

Subject 3741

July 30, 2018

SUMMARY OF TOPICS

The following new UL Standard is being proposed for preliminary review and comment only:

1. For Preliminary Review Only: The proposed first edition of the Standard for Photovoltaic Hazard Control, UL 3741, including applicable requirements for Canada. Fire fighters performing operations involving buildings with attached Photovoltaic (PV) arrays may be exposed to electrical hazards from damaged PV equipment. These requirements for PV Hazard Control components, equipment and systems provide a reduced level of shock hazard from energized PV system equipment and circuits located within the PV array after the operation of any required hazard control initiation function.

COMMENTS DUE: August 13, 2018

This proposal is for review and comment only (no ballot at this time). Please note that comments on a preliminary review document will not receive a response from the proposal author through CSDS. Instead, the proposal author will be asked to review the comments and adjust the proposals and/or supporting rationale as the author determines to be appropriate. The preliminary review process is an informal mechanism that provides authors with the opportunity to refine their proposals before they advance to the next stage in UL's standards development process.

In some cases, the author of the proposals may choose to discontinue them. In this case, the author need not do anything after preliminary review has ended. Normally, the next step in the process is the more formal STP ballot and stakeholder review process. Only comments posted during the STP ballot and stakeholder review process will be provided with a response in CSDS.

1. For Preliminary Review Only: The proposed first edition of the Standard for Photovoltaic Hazard Control, UL 3741, including applicable requirements for Canada. Fire fighters performing operations involving buildings with attached Photovoltaic (PV) arrays may be exposed to electrical hazards from damaged PV equipment. These requirements for PV Hazard Control components, equipment and systems provide a reduced level of shock hazard from energized PV system equipment and circuits located within the PV array after the operation of any required hazard control initiation function.

RATIONALE

Proposal submitted by: Tim Zgonena, UL LLC, on behalf of the several UL 3741 Task Groups

The introduction of distributed energy and the use of photovoltaic (PV) arrays on the customer or consumer side of distribution systems (on homes and buildings) has created new safety concerns for first responders, in particular fire fighters who attend fires or calls where PVs have been installed. There is a risk of shock to fire fighters when responding to calls where PV arrays have been installed if the systems are not properly shut off. A means of shutting down the systems is required to provide assurance and protection to fire fighters who may not be aware that the PVs are generating energy. The purpose of this proposed standard is to establish and expand requirements for the evaluation of a Rapid Shutdown PV Array. The proposed standard is based on a UL Outline of Investigation (UL

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1699B, Photovoltaic (PV) DC Arc-Fault Circuit Protection) developed in April 2011. In addition, in 2017, UL collaborated with Sandia National Laboratories under a US Department of Energy research project to perform research and gather data to facilitate the development of this proposed standard. This research supplements previous ground breaking research on the topic conducted by UL several years ago, and carried on with the support of UL's Firefighter Safety Research Institute, a nonprofit research center for advancing safety and effectiveness of the first responder community. The research addressed five critical aspects of first responder safety in tactics involving rooftop PV arrays:

1. Evaluate electric shock parameters for grounded and ungrounded/isolated PV arrays.
2. Define safe states for PV systems operation under emergency conditions.
3. Determine body impedance model for adult FF including PPE and tools including corresponding shock thresholds.
4. Harmonize safety standards and committee work.

This is a critical new technology and it is important to maintain consistent standards and requirements to speed implementation for the benefit of North American fire fighters. The technological solutions are advancing quickly, based on challenges with systemic performance of equipment based solutions, new research findings, and significant evolution of codes such as the National Electrical Code (NEC) and the Canadian Electrical Code (CEC). Proposing this bi-national standard will allow for the most up-to-date safety science approaches to be implemented to provide protection for fire fighters across North America.

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CONTENTS

INTRODUCTION

1 Scope	5
1.1 Introduction	5
1.2 Equipment and conditions included in scope	5
1.3 Equipment and conditions excluded from scope	6
2 Components	6
3 Units of Measurement	6
4 Undated References	6
5 Normative References	7
6 Glossary	9

CONSTRUCTION

7 Array Component Requirements	11
7.1 General	11
8 Protection Requirements	12
8.1 Basis of requirements	12
8.2 Application of requirements	13
9 Protective Elements	13
9.1 General	13
9.2 PV circuit-interrupting device	14
9.3 System or equipment ground circuit interrupting	14
9.4 Protection by enhanced insulation from live parts	14
9.5 Limited access to live parts of different voltage potential	14
10 Shock Hazard Thresholds for Fire Fighters	15
10.1 Body resistance	15
10.2 Personal protection equipment (PPE) resistance	16
11 Indication Systems	17
12 Safety Analysis	18
12.1 General	18
12.2 Safety analysis steps	18
12.3 Fire fighter PV array interactions	22

