



UL 1449

STANDARD FOR SAFETY

Surge Protective Devices

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UL Standard for Safety for Surge Protective Devices, UL 1449

Fifth Edition, Dated January 8, 2021

Summary of Topics

This revision of ANSI/UL 1449 dated December 15, 2022 includes the following changes in requirements:

- ***Addition of UL 969A as Alternate Option for Marking and Labeling; [68.1.1](#)***
- ***Clarifications and Updates to [Table 48.1](#) (Test Program);***
- ***Revisions to Capacitor Testing; [26.1](#), [26.3](#), [26.4](#), [69.1](#), [73.1](#), [85.42](#)***
- ***Clarification and Additional Text to [SA8.3](#) – [SA8.4](#) Covering Current Tests***
- ***Clarification to SB7 for Testing SPDs that Permit Follow Current; [SB7.1](#)***
- ***Clarification of Clause [SB8.2](#) Regarding SCCR Levels***
- ***Correction to Number of Test Samples in Clause [SB10.1](#);***
- ***Clearances for Altitude Over 2000 m; [19.2](#)***
- ***Type 4 Component Assemblies Surge Testing; [43.2](#)***
- ***Temperature Testing of Plug Blades in Direct Plug-In SPDs; [Table 40.1](#), [40.14](#), [40.17](#)***

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated March 4, 2022 and October 14, 2022.

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INTRODUCTION

1 Scope

1.1 These requirements cover enclosed and open-type Surge Protective Devices (SPDs) designed for repeated limiting of transient voltage surges as specified in the standard on 50 or 60 Hz power circuits not exceeding 1000 V and for PV applications up to 1500 V dc and designated as follows:

Type 1 – One port, permanently connected SPDs, except for watt-hour meter socket enclosures, intended for installation between the secondary of the service transformer and the line side of the service equipment overcurrent device, as well as the load side, including watt-hour meter socket enclosures and Molded Case SPDs intended to be installed without an external overcurrent protective device. Type 1 SPDs for use in PV systems can be connected between the PV array and the main service disconnect.

Type 2 – Permanently connected SPDs intended for installation on the load side of the service equipment overcurrent device; including SPDs located at the branch panel and Molded Case SPDs.

Type 3 – Point of utilization SPDs, installed at a minimum conductor length of 10 meters (30 feet) from the electrical service panel to the point of utilization, for example cord connected, direct plug-in, receptacle type and SPDs installed at the utilization equipment being protected. See marking in [85.4](#). The distance (10 meters) is exclusive of conductors provided with or used to attach SPDs.

Type 4 Component Assemblies – Component assembly consisting of one or more Type 5 components together with a disconnect (integral or external) or a means of complying with the limited current tests in [45.4](#).

Type 1, 2, 3 Component Assemblies – Consists of a Type 4 component assembly with internal or external short circuit protection.

Type 5 – Discrete component surge suppressors, such as MOVs that may be mounted on a PWB, connected by its leads or provided within an enclosure with mounting means and wiring terminations.

1.2 Except as indicated in [1.3](#), the products covered by this Standard are rated and intended for connection to circuits or supply sources having nominal voltage ratings as specified in [Table 45.1](#).

1.3 A product intended for connection to an ac circuit or supply source other than that specified in [1.2](#) may be examined and tested in accordance with the intent of the requirements in this standard and, if found to be substantially equivalent, may be judged to comply with this Standard.

1.4 These requirements cover cord-connected direct plug-in, and permanently connected SPDs intended for indoor and outdoor use in accordance with the National Electrical Code, ANSI/NFPA 70.

1.5 These requirements do not cover the interconnection of multiple field installed SPDs.

1.6 These requirements cover SPDs that may include components specifically intended to function as filters for conducted electromagnetic interference (EMI) or noise, in addition to limiting transient voltage surges. See Section [27](#).

1.7 These requirements cover SPDs employing circuit components intended to provide secondary protection for telephone communication circuits and circuit components intended to protect data communication or fire alarm circuits. See Section [28](#).

1.8 These requirements cover SPDs employing antenna connections for audio-video products. See Section [29](#).

1.9 An SPD that has a battery backup feature or other uninterruptible power supply equipment shall also comply with the applicable requirements in the Standard for Uninterruptible Power Supply Equipment, UL 1778. See Section [31](#).

1.10 These requirements cover SPDs/Panelboard Extension Modules. These products shall also comply with the Standard for Panelboards, UL 67. See Section [32](#).

1.11 These requirements do not evaluate the effect of SPDs on connected loads, the effect of SPDs on harmonic distortion of the supply voltage, the degree of attenuation provided by SPDs, nor the adequacy of the voltage protection rating of SPDs to protect specific connected equipment from upset or damage.

1.12 This standard does not cover cord connected or direct plug-in SPDs intended for use with medical equipment. Medical equipment is typically intended for use in General Patient Care Areas or Critical Patient Care Areas as defined by Article 517 of the National Electrical Code for Health Care Facilities. SPDs intended for such use shall comply with the requirements of the Standard for Safety of Medical Electrical Equipment, Part 1: General Requirements, UL 60601-1, and the Standard for Safety Requirements for Medical Electrical Systems, IEC 60601-1-1.

1.13 An SPD intended to serve as an outlet cover plate or outlet box hood shall comply with the requirement for faceplates in the Standard for Cover Plates for Flush Mounted Wiring Devices, UL 514D.

1.14 An SPD intended for use in a Lightning Protection System (LPS) shall comply with the Surge Protection requirements in the Standard for Installation Requirements for Lightning Protection Systems, UL 96A.

1.15 A Type 3 SPD may employ additional low voltage supplementary circuitry to power a USB charger.

1.16 A cord-connected or direct plug-in Type 3 SPD may employ a replaceable or non-replaceable rechargeable battery to power a USB output circuit.

1.17 A direct plug-in SPD employing more than two receptacles shall also comply with the applicable requirements in the Standard for Current Taps and Adapters, UL 498A.

1.18 A cord-connected SPD employing more than two receptacles shall also comply with the applicable requirements in the requirements in the Standard for Relocatable Power Taps, UL 1363 or the Standard for Furniture Power Distribution Units, UL 962A.

2 Referenced Publications

2.1 Any undated reference to a code or standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or standard.

2.2 The following publications are referenced in this Standard:

ANSI C84.1, *Electric Power Systems Voltage Ratings (60 Hz)*

ASTM E230/E230M, *Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

IEC 320, *Power Cords*

IEC 60601-1-1, *Safety Requirements for Medical Electrical Systems*

IEC 60664-1, *Insulation Coordination for Equipment within Low-voltage Supply Systems – Part 1: Principles, Requirements and Tests*

IEEE C37.09, *AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

IEEE C62.45, *Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits*

NEMA/WD 6, *Wiring Devices – Dimensional Specifications*

NFPA 70, *National Electrical Code*

UL 20, *Snap Switches*

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*

UL 67, *Panelboards*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 96A, *Installation Requirements for Lightning Protection Systems*

UL 224, *Extruded Insulating Tubing*

UL 248-14, *Low-Voltage Fuses – Part 14: Supplemental Fuses*

UL 248-16, *Low-Voltage Fuses – Part 16: Test Limiters*

UL 414, *Meter Sockets*

UL 452, *Antenna-Discharge Units*

UL 486A-486B, *Wire Connectors*

UL 486E, *Wiring Terminals for Use With Aluminum and/or Copper Conductors*

UL 489, *Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures*

UL 497, *Protectors for Paired-Conductor Communication Circuits*

UL 497A, *Secondary Protectors for Communication Circuits*

UL 497B, *Protectors for Data Communication and Fire Alarm Circuits*

UL 497C, *Protectors for Coaxial Communication Circuits*

UL 498, *Attachment Plugs and Receptacles*

UL 498A, *Current Taps and Adapters*

UL 508, *Industrial Control Equipment*

UL 514A, *Metallic Outlet Boxes*

UL 514B, *Conduit, Tubing, and Cable Fittings*

UL 514C, *Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers*

UL 514D, *Cover Plates for Flush Mounted Wiring Devices*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 746E, *Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards*

