.21.1-b for battery supply circuits shall be located between the battery and any component that may short circuit due to failure of the component, such as a capacitor or solid state device, and shall comply with the overcurrent protection test of 2.14, Protection, Battery Supply Circuits.

1.22 Protection of Receptacles

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

- a. The circuit is not capable of delivering current in excess of the rating of the receptacle under any conditions of loading; or
- b. Electronic protection is provided that cannot be defeated by a single fault.

1.23 Battery Supplies

- 1.23.1** Batteries intended for use with a portable fuel cell power system shall be supplied with the portable fuel cell power system.

- 1.23.2** The interior of a metallic enclosure or compartment housing a wet cell battery, such as a lead acid or nickel iron (alkaline) storage battery, shall be protected by two coats of acid (or alkali, as applicable) resistant paint, two coats of enamel individually baked on, or the equivalent. Listed or recognized VRLA or SLA batteries shall be exempt from this requirement.

- 1.23.3** A polymeric enclosure or compartment housing a wet cell battery, such as a lead-acid storage battery, shall be resistant to corrosion by acids or alkalis, as applicable.
- 1.23.4** The enclosure or compartment housing a wet cell battery, such as a lead-acid storage battery, shall be constructed so that spillage or leakage of the electrolyte from the volume of one battery container will be contained within the enclosure and prevented from:
- Reaching the outer surfaces of the portable fuel cell power system where contact with the user is possible;
 - Contaminating adjacent electrical components or materials; and
 - Bridging required electrical spacings.
- 1.23.5** A battery shall be so located and mounted that the terminals of cells will be prevented from coming in contact with the terminals of adjacent cells, or with the metal parts of the battery compartment, as the result of shifting of the battery.
- 1.23.6** Vented wet cell batteries may be integral with the portable fuel cell power system, provided all the following conditions are met:
- The enclosure or compartment housing the batteries is vented;
 - Arcing parts such as the contacts of switches, circuit breakers and relays are not located in the battery compartment; and
 - The battery compartment does not vent into compartments with enclosed spaces that contain arcing parts.
- Note: The requirements of 1.23.6 do not apply to sealed cell or valve regulated batteries.*
- 1.23.7** If vented wet cell batteries are housed in an enclosure or compartment, the ventilation shall provide four changes of air per hour and the portable fuel cell power system shall be marked in accordance with 1.36.11. Natural ventilation will be considered adequate for SLA and VRLA batteries, so long as 1.35, Instructions, is complied with.
- 1.23.8** A metal case or container of a battery, such as an alkaline battery, shall be insulated or spaced away so as not to contact uninsulated live parts of the portable fuel cell power system if such contact may result in a short circuit.
- 1.23.9** An enclosure or compartment housing batteries having metal containers or cases that are conductively connected to a battery electrode shall be such that the batteries are insulated or spaced from each other, or otherwise physically arranged, to prevent short-circuiting of part or all of the battery supply after installation in the portable fuel cell power system.
- 1.23.10** A battery that requires the addition of water shall have a means to determine the fluid level.
- 1.23.11** If transformer isolation is not provided between the ac input circuit of the portable fuel cell power system and the battery circuit:
- The battery terminals shall be guarded to reduce the likelihood of unintentional contact with the battery terminals; and

- b. The marking specified in 1.36.14 shall appear adjacent to the batteries.

1.24 Grounding and Bonding

1.24.1 Portable Standby Fuel Cell Power Systems

For portable standby fuel cell power systems with an output supplied by either an internal AC (inverter equipped fuel cell) power supply, or the electrical distribution system, an internal transfer switch (see Figure 6, Ground and Neutral Wiring For Two Source Systems) shall make and break all current carrying conductors such that:

- a. When the unit is supplying power from its internal AC source, the neutral to the load shall be transferred to the neutral established for the internal source and disconnected from the distribution system neutral.
- b. When the unit is supplying power directly from the electrical distribution system, the neutral to the load shall be transferred to the neutral provided by the distribution system and disconnected from the internal power supply neutral.
- c. The Receptacle Grounding Terminal shall be connected to the fuel cell equipment frame.

1.24.2 Portable Stand-Alone Fuel Cell Power Systems

The frame of a portable fuel cell power generator (generator) shall not be required to be externally grounded and shall be permitted to serve as the grounding electrode under the following conditions:

- a. The generator supplies only equipment mounted on the generator, cord-and-plug-connected equipment through receptacles mounted on the generator, or both, and
- b. The non-current-carrying metal parts of the equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame [See NEC 250.34 (A), NFPA-70].
- c. Otherwise grounding installation shall be in accordance with *National Electrical Code 250.20 (D)*, NFPA-70.

1.24.3 Portable Uninterruptible Fuel Cell Power Supplies

For portable uninterruptible fuel cell power supplies, Standard for *Uninterruptible Power Supply Equipment*, UL 1778, shall apply.

1.24.4 All exposed non-current-carrying metal parts within the fuel cell power system shall be electrically bonded to the frame of the fuel cell power unit.