PERFORMANCE

13 General	26
14 PVHC System Conditioning	26
14.1 Potential damage from firefighter operations	26
14.2 Damage from firefighter tool	27
14.2.1 Purpose	27
14.2.2 Apparatus	27
14.2.3 Procedure	28
14.3 Damage from falling firefighter	28
14.3.1 Purpose	28
14.3.2 Apparatus	28
14.3.3 Procedure – module or component level test	29
14.3.4 Procedure – mechanical assembly test	29
14.4 Damage from firefighter step, walk or crawl	29
14.4.1 Purpose	29

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Documents

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14.4.2 Apparatus	30
14.4.3 Procedure	30
14.5 Firefighter PPE damage test	30
14.5.1 Purpose	30
14.5.2 Apparatus	30
14.5.3 Procedure	31
15 Hazard Exposure	31
15.1 Firefighter impedance circuits	31
15.2 Source test circuits	31
15.3 Leakage current tests	32
15.3.1 Module leakage current test	32
15.3.2 Enclosure or other component leakage test	33
15.3.3 Array leakage measurements within array assemblies	34
16 Single Point Equipment Failure	34
17 System Level Faults	34

MANUFACTURING AND PRODUCTION TESTS

18 General	35
------------------	----

MARKINGS

19 General	35
------------------	----

INSTRUCTIONS

20 General	36
------------------	----

ANNEX A (NORMATIVE)

A.1 Standards for Components	38
------------------------------------	----

ANNEX B (NORMATIVE)

B.1 Safety Analysis Example	45
-----------------------------------	----

ANNEX C (NORMATIVE)

C.1 Common Construction Details Including Associated Risk Levels	46
--	----

ANNEX D (INFORMATIVE)

D.1 Marking - French Translations	47
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INTRODUCTION

1 Scope

1.1 Introduction

1.1.1 Fire fighters performing operations involving buildings with attached Photovoltaic (PV) arrays may be exposed to electrical hazards from damaged PV equipment. These requirements for PV Hazard Control components, equipment and systems provide a reduced level of shock hazard from energized PV system equipment and circuits located within the PV array after the operation of any required hazard control initiation function.

1.1.2 This standard is based on the presupposition that the PV array is installed by qualified persons in accordance with the installation instructions and all applicable installation codes and standards. Evaluation to this standard should not replace other requirements addressing the control of power source(s) for the purposes of worker safety during installation or maintenance. Energized circuits can remain in some PV array equipment after any required hazard control initiation function is operated.

NOTE: Requirements for PV arrays addressed in this standard are intended for compliance with the National Electrical Code (NEC), NFPA-70, requirements for controlling electrical shock hazards inside the array boundary as addressed in NEC section 690.12(B)(2), Rapid Shutdown of PV Systems on Buildings and with the Canadian Electrical Code (CEC) C22.1.

1.2 Equipment and conditions included in scope

1.2.1 These requirements relate to conditions where PV array equipment or systems are subjected to tests representing fire fighter operations during an emergency. These conditions may result in degradation or damage from stresses beyond those covered in existing product safety standards.

1.2.2 The acceptable shock hazard risk established by these requirements is based on defined assumptions related to specific personal protective equipment (PPE) in serviceable condition worn by fire fighters during fire fighting operations involving buildings. Consideration for damage to PPE that may result from the interaction with the PV array is included.

NOTE: See NFPA 1971 and NFPA 1851 for the selection, care, and maintenance of fire fighter PPE.

1.2.3 Types of fire fighter tools and extinguishing agents, including certain water plus foam solutions, during specific fire fighter tasks are considered in this standard.

NOTE: Specifications for these items are outlined in Fire Fighter PV Array Interactions, Section 12.3.

1.2.4 Body impedances of adult fire fighters are defined in this standard to set the criteria by which shock hazards are evaluated.

1.2.5 The materials and methods used to construct the PV array are included in the evaluation. The evaluation results in an identified list of hazard control components determined to be necessary for the PV hazard control function. The list of components, and any characteristics of other connected equipment or systems that are essential to maintain the operational integrity of the hazard control function are documented in the installation instructions in accordance with this standard.