UL 796, *Printed Wiring Boards*

UL 817, *Cord Sets and Power-Supply Cords*

UL 840, *Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment*

UL 962A, *Furniture Power Distribution Units*

UL 969, *Marking and Labeling Systems*

UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*

UL 1059, *Terminal Blocks*

UL 1077, *Supplementary Protectors for Use in Electrical Equipment*

UL 1283, *Electromagnetic Interference Filters*

UL 1310, *Class 2 Power Units*

UL 1363, *Relocatable Power Taps*

UL 1429, *Pullout Switches*

UL 1434, *Thermistor-Type Devices*

UL 1492, *Audio-Video Products and Accessories*

UL 1557, *Electrically Isolated Semiconductor Devices*

UL 1577, *Optical Isolators*

UL 1778, *Uninterruptible Power Supply Equipment*

UL 2054, *Household and Commercial Batteries*

UL 5085-1, *Low Voltage Transformers – Part 1: General Requirements*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

UL 60065, *Audio, Video, and Similar Electronic Apparatus Safety Requirements*

UL 60384-14, *Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains*

UL 60601-1, *Medical Electrical Equipment, Part 1: General Requirements*

UL 60691, *Thermal-Links – Requirements and Application Guide*

UL 60950-1, *Information Technology Equipment – Safety – Part 1: General Requirements*

UL 61058-1, *Switches for Appliances – Part 1: General Requirements*

3 Glossary

3.1 For the purpose of this Standard, the following definitions apply.

3.2 1.2/50 VOLTAGE WAVE – Voltage surge with a virtual front time of 1.2 μ s and a time to half-value of 50 μ s delivered across an open circuit.

3.3 8/20 CURRENT WAVE – Current surge with a virtual front time of 8 μ s and a time to half-value of 20 μ s delivered into a short circuit.

3.4 AC POWER INTERFACE – The electrical points where the SPD is electrically connected to the ac power system.

3.5 CIRCUIT BREAKER SPD – Combination circuit breaker and surge-protective devices (SPDs) designed to serve the dual function of providing overcurrent protection, and for repeated limiting of transient-voltage surges.

3.6 COMBINATION WAVE – (Also called "combination surge") A surge delivered by a generator which has the inherent capability of applying a 1.2/50 μ s voltage wave across an open circuit, and delivering an 8/20 μ s current wave into a short circuit. The exact wave that is delivered is determined by the generator's fictive impedance.

3.7 COMPONENT – SURGE PROTECTIVE DEVICE – An SPD intended solely for factory installation in another component, device or product and designated as Type 4 Component Assemblies, Type 1, 2 or 3 Component Assemblies or Type 5 SPD.

3.8 CORD CONNECTED (CC) – An SPD provided with a power-supply cord terminating in an attachment plug for connection of the device to a receptacle in the AC power circuit.

3.9 CREST (PEAK) VALUE (OF A WAVE, SURGE, OR IMPULSE) – The maximum value that a wave, surge, or impulse attains.

3.10 DIRECT PLUG-IN (DPI) – An SPD incorporating integral blades for direct insertion into a standard wall receptacle.

3.11 ELECTROMAGNETIC INTERFERENCE FILTER – A device intended to attenuate unwanted radio-frequency signals (such as noise or interference) generated from electromagnetic sources. EMI filters consist of capacitors and inductors used alone or in combination with each other and may be provided with resistors.

3.12 ENCLOSED SPD – An SPD provided with a complete enclosure in accordance with the construction requirements of this standard.

3.13 EQUIPMENT UNDER TEST (EUT) – Refers to the SPD being tested.

3.14 FACTORY WIRING – The connection of a wire, under controlled conditions, at a manufacturer's location.

3.15 FAULT CURRENT – The current from the connected power system that flows in a short circuit.

3.16 FIELD WIRING – The connection of a wire in the field, in accordance with the National Electrical Code, NFPA 70.

3.17 FOLLOW (POWER) CURRENT – The current from the connected power source that flows through an SPD during and following the passage of discharge current. Examples of devices that permit follow current are gas discharge tubes and thyristors.

3.18 HERMETICALLY SEALED DEVICE – A device that is sealed against the entrance of an external atmosphere and in which the seal is made by fusion; e.g., soldering, brazing, welding, or the fusion of glass to metal.

3.19 ISOLATED SECONDARY CIRCUIT – A circuit derived from an isolating source (such as a transformer, optical isolator, limiting impedance or electro-mechanical relay) and having no direct connection back to the primary circuit (other than through the grounding means). A secondary circuit that has a direct connection back to the primary circuit is considered part of the primary circuit.

3.20 MAXIMUM CONTINUOUS OPERATING VOLTAGE (MCOV) – The maximum designated root-mean-square (rms) value of the power frequency voltage that may be continuously applied to the mode of protection of an SPD.

3.21 MEASURED LIMITING VOLTAGE – The maximum magnitude of voltage, measured at the leads, terminals, receptacle contacts, and similar locations after the application of an impulse of specified waveshape and amplitude.

3.22 MODES OF PROTECTION – Electrical paths where the SPD offers defense against transient overvoltages. Examples include, Line to Neutral (L-N), line to Ground (L-G), Line to Line (L-L) and Neutral to Ground (N-G).

3.23 MOLDED CASE SPD – A One-Port SPD incorporated within a molded case and intended for use in a space normally occupied by a circuit breaker within a panelboard complying with the Standard for Panelboards, UL 67. Molded Case SPD's may consist of a one piece SPD or may be of a two piece, "Pullout SPD" design. See [3.36](#) – [3.38](#) for description of a Molded Case SPD of the "Pullout" configuration.

3.24 NOMINAL DISCHARGE CURRENT (I_n) – Peak value of the current, selected by the manufacturer, through the SPD having a current waveshape of 8/20 where the SPD remains functional after 15 surges.

3.25 NOMINAL SYSTEM VOLTAGE – A nominal value assigned to designate a system of a given voltage class in accordance with ANSI C84.1. For the purpose of this standard, nominal system voltages include, but are not limited to, 120, 208, 240, 277, 347, 480, 600 Vac.

3.26 NOMINAL VARISTOR VOLTAGE – The voltage across the varistor at 1mA, DC.

3.27 NORMAL OPERATING VOLTAGE RATING – The normal ac power frequency voltage rating assigned to an SPD by the manufacturer. For an SPD, other than a Component-SPD, it is generally equal to the nominal value of the root-mean-square power-frequency phase voltage of the ac circuit (for example, 120, 208, 240, 347, 480, or 600 Vrms).

3.28 ONE-PORT SPD – An SPD having provisions (terminals, leads, plug) for connection to the ac power circuit but no provisions (terminals, leads, receptacles) for supplying current to ac power loads.

3.29 OPEN-TYPE SPD – A Type 1, 2 or 3 SPD, with an incomplete or partial enclosure and with field wiring terminals and/or leads, suitable for field installation, in accordance with the National Electrical Code, ANSI/NFPA 70, within a suitable enclosure.

3.30 OPPOSITE POLARITY – A difference in potential between two points, such that shorting of these two points would result in a condition involving an overload, rupturing of printed wiring-board-tracks, components, or fuses, and the like.

3.31 PEAK LET-THROUGH CURRENT (I_p) – The maximum current through a circuit during a fault.

3.32 PERMANENTLY CONNECTED (PC) – An SPD provided with terminals or leads for field connection to wiring systems in accordance with the National Electrical Code, ANSI/NFPA 70.

3.33 PHASE ANGLE – The point on the ac power sine wave, expressed in terms of electrical degrees between 0 and 360, at which the transient surge is applied.

3.34 POWERED TESTING – Refers to surge testing that is done while the SPD is electrically connected to the ac power system, at the nominal system voltage, or the manufacturer's operating voltage rating, whichever is greater.

3.35 PRIMARY CIRCUIT – A circuit in which the wiring and components are conductively connected to the AC power interface.

3.36 PULLOUT BASE – An assembly designed for mounting in place of a plug-in circuit breaker within a panelboard, that is for use with specified SPD pullout module(s) as part of a Pullout SPD.

3.37 PULLOUT MODULE – An SPD incorporated within a housing that is detachable from its pullout base, intended to be replaceable and field installable.

3.38 PULLOUT SPD – A Molded Case SPD that consists of a detachable "pullout module" and "pullout base", intended for use in a space normally occupied by a circuit breaker within a panelboard complying with the Standard for Panelboards, UL 67.

3.39 RACK-MOUNTED CORD-CONNECTED TYPE 3 SPD – A cord-connected Type 3 SPD provided with mounting means for securement to a stationary (intended to be fastened in place or located in a dedicated space) or portable (capable of being easily moved by hand from place to place in normal use) equipment rack.