1.24.5 Protective bonding shall consist of directly connected structural parts or discrete conductors or both. It shall withstand all thermal and dynamic stresses to which it could be subjected before one of the overcurrent protection means disconnects the equipment from its load or the supply. Compliance is checked by inspection, and when necessary, by measurement of the cross-sectional area of bonding conductors.

- a. The impedance, or resistance in the case of DC powered equipment, between the protective conductor terminal and each accessible part for which protective bonding is specified shall not exceed 0.1 Ohm. Cord impedance resistance does not form part of the specified bonding impedance (resistance).
- b. The resistance is to be determined by any convenient method (such as a Whetstone Bridge or other precision instrument), except that when unacceptable results are obtained, a reference measurement is to be taken in accordance with 1.24.5-c.
- c. When a reference measurement is required as noted in 1.24.5-b, compliance is checked by applying a test current for 1 minute and then calculating the impedance, or resistance in the case of DC powered equipment. The test current is the greater of 10 Amps D.C. or 10 Amps r.m.s. at rated frequency or a current equal to 1.25 times the rated current of any overcurrent protection device.

1.25 Static Transfer Switches

This section applies to static transfer switches intended for incorporation in uninterruptible ac power supplies (UPS).

1.25.1 Failure or malfunctioning of a solid-state power-switching component shall result in a fail-safe condition (see 1.25.7) under either of the following conditions:

- a. Failure of a solid state power-switching component and another solid state component (such as in a control circuit); or
- b. Failure of a solid-state power-switching component and a mechanical component (e.g., relay, contactor, or the like) for static switches employing such a device in conjunction with a power-switching semiconductor. Failure analysis of the mechanical device shall not be required if the current through the contacts is the same or less than the rated current of the device and the overload test evaluation is performed at 6 times rated current. The control circuit that operates the mechanical device shall be subjected to a component failure analysis.

Note: *The intent of 1.25.1 is to prevent voltage from appearing where it is not expected (such as on the utility line) upon failure of a power-switching component and another solid state or mechanical component.*

1.25.2 If a relay is used to transfer from the ac input line to the inverter, the overload current rating of the relay contacts shall be greater than the peak current that flows through the relay contacts during the output short-circuit test of 1.25.7. The overload current rating shall be considered to be 150 percent of the rated load current rating for a device rated in amperes and 600 percent of the rated load current rating for devices rated in horsepower.

1.25.3 Overcurrent protection shall be provided for each static switch source in each ungrounded line. If the overcurrent devices are not integral with the uninterruptible power supply they shall be specified on a label.

1.25.4 Mechanical isolating means shall be provided for servicing the power supply where failure of or leakage through a solid-state device could result in transfer of energy between two or more power sources. The disconnecting means shall be provided as an integral part of the uninterruptible power supply and be connected into the circuit in such a way that when

opened it will prevent transfer of energy between the different power sources. To facilitate servicing, barriers or other suitable means and/or marking shall be provided for protecting service personnel from live parts located ahead of isolating switches.

- 1.25.5** Automatic mechanical isolating means shall be provided as an integral part of the uninterruptible power supply to prevent transfer of energy from a single branch private supply system (such as a battery and inverter) to a branch of a multibranch system (such as a utility system) upon loss or shutdown of the utility system unless backfeed is not possible when evaluated in accordance with 1.25.1. The isolating means may be a relay, contactor, motorized circuit breaker or other device with an air gap between contacts.
- 1.25.6** Static transfer switches shall be tested as part of the uninterruptible power supply to determine their acceptability for the application.
- 1.25.7** Compliance with the requirements of 1.25.1 shall be verified by shorting one power switching component (e.g., SCR) and placing one fault on another component, such as in the control circuit. The fault placed on the component shall simulate the failure mode of that component (e.g., cathode to anode short on SCR, emitter to collector short or open on a transistor, or welding of a relay contact in the control circuit). This analysis shall be performed first with the utility supply energized and repeated with the utility supply not energized.
- 1.25.8** The dielectric strength test shall be performed on a static transfer switch with the solid state devices, or assemblies, normally connected between the systems, disconnected.

1.26 Heaters and Vessels (If Part of the Portable Fuel Cell Power System)

- 1.26.1** Electric heaters, when provided for protection of equipment at low ambient temperatures, shall comply with the applicable sections of the Standard for *Electric Heating Appliances, UL 499* or the Standard for *Electric Air Heaters, ANSI/UL 1025*.
- When for use in hazardous locations within the portable fuel cell power system, such heaters also shall comply with the applicable sections of the Standard for *Electric Heaters for Use in Hazardous (Classified) Locations, ANSI/UL 823*.
- 1.26.2** Gas heaters, when provided for protection of equipment at low ambient temperatures, shall comply with the applicable sections of the Standard for *Gas Unit Heaters and Gas-Fired Duct Furnaces, ANSI Z83.8 • CSA 2.6*, or other nationally recognized standard(s) covering such equipment.
- 1.26.3** Pressurized vessels, such as heat exchangers, 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 the applicable section(s) of the *ASME Boiler and Pressure Vessel Code*.
- 1.26.4** Unpressurized vessels, such as tanks and similar containers, shall be of stainless steel, cast iron, aluminum, plastic, reinforced plastic, ceramic, or other material especially suited to the application for which the tank or container is intended.