1.2.6 The evaluation is based on a risk assessment of the electrical shock hazards to fire fighters working in the vicinity of the PV array.

1.2.7 The evaluation addresses the electrical hazard potential of PV array equipment on or integrated into buildings.

1.3 Equipment and conditions excluded from scope

1.3.1 The evaluation does not include equipment where the hazard control systems or functions have been rendered ineffective due to physical damage not specifically addressed in this standard. Examples of physical damage not addressed are the direct exposure of components to fire, high-pressure hose spray, or major systemic physical damage such as building collapse.

1.3.2 The evaluation does not include consideration for any damage to PPE that occurred prior to fire fighter interaction with the PV array.

1.3.3 The use of extinguishing agents not specified in this standard, such as seawater or high foam concentrations, are not included in the evaluation.

1.3.4 These requirements are not intended to address hazards to electrical technicians or other persons interacting with PV array equipment.

1.3.5 Though all components, equipment, and systems that could be used to construct the PV array are considered in the evaluation, not all array components are required to be identified as hazard control components, or be specifically addressed in the installation instructions for the purposes of this standard.

1.3.6 These requirements do not address any electrical shock hazards not covered by this standard or other hazards that PV arrays may present such as slip, trip or fall hazards.

1.3.7 This standard does not address fire fighter interactions involving ground mounted PV array equipment.

NOTE: Additional installation requirements addressing rapid shutdown of PV system circuits can be found in the National Electrical Code (NEC), NFPA 70, Section 690.12, Rapid Shutdown of PV Systems on Buildings, and the Canadian Electrical Code (CEC) C22.1 64-218 requirements.

2 Components

2.1 A component of a product covered by this standard shall comply with the requirements for that component. See Annex A for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the CSA or UL standards as appropriate for the country where the product is to be installed.

3 Units of Measurement

3.1 Values and their respective units of measurement that are stated without parentheses constitute the requirement of the standard and those in parentheses constitute explanatory or approximate information.

4 Undated References

4.1 Any undated reference appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that standard.

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Some of the standard references are country specific depending upon whether or not the energy storage system is intended for installation in the United States, in Canada, or both.

UL Standards

969

Marking and Labeling Systems

1703

Flat-Plate Photovoltaic Modules and Panels

1741

Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

2703

Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels

4703

Photovoltaic Wire

6703

Connectors for Use in Photovoltaic Systems

9703

Outline for Distributed Generation Wiring Harnesses

UL 61730-1

Photovoltaic (PV) Module Safety Qualification - Part 1: Requirements For Construction

UL 61730-2

Photovoltaic (PV) Module Safety Qualification - Part 2: Requirements For Testing

3703

Solar Trackers

CSA Group Standards

C22.1

Canadian Electrical Code, Part I Safety Standard for Electrical Installations

C22.2 No. 330

Photovoltaic Rapid Shutdown Systems

C22.2 No. 0.15

Adhesive Labels

Institute of Electrical and Electronics Engineers (IEEE) Standards Association

IEEE 1547

Interconnecting Distributed Resources with Electric Power Systems

IEEE 1547.1

*Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems***International Electrotechnical Commission (IEC) Standards**

IEC 60812

Standard for Analysis Techniques for System Reliability – Procedures for Failure Mode and Effects Analysis (FMEA)

IEC 60479-1

Effects of current on human beings and livestock - Part 1: General aspects

IEC TS 60479-2

*Effects of current on human beings and livestock - Part 2: Special aspects***International Standards Organization (ISO) Standards**

ISO 3864-2

Graphical Symbols - Safety Colours and Safety Signs - Part 2: Design Principles for Product Safety Labels

ISO/IEC 31010

*Risk Management – Risk Assessment Techniques***National Fire Protection Association (NFPA) Codes and Standards**

NFPA 70

National Electrical Code

NFPA 1001

Standard for Fire Fighter Professional Qualifications

NFPA 1410

Standard on Emergency Scene Operations

NFPA 1700

Guide for Structural Fire Fighting

NFPA 1851

Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting

NFPA 1981

Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services

NFPA 1971

Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting

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National Electrical Manufacturers Association (NEMA) Standards

NEMA Z535.1
Safety Colors

NEMA Z535.2
Environmental and Facility Safety Signs

NEMA Z535.3
Criteria for Safety Symbols

NEMA Z535.4
Product Safety Signs and Labels

NEMA Z535.5
Safety Tags and Barricade Tapes (for Temporary Hazards)

NEMA Z535.6
Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials

6 Glossary

6.1 For the purpose of this standard, the following definitions apply.

6.2 ARRAY – A mechanically and electrically integrated grouping of modules with support structure including any attached system components such as inverter(s) or dc-to-dc converter(s) and combiner boxes.