3.40 RECEPTACLE SPD – A receptacle outlet incorporating an integral SPD.

3.41 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist at any part if:

- a) The potential between the part and earth ground or any other accessible part is more than 30 V rms (42.4 V peak); and
- b) The continuous current flow through a 1500 Ω resistor connected across the potential exceeds 0.5 mA.

3.42 RISK OF FIRE – A risk of fire is considered to exist at any two points in a circuit where:

- a) The open circuit voltage is more than 30 Vrms (42.4 V peak) and the energy available to the circuit under any condition of load including short circuit, results in a current of 8A or more after 1 minute of operation; or
- b) A power of more than 15 watts can be delivered into an external resistor connected between the two points.

3.43 SERVICEABLE PART – A part or component of an SPD that is intended to be replaced or otherwise serviced during the life of the SPD.

3.44 SERVICE EQUIPMENT OVERCURRENT DEVICE – The first overcurrent protection device between the service transformer secondary and the service entrance.

3.45 SHORT CIRCUIT CURRENT RATING (SCCR) OF SPD – The suitability of an SPD for use on an AC power circuit that is capable of delivering not more than a declared rms symmetrical current at a declared voltage during a short circuit condition.

3.46 SUPPLEMENTARY PROTECTION DEVICE – A device intended for use as overcurrent, over- or under-voltage, or over-temperature protection within electrical equipment where branch circuit overcurrent protection is already provided, or is not required.

3.47 SURGE – A transient wave of current, potential or power in an electric circuit. For the purposes of this standard, surges do not include temporary overvoltages (TOV) consisting of an increase in the power frequency voltage for several cycles.

3.48 SURGE PROTECTIVE DEVICE (SPD) – A device composed of at least one non-linear component (see [3.55](#) and [3.56](#)) and intended for limiting surge voltages on equipment by diverting or limiting surge current and is capable of repeating these functions as specified. SPDs were previously known as Transient Voltage Surge Suppressors or secondary surge arresters.

3.49 SPD DISCONNECTOR – Device(s) (internal and/or external) required for disconnecting an SPD from the power system. These devices may provide overcurrent (fuse or circuit breaker) and/or over temperature (thermal responsive devices) protection.

3.50 THERMAL-LINK – A non-resettable device incorporating a thermal element (a metallic or non-metallic fusible material that is part of a THERMAL-LINK and is responsive to temperature by a change of state such as from solid to liquid at the temperature for which it is calibrated – as defined in UL 60691) which will open a circuit once only when exposed for a sufficient length of time to a temperature in excess of that which it has been designed.

3.51 THERMAL RESPONSIVE DEVICE – A non-resettable device or mechanical element that will disconnect a series connected circuit or component, when exposed for a sufficient length of time to a temperature in excess of that which it has been designed.

3.52 TWO-PORT SPD – An SPD having provisions (terminals, leads, plug) for connection to the ac power circuit and provisions [terminals, leads, receptacles(s)] for supplying current to one or more ac

power loads. SPDs provided with a minimum of two adjacent terminals for each circuit conductor may be considered and tested as a two-port SPD.

3.53 VOLTAGE AND CURRENT LIMITING TYPE SPD – An SPD that has a high impedance to surges at the input, such as a series connected inductor, followed by voltage limiting or voltage switching components.

3.54 VOLTAGE PROTECTION RATING (VPR) – A rating selected from a list of preferred values as given in [Table 84.1](#) and assigned to each mode of protection. The value of VPR is determined as a higher value taken from [Table 84.1](#) to the average measured limiting voltage determined during the first set of measured limiting voltages tests during the transient-voltage surge suppression test using the combination wave generator at a setting of 6kV, 3kA.

3.55 VOLTAGE-LIMITING-TYPE SPD – An SPD that has a high impedance when no surge is present, but will reduce it continuously with increased surge current and voltage. Common examples of components used as nonlinear devices are varistors and suppressor diodes. These SPDs are sometimes called "clamping-type" SPDs.

3.56 VOLTAGE-SWITCHING-TYPE SPD – An SPD that has a high impedance when no surge is present, but can have a sudden change in impedance to a low value in response to a voltage surge. Common examples of components used as nonlinear devices are spark gaps, gas tubes, and silicon-controlled rectifiers. These SPDs are sometimes called crowbar-type SPDs.

4 Components

4.1 Except as indicated in [4.2](#), a component of a product covered by this Standard shall comply with the requirements for that component. See [2.2](#) for a list of standards covering components generally used in the products covered by this Standard.

4.2 A component is not required to comply with a specific requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or
- b) Is superseded by a requirement in this standard. For example, when two or more testing methods are allowed in a standard or standards listed in [2.2](#), and one or more of those testing methods are documented in this standard, only the testing method or methods documented in this standard shall be used in component evaluation.

4.3 A component shall be used in accordance with its rating established for the intended conditions of use.

4.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

5 Units of Measurement

5.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

5.2 All units of voltage and current specified in this standard are root-mean-square values unless otherwise indicated.

CONSTRUCTION

6 General

6.1 An SPD shall be so formed and assembled that it has the strength and rigidity necessary to withstand the handling that can be encountered during shipment, installation and use without increasing the risk of fire, electric shock, and injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other defects.

6.2 A direct plug-in type SPD shall comply with the general requirements for current taps and adapters in the Standard for Current Taps and Adapters, UL 498A.

6.3 A cord-connected type SPD shall comply with the general requirements in the Standard for Relocatable Power Taps, UL 1363.

6.4 Watt-hour meter socket adapter Type 1 SPDs shall also comply with the applicable requirements of the Standard for Meter Sockets, UL 414.

6.5 A Type 3 SPD intended for outdoor use shall not exceed 0.45 m (18 in.) in length including the cord and plug, and shall be constructed such that the Enclosure does not obstruct a receptacle hood when in use.

6.6 Unless specified otherwise, open-type SPDs shall comply with the applicable requirements for the SPD Type, as specified in this standard.

7 Enclosure

7.1 Type 1 and Type 2 SPDs

7.1.1 General

7.1.1.1 An enclosure and a part of an enclosure, such as door, cover, or tank, shall be provided with means for firmly securing it in place.

7.1.1.2 An enclosure other than a Type 1 (indoor use only) enclosure shall comply with the requirements for the type designation indicating the conditions for which it is intended, as specified, for Enclosure Types, in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

7.1.1.3 Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part that is to be removed to install field wiring or for operation of the equipment. Sheet-metal screws may thread into sheet-metal nuts that are permanently mounted and protected against corrosion. Machine screws and self-tapping machine screws may thread-directly into sheet-metal walls.

7.1.1.4 Sheet-metal screws mounting internal components that are not removed for installation or operation may thread directly into metal.

7.1.1.5 A snap-on cover giving access to uninsulated live parts that does not require a tool for removal shall perform acceptably when subjected to the Snap-On Cover Tests, Section [60](#).

7.1.1.6 An enclosure cover shall be hinged if it gives access to a fuse or any other overload-protective device, the functioning of which requires renewal, or if it is necessary to open the cover in connection with the normal operation of the SPD.

Exception: A hinged cover is not required for an SPD when the fuse or overload protector is not in series with a load circuit and opens only in the event of a malfunction of a discrete suppression component.

7.1.1.7 A door or cover giving access to a fuse shall shut closely against a 6.4 mm (1/4 inch) rabbet or the equivalent, or shall have either turned flanges for the full length of four edges or angle strips fastened to it. Flanges or angle strips shall fit closely with the outside of the walls of the box and shall overlap the edges of the box by not less than 12.7 mm (1/2 inch). A combination of flange and rabbet or a construction that affords equivalent protection is acceptable.

7.1.1.8 Strips used to provide rabbets, or angle strips fastened to the edges of a door, shall be secured at:

- a) Not less than two points;
- b) Not more than 38.1 mm (1-1/2 inches) from each end of strip; and
- c) Points between these end fastenings to be not more than 152 mm (6 inches) apart.

7.1.2 Cast metal

7.1.2.1 Cast metal for an enclosure shall be at least 3.2 mm (1/8 inch) thick at every point, of greater thickness at reinforcing ribs and door edges, and not less than 6.4 mm (1/4 inch) thick at tapped holes for conduit.