6.3 ARRAY BOUNDARY – A zone extending 305 mm (1 ft) from the array in all directions.

6.4 BASIC INSULATION – Insulation which provides a single level of protection against electric shock under fault-free conditions.

NOTE: Basic insulation may serve also for functional purposes. For the purposes of this standard, references to basic insulation only apply to components in which there are not existing requirements for double or reinforced insulation. As an example, references to basic insulation will not apply to PV conductors since they are required by the NEC and UL 4703 to have double or reinforced insulation.

6.6 DOUBLE INSULATION – Insulation comprising both basic insulation and supplementary insulation.

6.7 ENERGIZED CIRCUIT– A circuit with voltage potential measured from line to line or from line to ground.

6.8 ENHANCED INSULATION – Any combination of double or reinforced insulation. Also includes switchable semiconductors or impedance to attenuate live circuits.

6.9 EQUIPMENT UNDER TEST (EUT) – Generic reference to the equipment, component or system being evaluated.

6.11 FIRE FIGHTER (FF) – A person who has demonstrated the knowledge and skills to function as an integral member of a fire-fighting team under direct supervision in hazardous conditions. A fire fighter is required to wear PPE and is trained in the use of that PPE.

NOTE: For the purposes of this standard, it is assumed that a fire fighter will have:

- a) A base level of fire fighting training;
- b) An established hierarchy of command and responsibility;
- c) A minimum amount of PPE; and
- d) A common set of fire fighting tools.

See NFPA 1001 or appropriate equivalent standard for further information on qualifications of fire fighters.

6.12 FIRE FIGHTER INTERACTION – An action that may occur during the performance of a task that subjects the fire fighter to direct or indirect contact with array equipment or components.

6.13 FUNCTIONAL SAFETY– Part of the hazard reduction for emergency responders, which depends on the correct execution of specific functions performed by mechanical assemblies, electrical circuits, components, or software.

6.14 HAZARD CONTROL COMPONENTS – Components of a PV system that during the evaluation of the array, are determined to be necessary to the function of the PV hazard control system. These components may be integral to the general function of the PV system or may be independent components not related to the general function of the PV system.

6.17 PERSONAL PROTECTIVE EQUIPMENT (PPE) – The full complement of garments fire fighters are normally required to wear while on emergency scene, including turnout coat, protective trousers, fire-fighting boots, fire-fighting gloves, a protective hood, a helmet with eye protection, a self-contained breathing apparatus (SCBA) and a personal alert safety system (PASS) device.

NOTE: For the purposes of establishing baseline risk factors, the requirements of this standard assume that fire fighters are equipped with standard and basic levels of PPE, and are trained in the following:

- a) The proper use and maintenance of protective equipment;
- b) An understanding of when personal protective equipment is necessary;
- c) An understanding of the kind of protective equipment that is necessary;
- d) An understanding of the limitations of personal protective equipment in protecting fire fighters from injury; and
- d) Proper procedures for putting on, adjusting, wearing, removing and maintaining personal protective equipment.

See NFPA 1001, Chapter 3, or appropriate equivalent standard for further descriptions of personal protective clothing and equipment. See NFPA 1971 or appropriate equivalent standard for further information on protective ensembles for fire fighters. See NFPA 1981 or appropriate equivalent standard for further information on types of SCBA.

6.19 PV HAZARD CONTROL COMPONENT (PVHCC) – A component of a PVHCE. PVHCC are often incomplete but may serve a function related to compliance of PVHCE. See Figure 1 for an example of a PVHCC.

6.20 PV HAZARD CONTROL EQUIPMENT (PVHCE) – A complete piece of equipment evaluated for compliance with this standard that performs a function related to reduction of electric shock hazards for fire fighters performing their work in the vicinity of the PV array. See Figure 1 for an example of PVHCE.

6.21 PV HAZARD CONTROL SYSTEM (PVHCS) – Systems of one or more PVHCE and other specific or generic specified PV array equipment that have been evaluated to comply with the system requirements of this standard. See Figure 1 for an example of a PVHCS.

6.22 REINFORCED INSULATION – A single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified.

NOTE: A single insulation system does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as basic or supplementary insulation.

6.23 STRUCTURAL FIRE FIGHTING – The activities of rescue, fire suppression, and damage mitigation on or in buildings.

Note from Task Group: This term is not presently used but it will be added to the scope and PPE section.

6.24 SUPPLEMENTARY INSULATION – Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

6.25 WIRE MANAGEMENT / SECUREMENT SYSTEM – Methods within a PV array that do not involve enclosure of wires in raceway or conduit, such as wires or bundles of wires secured to a racking system, cable tray or channel by the use of clips, clamps, ties, or similar restraining components.

CONSTRUCTION

7 Array Component Requirements

7.1 General

7.1.1 Figure 1 shows an example of potential PVHC implementations relative to the scope of the standard, including a collection of likely or possible components. The standard is intended to supplement the required applicable equipment and component standards. The PVHC evaluation under this standard may encompass only a portion of the identified components as necessary to achieve the required level of shock hazard reduction.

7.1.2 A PV hazard control system may be comprised of either an individual piece of equipment that fulfills the necessary functions, or multiple pieces of equipment coordinated to perform the functions as defined in the installation instructions to reduce but not eliminate risk of electric shock hazard within a damaged PV array during fire-fighting procedures.

Figure 1, PV Hazard Control Standard Functional Diagram - To view Figure, click on "Supporting Documentation" under the Quick View tab on the right-hand side of the CSDS work area.

NOTE: Examples of systems, equipment and components include:

PVHCS: e.g. Combination of specific mounting system (6), use of switching and array segmenting devices (5), and inverter control (3)(4).

PVHCE: e.g. Array combiner box with internal switching (2)

PVHCC: e.g. Switching component located mid string (5)

7.1.3 Examples of enhanced protection measures are identified by numbered components in Figure 1:

- 1) Power electronic devices within the string, on or within module(s) that separate strings into lower voltage segments.
- 2) Combiner box level switching devices that isolate PV output circuits from inverter, other strings and/or from ground potential.
- 3) Control and communication devices that coordinate switching of PVHC devices (i.e. inverter(s), J-box and/or string switching devices in response to rapid shutdown activation.
- 4) Inverter input circuit disconnection and isolation.
- 5) String or sub-string level switching (electrical or electromechanical disconnection) devices located within the array.
- 6) Mechanical and or access prevention protection provided by mounting system hardware, enhanced physical protection of modules, wiring and wire management, separation of circuits, etc.

7.1.4 PVHC Systems shall be built with equipment compliant with the following standards, UL 1741, UL 1703, UL 61730-1, UL 61730-2, UL 2703, UL 3703, UL 6703, and UL 9703.

8 Protection Requirements

8.1 Basis of requirements

8.1.1 The requirements outlined in this Standard are intended to reduce the likelihood of muscle tetanization (let-go) and ventricular fibrillation from electrical shock of potentially damaged PV arrays during fire fighter operations.

8.1.2 Under normal conditions and abnormal conditions evaluated under product safety standards, PV systems do not present a shock hazard. When properly installed in accordance with the manufacturer's instructions and installation codes, protection from access to live circuits, is incorporated in components and conductors, and this insulation is the primary means to guard against the physiological effects described in 8.1.1. Other measures already required for PV systems and components address safety and fire-protection objectives but may not necessarily protect against these physiological effects accounting for the specific fire fighter interactions and resulting effects on PV systems equipment. In the event of low impedance insulation failure as a result of component single-point failures or system level faults in the course of fire fighter operations, at least one secondary protective mechanism shall be in place to address these effects.

8.1.3 For the purposes of reducing shock hazards in this standard, it is assumed that fire fighters will have:

- a) Required training for fire fighter operations.
- b) An established hierarchy of command and responsibility.
- c) A minimum required PPE.
- d) A minimum or common set of fire fighting tools.

NOTE: Legal requirements for training and a minimum PPE requirements as identified by the AHJ.

8.2 Application of requirements

8.2.1 Protection Requirements, Section 8, applies to components of the PV system that are capable of being contacted during fire fighter operations and that could be energized during foreseeable fault conditions. At each component, a determination shall be made regarding whether the secondary protective mechanism(s) provided are capable of limiting risk of injury to fire fighters. It is possible that several protective mechanisms will be required to be used, in various combinations, on a single PV system to provide protection depending on the design.