Exception No. 1: At other than at plain or threaded conduit holes, die-cast metal shall not be less than 2.4 mm (3/32 inch) thick for an area greater than 154.8 cm² (24 square inches) or having any dimensions greater than 152 mm (6 inches), and shall not be less than 1.6 mm (1/16 inch) thick for an area of 154.8 cm² (24 square inches) or less and having no dimension greater than 6 inches (152 mm). The area limitation for metal that is 1.6 mm (1/16 inch) thick may be obtained by the provision of reinforcing ribs subdividing a larger area.

Exception No. 2: Cast metal that is a minimum 0.89 mm (0.035 inch) thick may be employed instead of 1/16 inch-thick (1.6 mm) die-cast metal if the enclosure is not intended to be used as a splice box and if the voltage rating of the complete device is such that the voltage between any two conductors is 250 V or less and is limited to direct current or single-phase alternating current.

7.1.3 Sheet metal

7.1.3.1 The thickness of a sheet-metal enclosure shall not be less than that indicated in [Table 7.1](#) and [Table 7.2](#), except that uncoated steel shall not be less than 0.81 mm (0.032 inch) thick, zinc-coated steel shall not be less than 0.86 mm (0.034 inch) thick, and nonferrous metal shall not be less than 1.14 mm (0.045 inch) thick at points at which a wiring system is to be connected.

7.1.3.2 [Table 7.1](#) and [Table 7.2](#) are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

7.1.3.3 With reference to [Table 7.1](#) and [Table 7.2](#), a supporting frame is a structure of angle or channel, or a folded rigid section of sheet metal that is firmly attached to and has essentially the same outside dimensions as the enclosure surface and that has such torsional rigidity as to resist bending moments that may be applied by the enclosure surface when it is deflected. A construction that is considered to have equivalent reinforcing is one that produces a structure that is as rigid as one built with a frame of angles or channels. Constructions that are considered to be without supporting frame include:

- a) Single sheet with formed flanges (formed edges);

- b) A single sheet that is corrugated or ribbed;
- c) An enclosure surface loosely attached to a frame; for example, with spring clips; and
- d) An enclosure surface having an unsupported edge.

Table 7.1
Thickness of Metal for Enclosures – Carbon Steel or Stainless Steel

Without support frame ^a		With supporting frame or equivalent reinforcing ^a				Minimum acceptable thickness			
Maximum width ^b		Maximum length ^c		Maximum width ^b		Maximum length		Uncoated	
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	mm	(inches)
10.2	(4.0)	Not limited		15.0	(6.25)	Not limited		0.51	(0.020)
12.1	(4.75)	14.6	(5.75)	17.1	(6.75)	21.0	(8.25)		0.58
15.2	(6.0)	Not limited		24.1	(9.5)	Not limited		0.66	(0.026)
17.8	(7.0)	22.2	(8.75)	25.4	(10.0)	31.8	(12.5)		0.74
20.3	(8.0)	Not limited		30.5	(12.0)	Not limited		0.81	(0.032)
22.9	(9.0)	29.2	(11.5)	33.0	(13.0)	40.6	(16.0)		0.86
31.8	(12.5)	Not limited		49.5	(19.5)	Not limited		1.07	(0.042)
35.6	(14.0)	45.7	(18.0)	53.3	(21.0)	63.5	(25.0)		1.14
45.7	(18.0)	Not limited		68.6	(27.0)	Not limited		1.35	(0.053)
50.8	(20.0)	63.5	(25.0)	73.7	(29.0)	91.4	(36.0)		1.42
55.9	(22.0)	Not limited		83.8	(33.0)	Not limited		1.52	(0.060)
63.5	(25.0)	78.7	(31.0)	88.9	(35.0)	109.2	(43.0)		1.60
63.5	(25.0)	Not limited		99.1	(39.0)	Not limited		1.70	(0.067)
73.7	(29.0)	91.4	(36.0)	104.1	(41.0)	129.5	(51.0)		1.78
83.8	(33.0)	Not limited		129.5	(51.0)	Not limited		2.03	(0.080)
96.5	(38.0)	119.4	(47.0)	137.2	(54.0)	167.6	(66.0)		2.13
106.7	(42.0)	Not limited		162.6	(64.0)	Not limited		2.36	(0.093)
119.4	(47.0)	149.9	(59.0)	172.7	(68.0)	213.4	(84.0)		2.46
132.1	(52.0)	Not limited		203.2	(80.0)	Not limited		2.74	(0.108)
152.4	(60.0)	188.0	(74.0)	213.4	(84.0)	261.6	(103.0)		2.82
160.0	(63.0)	Not limited		246.4	(97.0)	Not limited		3.12	(0.123)
185.4	(73.0)	228.6	(90.0)	261.6	(103.0)	322.6	(127.0)		3.20

^a See 7.1.3.3.

^b The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have common supports and be made of a single sheet.

^c Not limited applies only if the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

Table 7.2
Thickness of Metal for Enclosures of Aluminum, Copper, or Brass

Without support frame ^a		With supporting frame or equivalent reinforcing ^a		Minimum acceptable thickness
Maximum width ^b	Maximum length ^c	Maximum width ^b	Maximum length	
cm (inches)	cm (inches)	cm (inches)	cm (inches)	cm (inches)
7.6 (3.0)	Not limited	17.8 (7.0)	Not limited	0.58 (0.023)
8.9 (3.5)	10.2 (4.0)	21.6 (8.5)	24.1 (9.5)	
10.2 (4.0)	Not limited	25.4 (10.0)	Not limited	0.74 (0.029)
12.7 (5.0)	15.2 (6.0)	26.7 (10.5)	34.3 (13.5)	
15.2 (6.0)	Not limited	35.6 (14.0)	Not limited	0.91 (0.036)
16.5 (6.5)	20.3 (8.0)	38.1 (15.0)	45.7 (18.0)	
20.3 (8.0)	Not limited	48.3 (19.0)	Not limited	1.14 (0.045)
24.1 (9.5)	29.2 (11.5)	53.3 (21.0)	63.5 (25.0)	
30.5 (12.0)	Not limited	71.1 (28.0)	Not limited	1.47 (0.058)
35.6 (14.0)	40.6 (16.0)	76.2 (30.0)	94.0 (37.0)	
45.7 (18.0)	Not limited	106.7 (42.0)	Not limited	1.91 (0.075)
50.8 (20.0)	63.4 (25.0)	114.3 (45.0)	139.7 (55.0)	
63.5 (25.0)	Not limited	152.4 (60.0)	Not limited	2.41 (0.095)
73.7 (29.0)	91.4 (36.0)	162.6 (64.0)	198.1 (78.0)	
94.0 (37.0)	Not limited	221.0 (87.0)	Not limited	3.10 (0.122)
106.7 (42.0)	134.6 (53.0)	236.2 (93.0)	289.6 (114.0)	
132.1 (52.0)	Not limited	312.4 (123.0)	Not limited	3.89 (0.153)
152.4 (60.0)	188.0 (74.0)	330.2 (130.0)	406.4 (160.0)	

^a See 7.1.3.3.

^b The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have common supports and be made of a single sheet.

^c Not limited applies only if the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

7.1.4 Nonmetallic

7.1.4.1 The enclosure shall comply with the applicable mechanical/electrical property considerations, flammability, moisture-absorptive properties and thermal requirements for fixed and stationary equipment as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 1: The enclosure of a Receptacle SPD shall comply with the enclosure requirements in the Standard for Attachment Plugs and Receptacles, UL 498.

Exception No. 2: The enclosure of a Circuit Breaker SPD shall comply with the enclosure requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489.

Exception No. 3: The enclosure of a one-piece Molded Case SPD shall comply with the enclosure requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489.

Exception No. 4: The enclosure of a Pullout SPD shall comply with the enclosure requirements in 33.2.

7.1.4.2 The enclosure shall comply with the Non-Metallic Enclosure Conduit Connection, Enclosure Impact, Crushing and Mold-Stress Relief Test requirements of Sections [61](#), [62](#), [63](#), and [64](#), respectively, of this Standard.

7.1.4.3 A part such as a dial or nameplate that is considered to be a part of the enclosure shall be of metal or other material as specified for the enclosure in [7.1.2.1](#) – [7.1.3.2](#).

7.1.4.4 A nonmetallic part such as a reset knob, lever, polymeric overlay, or button protruding through a hole in the enclosure shall be of a material classified as V-0, V-1, V-2 as determined by the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, if the area of the hole is not greater than 650 mm² (1 in²). Nonmetallic parts protruding through a hole, the area of which is greater than 650 mm² (1 in²), shall be made of materials that comply with the requirements in [7.1.4.1](#).

Exception: An enclosure evaluated to the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, satisfies the requirements of [7.1.4.4](#).

7.1.5 Wiring openings

7.1.5.1 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or if an equivalent construction is employed, there shall not be less than three or more than five threads in the metal. The construction of the device shall be such that a conduit bushing can be properly attached. If threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall not be less than 3-1/2 threads in the metal. In addition, there shall be a smooth, well-rounded inlet hole for the conductors that provides protection to the conductors equivalent to that provided by a standard conduit bushing, and the inlet hole shall have an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

7.1.5.2 An enclosure threaded for support by rigid conduit shall provide at least five full threads for engaging the conduit.

7.1.5.3 Clamps and fasteners for the attachment of raceways, such as conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, or service cable, that are supplied as a part of an enclosure shall comply with the requirements in the Standards for Metallic Outlet Boxes, UL 514A; Conduit, Tubing, and Cable Fittings, UL 514B; and Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C.

7.1.5.4 A knockout in a sheet-metal enclosure shall be reliably secured but shall be capable of being removed without undue deformation of the enclosure.

7.1.5.5 A knockout shall be provided with a flat surrounding surface for proper seating of a conduit bushing, and shall be so located that installation of a bushing at any knockout likely to be used during installation will not result in unacceptable spacing between uninsulated live parts and the bushing.

7.1.5.6 For an enclosure not provided with conduit openings, or knockouts, spacings not less than the minimum required in Spacings, Section [18](#) shall be provided between uninsulated live parts and a conduit bushing installed at any location likely to be used during installation. Permanent marking on the enclosure, a template, or a full-scale drawing furnished with the device may be used to limit such a location.

7.1.5.7 In measuring a spacing between an uninsulated live part and a bushing installed in the knockout referred to in [7.1.5.5](#) and [7.1.5.6](#), it is to be assumed that a bushing having the dimensions indicated in [Table 7.3](#) is in place, and that a single locknut is installed on the outside of the enclosure.

Table 7.3
Dimensions of Bushings

Trade size of conduit, inches	Bushing dimensions, mm (inches)	
	Overall diameter	Height
1/2	25.4 (1)	9.5 (3/8)
3/4	31.4 (1-15/64)	10.7 (27/64)
1	40.5 (1-19/32)	13.1 (33/64)
1-1/4	49.2 (1-15/16)	14.3 (9/16)
1-1/2	56.0 (2-13/64)	15.1 (19/32)
2	68.7 (2-45/64)	15.9 (5/8)
2-1/2	81.8 (3-7/32)	19.1 (3/4)
3	98.4 (3-7/8)	20.6 (13/16)
3-1/2	112.7 (4-7/16)	23.8 (15/16)

7.1.5.8 No wire other than wires leading to a part mounted on a door or cover shall be brought out through the door or cover.

7.2 Type 3 SPD cord-connected

7.2.1 General

7.2.1.1 The enclosure shall not have any openings or knockouts that may be used for permanent mounting or connection to a permanent wiring system.

7.2.1.2 An opening in an enclosure shall have such size and shape – or shall be so covered by screening or barrier or by an expanded, perforated, or louvered panel – that a test rod having a diameter of 1.6 mm (1/16 inch) shall be prevented from contacting uninsulated current-carrying parts. Accessibility shall be evaluated by performing the enclosure accessibility test in [67.1](#).

7.2.1.3 A keyhole slot, notch, or similar means for temporary mounting, if provided, shall be so located that the supporting screws or the like cannot damage any electrical insulation or reduce spacings to live parts.

7.2.1.4 A barrier that covers a mounting hole and thereby forms part of the required enclosure shall be subjected to the Mounting Hole Barrier Tests, Section [65](#).

7.2.1.5 An SPD intended for outdoor use shall comply with the applicable performance requirements for a Type 3R enclosure as specified in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

7.2.2 Metallic

7.2.2.1 A metal enclosure of a Type 3 SPD shall have a minimum thickness in accordance with [Table 7.4](#).

Table 7.4
Minimum Acceptable Thicknesses of Enclosure Metal

Metal	At small, flat unreinforced surfaces and at surfaces of a shape or size to provide adequate mechanical strength		At relatively larger unreinforced flat surfaces	
	mm	(inch)	mm	(inch)
Die-cast metal	1.2	(3/64)	2.0	(5/64)
Cast malleable iron	1.6	(1/16)	2.4	(3/32)
Other cast metal	2.4	(3/32)	3.2	(1/8)
Uncoated sheet steel	0.66	(0.026)	0.66	(0.026)
Galvanized sheet steel	0.74	(0.029)	0.74	(0.029)
Nonferrous sheet metal	0.91	(0.036)	0.91	(0.036)

7.2.3 Nonmetallic

7.2.3.1 A nonmetallic enclosure shall comply with the applicable mechanical/electrical property considerations, flammability and thermal requirements for non-attended, non-intermittent duty portable equipment as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: A rack-mounted cord-connected Type 3 SPD intended for use in stationary equipment shall comply with the flammability requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, for stationary equipment.

7.2.3.2 The enclosure shall comply with the Strain Relief, Enclosure Impact, Crushing, and Mold Stress-Relief Distortion Test requirements of Sections [57](#), [62](#), [63](#), and [64](#) respectively, of this Standard.

7.2.3.3 An SPD intended for outdoor use having a nonmetallic enclosure shall additionally comply with the Water Resistance and UV exposure requirements specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.3 Type 3 SPD direct plug-in

7.3.1 General

7.3.1.1 The enclosure shall comply with the enclosure requirements in the Standard for Current Taps and Adapters, UL 498A, and with the requirements specified in [7.2.1.1](#), [7.2.3.1](#) and [7.2.3.2](#), as applicable.

Exception: The enclosure may have means for permanent attachment to a (duplex) receptacle rated 15A, 125V. When provided with means for permanent attachment, the SPD need not comply with requirements specified in [7.3.1.2](#) and [7.3.1.3](#) but shall comply with the Grounding Contact Test as specified in [16.11](#).

7.3.1.2 A unit shall:

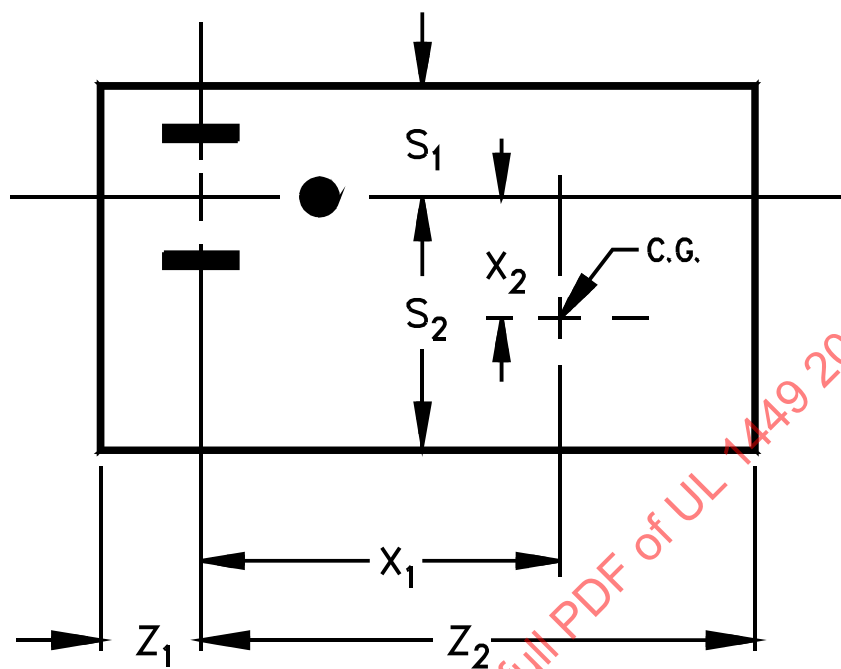
- a) Have a mass of 0.79 kg (28 ounces) or less; and
- b) Comply with the specifications in [Table 7.5](#).