8.2.2 The evaluation of a PVHC includes a determination of the effectiveness of each specific protective mechanism employed at each component of the PV array/system identified in 8.2.1.

8.2.3 PVHC effectiveness in this standard is determined by construction and design features, and by performance testing under various conditions. The extent of performance testing required is dependent on the construction and design features. Designs that meet a minimum level of protection and/or have operational limits below the thresholds specified in this standard to reduce shock hazards can reduce or eliminate testing requirements.

8.2.4 A safety analysis as defined in Section 12 shall be performed to select the components, foreseeable faults, anticipated fire fighter interactions, and performance tests to be evaluated for a specific PVHCS or PVHCE protection.

9 Protective Elements

9.1 General

9.1.1 A wide range of protective elements may be employed as part of the PVHC system, including but not limited to the those summarized in Normative References, Section 5. This Section defines requirements for certain elements that may be used.

9.1.2 Electronic protective elements of a PVHCE or PVHCS shall comply with the PVRSE and PVRSS requirements of UL 1741.

9.2 PV circuit-interrupting device

9.2.1 PV circuit-interrupting devices shall revert to the isolated or attenuated condition upon activation of PVHC, upon loss of control power or upon loss of communication signal, and shall interrupt power to the intended connected PV source circuitry within the required time. The interrupting device's primary function may be to achieve one or both of the following:

- a) Energized circuit segmentation.
- b) Limit current flow to below thresholds defined in this standard.

9.3 System or equipment ground circuit interrupting

9.3.1 Circuit-interrupting devices such as ground fault interrupters intended to disconnect grounded conductor(s) upon activation of PVHC, shall revert to the isolated or attenuated condition position upon loss of control power or upon loss of communication signal in 30 seconds or less.

NOTE: PV GFDI ground fault protection is normally not intended to prevent shock, but this methodology to open the ground bond as a precaution could potentially reduce electric shock hazards under some array fault conditions. In this case the interrupting device is opening as a precaution to alter the shock hazard potential of energized circuits in subsequent fire fighter interactions.

9.4 Protection by enhanced insulation from live parts

9.4.1 Enhanced insulation measures may be achieved using double-insulation, reinforced insulation or supplementary insulation.

9.4.2 Protection measures comprising exposed conductive parts shall be evaluated in Section 12 for their likelihood to become energized under relevant single point failure and system level fault conditions.

9.4.3 Devices intended to limit current to acceptable levels upon activation of PVHC, by inserting impedance into (rather than interrupting) circuits, shall comply with the UL 1741 requirements for PVRSE attenuation and semiconductor switching component devices as well as rapidly revert to the high impedance condition upon loss of control power or upon loss of communication signal.

9.5 Limited access to live parts of different voltage potential

9.5.1 Protective measures to limit simultaneous access to live parts and/or circuits of different voltage potential, that could place a fire fighter into a current path, may be achieved by designs placing inherent distance between circuits, by physical barriers, or equivalent means.

9.5.2 Circuits with secondary protection relying solely on distance between live parts of different potential that may be exposed through fire fighter interactions that may be exposed through fire fighter interactions that exceed defined hazard limits shall be separated by a minimum of 2.4 m (8 ft).

Exception: Live parts that may be exposed through fire fighter interactions may be closer than 2.4 m (8 ft) if they do not exceed the PVHC shock hazard thresholds following the fire fighter interaction preconditioning.

9.5.3 Secondary protection provided by physical barriers may be similar in effect to enhanced insulation measures. Whereas enhanced insulation protects against exposure to a live part, access limiting by physical barriers acts to prevent personnel from simultaneously contacting two or more circuits of different potentials.

9.5.4 Physical barriers comprising exposed conductive parts shall be evaluated in Section 12 for their likelihood to become energized under foreseeable single point failure and system level fault conditions.

10 Shock Hazard Thresholds for Fire Fighters

10.1 Body resistance

10.1.1 This section provides body resistance data for adult male and female fire fighters. The limits for adult females are roughly 2/3 of the limits for men so this standard will use the female limits, which will be worst case.

Table 1
Adult female body resistance

Volts	Hand to Hand Resistance	Hand to One Foot Resistance
25	3875	4801
50	2900	3593
75	2275	2819
100	1900	2354
125	1675	2075
150	1475	1828
175	1350	1673
200	1275	1580
225	1225	1518
400	950	1177
500	850	1053
700	775	960
1000	775	960
Note: Table values are based on IEC 60479-1, Table 10, 50% column.		