Table 7.5
Specifications for Plug-In Products

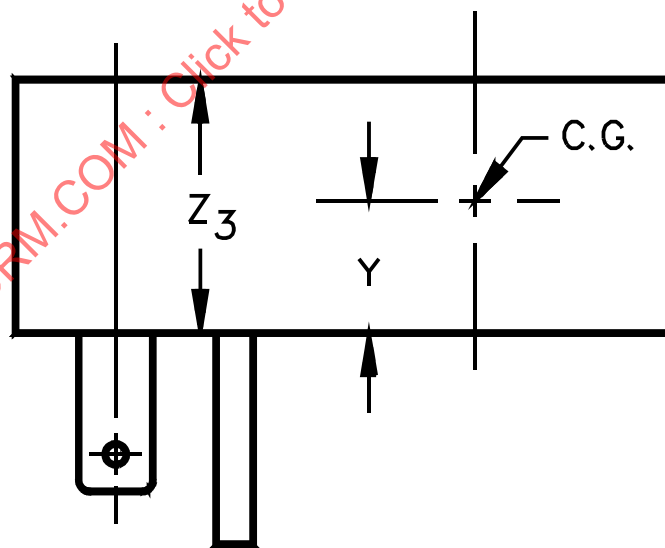
$WY/Z \leq 1.36 \text{ kg (48 ounces)}$ $WY/S \leq 1.36 \text{ kg (48 ounces)}$ $WX \leq 0.56 \text{ N}\cdot\text{m (80 ounce-inches)}$
<i>in which:</i> <i>W is the weight in kg (ounces)</i> <i>Y is the distance, in mm (inches), illustrated in Figure 7.1</i> <i>Z is the shorter distance, in mm (inches), of Z_1 or Z_2 illustrated in Figure 7.1</i> <i>S is the shorter distance, in mm (inches), of S_1 or S_2 illustrated in Figure 7.1</i> <i>X is the longer distance, in mm (inches), of X_1 or X_2 illustrated in Figure 7.1</i>

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Figure 7.1
Dimensions of a Plug-In Product



FRONT VIEW



SIDE VIEW

C.G. = Center of Gravity

7.3.1.3 When determining the moment and weight specified in [7.3.1.2](#), a mounting tab is not to be included in measurements of the linear dimensions for the purpose of determining moments unless:

- a) The tab and enclosure withstand the Enclosure Impact Tests, Section [62](#), with one impact on the tab itself, without deformation; and
- b) For a non-metallic unit having an integral tab, the tab and enclosure do not distort when subjected to the Mold Stress-Relief Distortion Test, Section [64](#).

7.3.1.4 When inserted in a parallel-blade duplex receptacle, any part of a unit shall not interfere with full insertion of an attachment plug into the adjacent receptacle.

Exception: A unit that renders the adjacent receptacle completely unusable is acceptable.

7.3.1.5 The enclosure of a unit shall be capable of being gripped for removal from the receptacle to which it is connected, and the perimeter of the face section from which the blades project shall not be less than 6.4 mm (1/4 inch) from any point on either blade.

7.4 Open-type SPDs

7.4.1 Any part of an open-type SPD intended to be installed through an opening in or as part of an enclosure shall comply with the Enclosure requirements for the SPD Type.

8 Protection Against Corrosion

8.1 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This applies to all springs and other parts upon which proper mechanical operation may rely.

Exception No. 1: Parts such as bearings, thermal elements, if such protection is impracticable.

Exception No. 2: Small minor parts of iron or steel such as washers, screws, or bolts that are not current-carrying and are not in the equipment grounding conductor path, if corrosion of such unprotected parts is not likely to result in a risk of fire, electric shock, or injury to persons.

Exception No. 3: Parts made of stainless steel, properly polished or treated if necessary.

8.2 The requirements in [8.1](#) apply to all enclosing cases whether of sheet steel or cast iron, and to all springs and other parts upon which mechanical operation may depend.

9 Insulating Materials

9.1 General

9.1.1 A barrier or integral part, such as an insulating washer or bushing, and a base or support for the mounting of live parts, shall be of a moisture-resistant material that will not be damaged by the temperature and stresses to which it may be subjected under conditions of actual use.

9.1.2 An insulating material is to be investigated with respect to its acceptability for the application in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Materials, such as mica, ceramic, or some molded compounds are usually acceptable for use as the sole support of live parts. If it is necessary to investigate a material to determine its acceptability, consideration is to be given to such factors as its mechanical strength, resistance to ignition sources, dielectric strength, insulation resistance, and heat-resistant properties in both the aged and unaged

conditions, the degree to which it is enclosed, and any other features affecting the risk of fire and electric shock.

9.1.3 When required by 9.1.2, the Inclined-Plane Tracking Test, UL 746C, shall be conducted on the insulating material used in SPDs rated over 600V at the rated voltage of the SPD. For dc rated SPDs, the equivalent ac voltage may be used where $V_{ac} = V_{dc} / 1.414$.

9.1.4 Ordinary vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not as sole support for uninsulated live parts.

9.2 Bushings

9.2.1 At a point where a cord or lead passes or is intended to pass through an opening in a wall, barrier, or enclosure case, there shall be a bushing or the equivalent that shall be secured in place and that shall have a smoothly rounded surface against which the lead or cord may bear.

9.2.2 If the cord hole is in wood, porcelain, phenolic composition, or other nonconducting material, a smoothly rounded surface is considered to be the equivalent of an insulating bushing.

9.2.3 Ceramic materials and some molded compositions are acceptable generally for insulating bushings.

9.2.4 A fiber bushing shall not be less than 1.2 mm (3/64 inch) thick, and shall be so formed and secured in place so as not to be affected adversely by conditions of ordinary moisture. It shall be employed only where it is not subjected to a temperature higher than 90°C (194°F) under normal operating conditions.

9.2.5 If an insulated metal grommet is employed instead of an insulating bushing, the insulating material shall not be less than 0.8 mm (1/32 inch) thick and shall completely fill the space between the grommet and the metal in which it is mounted.

10 Current-Carrying Parts

10.1 A current-carrying part shall have mechanical strength, an ampacity acceptable for the service, and shall be of metal that is acceptable for the particular application.

10.2 Uninsulated live parts, including terminals, shall be so secured to their supporting surfaces – by methods other than friction between surfaces – so as not to turn or shift in position if such motion may result in reduction of spacings to less than those required elsewhere in this standard.

10.3 A lockwasher is generally acceptable at a terminal or connection stud.

11 Internal Wiring

11.1 Wire employed for the internal wiring of a device shall be acceptable for the particular application.

11.2 The internal wiring shall be rated for the voltage and temperature to which it may be subjected to under normal operating conditions.

11.3 18 AWG [0.82 mm² (0.04 inches)] rubber-covered wire when provided as part of a device shall be at least Type RFH-1 or equivalent, if a potential of 300 V or less is involved 18 and 16 AWG [0.82 and 1.3 mm² (0.04 and 0.05 inches)] wires shall be at least Type RFH-2 or equivalent, if a potential greater than 300 V is involved. A 14 AWG [2.1 mm² (0.06 inches)] or larger wire shall be Type T, RH or RHW or equivalent.

11.4 For a Type 1 or Type 2 SPD, line and ground connecting conductors shall not be smaller than 14 AWG (2.1 mm²) copper or 12 AWG (3.3 mm²) aluminum.

11.5 If the use of a short length of insulated conductor – such as a short coil lead – is not practical, electrical insulating tubing may be used on each conductor. The tubing is not to be subjected to sharp bends, tension, compression, or repeated flexing or to contact with sharp edges, projections, or corners. The wall thickness shall comply with the individual requirements for the tubing.

11.6 Extruded insulating tubing shall be rated for temperature and voltage application and shall comply with the requirements in the Standard for Extruded Insulating Tubing, UL 224.

11.7 The internal wiring and electrical connections between parts of a device shall be protected or enclosed.

11.8 Wires within an enclosure, compartment, raceway, or the like shall be so positioned or protected that contact with any rough, sharp, or movable part is prevented.

11.9 A screw provided for use in mounting the device to an outlet box or other enclosures shall not project more than 22.2 mm (7/8 inch) beyond the strap or cover and shall have flat or blunt ends. The end of the screw may have thread-cleaning slots or grooves but shall not have any burrs, fins, or other sharp edges that could damage wiring.

11.10 Screw threads, including those of sheet metal screws, shall not be exposed for more than 4.76 mm (3/16 inch) inside a compartment containing wiring and shall be so located that contact with conductor insulation is unlikely.

11.11 Suitably insulated wires may be bunched and passed through a single opening in a metal wall within the enclosure of the product.

11.12 A bare conductor or a conductor utilizing noncarbonizable beads for insulation shall not be employed outside of an enclosure device. A bare conductor, if used within an enclosure, shall be so supported that the spacings required elsewhere in this Standard will be maintained. If necessary, a force of 10 N (2.25 lbf) shall be applied to any point on internal parts in an endeavor to reduce the spacing while taking measurements.

11.13 All splices and connections shall be mechanically secure and shall make reliable electrical contact. Solder connections shall be made mechanically secure prior to soldering. A lead is considered to be mechanically secure if it is:

- a) Wrapped at least halfway (180 degrees) around a terminal;
- b) Provided with at least one right angle bend when passed through an eyelet or opening; or
- c) Twisted with other conductors.

Exception: Wiring through openings on printed wiring boards need not be mechanically secure before soldering.

11.14 A splice shall be provided with insulation equivalent to that of the wires involved if the required spacing between the splice and other metal parts is not permanently maintained.

11.15 In determining whether splice insulation consisting of coated-fabric, thermoplastic, or another type of tape or tubing is acceptable, consideration is to be given to such factors as mechanical strength, dielectric properties, heating and moisture-resistant characteristics, and the like.

11.16 Where stranded wiring is connected to a wire-binding screw, the construction shall be such that any loose strand of wire is prevented from contacting live parts of opposite polarity or dead metal parts that may be grounded. This can be accomplished by use of upturned lugs on the terminal plate, pressure terminal connectors, soldering lugs, crimped eyelets, or equivalent means.

11.17 Soldered stranded (bunch tinned/solder dipped/tinned bonded) wire shall not be used with the terminals of a receptacle unless the receptacle has been investigated for such use.

11.18 The internal wiring of a cord-connected two-port SPD shall be at least of the same gauge (AWG) as the power-supply cord.

Exception No. 1: Non-load current-carrying conductors need not be of the same gauge as the power-supply cord.

Exception No. 2: Smaller AWG conductors may be used if:

- a) Supplementary overcurrent protection is provided; and*
- b) The results of the Temperature Test (Section 40), the Fault Current Test (Section 50) for grounding-path conductors only, and the Overcurrent Test (Section 51) are acceptable using the smaller AWG size.*

11.19 The internal wiring of a direct plug-in two-port SPD shall be at least of the same gauge (AWG) as the branch-circuit conductors on which the device is intended to be installed.

Exception No. 1: Non-load current-carrying conductors need not be of the same gauge as the branch circuit conductors.

Exception No. 2: Smaller AWG conductors may be used if:

- a) Supplementary overcurrent protection is provided; and*
- b) The results of the Temperature Test (Section 40), the Fault Current Test (Section 50) for grounding-path conductors only, and the Overcurrent Test (Section 51) are acceptable using the smaller AWG size.*

Exception No. 3: A direct plug-in two-port SPD rated 15A or less may employ 14 AWG internal wiring.

12 Supplementary Protection

12.1 Supplementary overcurrent or overtemperature protection, if provided in SPDs, shall be readily replaceable or resettable.

Exception: The supplementary protection need not be readily replaceable or resettable if, when it opens, the entire SPD is intended to be replaced and the supplementary protection is inaccessible to the user by the use of ordinary tools (such as slotted or phillips type screwdrivers, pliers, etc.), or the unit is otherwise sealed.

12.2 All supplementary overcurrent protection devices shall be capable of clearing a fault current of not less than that indicated in Table 12.1. A supplementary overcurrent protection device, in series with the load, shall also comply with UL 1077, including overload testing in UL 1077 for motor starting at 6 times the AC full load current.

Exception No. 1: A fuse that is capable of clearing a fault current of not less than that indicated in [Table 12.1](#) and complies with the requirements in the Standard for Low-Voltage Fuses – Part 14: Supplemental Fuses, UL 248-14, is able to be used as a supplementary protection device.

Exception No. 2: A circuit breaker or fuse that complies with [12.12](#) is able to be used as a supplementary protector.

Table 12.1
Available Fault Current^a

Permanently connected devices ^b		Cord connected or direct plug-in devices ^b		
Rating, A	Minimum available fault current (short circuit current), amperes ^c	Rating volts	Rating, volts times amperes	Available fault current, amperes
100 A or less	5,000	250 ac or less	1175 or less	200
101 – 400 A	10,000		1176 to 1920	1000
Over 400 A	25,000		1921 to 4080	2000
			4081 to 9600	3500
			More than 9600	5000
		More than 250 ac	1920 or less	1000
			More than 1920	5000

^a Available fault current/short circuit current either at the point of application of the SPD or equal to or greater than the rating of the panel in which it is installed."

^b For one-port SPD, the available fault current/short circuit current rating shall be based on the ampere rating of the circuit that the SPD is intended to be connected to, in accordance with the manufacturer's ratings as detailed in [84.1](#).

^c Higher fault current/short circuit current ratings, as detailed in [Table 12.2](#) are able to be used. When higher ratings are selected, they must be utilized for all applicable tests that reference this table.

Table 12.2
Available Fault Current (Short Circuit Current) Rating – RMS Symmetrical Current in Amperes

5,000
10,000
14,000
18,000
22,000
25,000
30,000
42,000
50,000
65,000
85,000
100,000
125,000
150,000
200,000

12.3 A thermal-Link device provided in a Type 1, 2, 3 SPD or Type 1, 2, 3 Component Assembly and not connected in series with the load, shall comply with the requirements in the Standard for Thermal-Links – Requirements and Application Guide, UL 60691.

Exception No. 1: For a one port Type 1, 2 SPD or Type 1, 2 Component assembly compliance with [46](#) satisfies this requirement.

Exception No. 2: For a Type 3 SPD or Type 3 Component Assembly compliance with Section [47](#) satisfies this requirement where the temperature of the thermal link does not exceed 40°C.

12.4 A thermal-Link device provided in a Type 3 SPD or Type 3 Component Assembly and connected in series with the load, shall be capable of clearing a fault current of not less than that indicated in [Table 12.1](#) and shall comply with the requirements in the Standard for Thermal-Links – Requirements and Application Guide, UL 60691. The thermal link shall have a general purpose rating.

Exception: Compliance with [48](#) satisfies the second part of this requirement.

12.5 A thermal responsive device, provided as part of the SPD, in a one port Type 1 or Type 2 SPD, or a Type 1, 2 Component Assembly, and not connected in series with the load, shall comply with the requirements in Section [46](#).

12.6 A thermal responsive device or a thermal link, provided as part of an SPD, in a two port Type 2 SPD or a Type 2 Component Assembly where the thermal responsive device is in series with the load, shall comply with the requirements in Section [47](#). The thermal responsive devices shall also be capable of clearing a fault current of not less than that indicated in [Table 12.1](#).

Exception: If the thermal disconnect is not in series with the load and does not exceed 40°C during normal operation it shall comply with [46](#).

12.7 A thermal responsive device provided in a Type 3 SPD or a Type 3 Component Assembly that's in series with the load shall comply with the requirements in [48](#) and shall also be capable of clearing a fault current of not less than that indicated in [Table 12.1](#).

12.8 A thermal responsive device provided in a Type 3 SPD or a Type 3 Component Assembly that's not in series with the load where the temperature does not exceed 40°C shall comply with the requirements in Section [47](#).

12.9 An MOV provided with an integral thermal responsive device or thermal link, intended to be connected in series with the load, shall comply with the requirements in [48](#), and shall also be capable of clearing a fault current of not less than that indicated in [Table 12.1](#).

12.10 An MOV provided with an integral thermal responsive device or thermal link, not intended to be connected in series with the load, shall comply with the requirements in Section [47](#).

12.11 A thermal responsive device or a thermal link provided in a Type 4 Component Assembly shall comply with the requirements specified in [12.9](#) or [12.10](#) as appropriate.

12.12 A circuit breaker or fuse, provided in series with the load in a permanently connected two-port SPD, shall be suitably rated, capable of clearing a fault current of not less than that indicated in [Table 12.1](#) and acceptable for branch-circuit protection in accordance with the National Electrical Code, ANSI/NFPA 70 – for example, circuit breakers or Class CC, J, T, G, H, K, L, RK1 or RK5 cartridge fuses or Type S or Edison-base plug fuses are acceptable for the application. Other types of overcurrent protection devices are to be investigated to determine their acceptability for the application.

12.13 An SPD that is provided with fuses that are intended to be replaced in the field shall be marked in accordance with [85.8](#).

12.14 Fuses that are intended to be replaced in the field in a permanently connected SPD shall be either installed in an extractor type fuse holder or located behind a hinged cover as indicated in [7.1.1.6](#).

12.15 A supplementary protection device shall not be connected as to interrupt the equipment grounding conductor path.

12.16 A supplementary protection device shall not open during the Temperature Test, Section [40](#) or the Surge Testing, Section [41](#).

12.17 A cord-connected SPD with four or more receptacle outlets shall be provided with supplementary overcurrent protection as specified in the Standard for Relocatable Power Taps, UL 1363.

12.18 A single-pole supplementary protection device shall be connected in the ungrounded (line) conductor of the supply circuit, only. A double-pole device shall be connected on both the ungrounded and grounded (neutral) conductors such that when it operates, it opens both ungrounded and grounded conductors.

12.19 An MOV provided with an integral PTC thermistor shall comply with the requirements in Section [77](#), and the PTC thermistor shall comply with the requirement of the Standard for Thermistor-Type Devices, UL 1434 as current limiting devices with 100,000 times endurance cycles.

13 Accessibility of Live Parts

13.1 The electrical parts of an SPD that do not require use of a tool to access, shall be so located or enclosed that persons are protected against inadvertent contact with uninsulated current-carrying parts and film-coated magnet wire and accessibility shall be evaluated by performing the accessibility of live parts test in [67.2](#).

Exception: The exposed terminals of Receptacle Type and Molded Case SPDs, that are intended to be enclosed after installation, need not comply with the accessibility of live parts.

14 Supply Connections

14.1 Type 1, Type 2 and Type 3 SPD – Permanently connected

14.1.1 General

14.1.1.1 Supply connections are considered to be those that are made in the field when a device is installed.

14.1.1.2 An outlet box, terminal box, wiring compartment, or the like in which connections to the power-supply circuit are to be made in the field shall be free from sharp edges, including screw threads, burrs, fins, moving parts, or the like, that can damage the insulation on a conductor.

14.1.1.3 A terminal box or compartment on a fixed device shall be so located that wire connections therein will be accessible for inspection, without disturbing the wiring, after the device is installed in the intended manner.

Exception No. 1: Wire connections to a device intended to be mounted on an outlet box may be accessible upon removal of the device from the outlet box.

Exception No. 2: An electrical component, such as a switch, fuseholder, overcurrent protective device, or the like, may be mounted on a wiring compartment cover provided that:

- a) A component connecting leads are of sufficient length to provide for the making, and examination, of field-wiring connections without placing additional stress on the component wiring terminals;
- b) Any of the component connections are not to be field wired;
- c) Strain relief is provided to prevent stress from being transmitted to the component wiring terminations, and comply with the Strain Relief Test, Section [57](#);
- d) The minimum size of the component leads is 18 AWG (0.82 mm²); and
- e) Wiring terminals on the component are recessed or protected by barriers of insulating material or the equivalent that will provide protection from contact with wiring installed in the box.

14.1.1.4 A permanently-connected SPD shall have a field-wiring terminal, wiring lead, conduit fitting, a knockout or other opening in the enclosure and wire bending space, for the connection of a wiring system in accordance with the National Electrical Code, ANSI/NFPA 70 and acceptable for the purpose.

Exception No. 1: An enclosure need not have provision for the connection of a wiring system, such as a conduit hub, a knockout or a fitting, if it is intended to be drilled or punched in the field to accommodate a wiring system and is provided with appropriate installation instructions.

Exception No. 2: Conduit fittings, knockouts, other openings in the enclosure and wire bending space, for the connection of a wiring system are not required for open-type SPDs.

Exception No. 3: An SPD intended for connection using exposed wiring methods and marked in accordance with [85.36](#) need not have a conduit hub, a knockout, or similar fitting. The SPD shall have provisions to be installed in accordance with National Electrical Code, ANSI/NFPA 70 Article 398. Strain relief means must be provided to prevent stress from being transmitted to the wiring terminations, and comply with the Strain Relief Test, Section [57](#) with the specified cable installed.

14.1.1.5 An SPD that is acceptable for use with a fitting for only one type of wiring system shall be supplied with such a fitting. Installation instructions shall be provided if use of the fitting is not explicit.

14.1.2 Pigtail (flying) leads

14.1.2.1 An SPD provided with integral pigtail leads intended for connection in the field to a power supply circuit conductor shall be provided with a conduit connection means that is acceptable in accordance with the National Electrical Code, ANSI/NFPA 70.

14.1.2.2 For one port SPD Types 1 and 2, the pigtail lead shall not be smaller than 14 AWG (2.1 mm²) copper or 12 AWG (3.3 mm²) aluminum.

Exception: SPD Types 1, 2 and 4 Component Assemblies with integral pigtail leads intended to be connected to a power supply circuit conductor shall not be smaller than 18 AWG (0.82 mm²) and shall not be shorter than 152 mm (6 inches), when measured from the point of exit from the conduit connector. Insulation on such a lead shall be:

- a) At least 0.8 mm (1/32 inch) thick thermoplastic; or
- b) At least 0.4 mm (1/64 inch) thick rubber plus a braid cover for 300 V or less applications; or
- c) At least 0.8 mm (1/32 inch) thick rubber plus a braid cover for applications between 301 and 600 V.

14.1.2.3 A pigtail lead, described in [14.1.2.1](#) shall comply with the Conductor Secureness Test, Section [59](#).

14.1.2.4 If a lead is intended for field connection to the supply circuit, and the lead's other end terminates at an accessible terminal screw, the terminal screw shall be staked, soldered, or otherwise rendered non removable.

Exception: The terminal screw need not be inaccessible if suitable for field wiring.

14.1.3 Pressure wire connectors

14.1.3.1 A field-wiring pressure wire connector provided with or specified for use an SPD shall comply with one of the following, as applicable:

- a) The performance requirements in the Standard for Wire Connectors, UL 486A-486B; or
- b) The performance requirements in the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E.

14.1.3.2 The tightening torque for a field-wiring terminal shall be as specified by the SPD manufacturer and shall be marked as specified in 80.35 or 81.1. The specified tightening torque shall not be less than 90 percent of the value employed in the temperature test or static heating test as specified in the requirements in the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E, for that wire size corresponding to the ampere rating of the industrial control equipment.

Exception: When the tightening torque is less than 90 percent of the value specified, the connector shall be investigated in accordance with UL 486A-486B, or UL 486E, with the lesser assigned torque value.

14.1.3.3 A pressure wire terminal shall comply with the Verification of the Performance of Terminal Assemblies Test in the Standard for Terminal Blocks, UL 1059.

14.1.4 Wire binding screws

14.1.4.1 For a connections intended for 10 AWG (5.3 mm²) or smaller, a wiring binding screw may be used.

14.1.4.2 A wire-binding screw employed at a wiring terminal shall not be smaller than No. 8 (4.2 mm diameter), except that a No. 6 (3.5 mm diameter) screw may be used for the connection of a 14 AWG (2.2 mm²) conductor.

14.1.4.3 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.76 mm (0.030 inch) thick and there shall not be less than two full threads in the metal.

14.1.4.4 A wire-binding screw shall thread into metal.

14.1.4.5 The parts to which wiring connections are to be made may consist of clamps or binding screws with terminal plates having upturned lugs or the equivalent to hold the wires in position.

Exception: Upturn lugs are not required when the installation instructions require prepared conductors (i.e. ring type or fork type crimp terminals) to be used.

14.1.5 Spring type terminations

14.1.5.1 Spring type terminations shall comply with the requirements in Spring Force Connections in the Standard for Terminal Blocks, UL 1059.

14.1.6 Other means

14.1.6.1 Other equally effective connection means may be used if investigated for the purpose.

14.1.7 Lead and terminal identification

14.1.7.1 A field-wiring terminal intended for the connection of a grounded conductor shall be substantially white in color and shall be easily distinguishable from the other terminals, or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as on an attached wiring diagram. If wire leads are provided instead of terminals, the surface of the grounded conductor shall be finished to show white or grey color and shall be easily distinguishable from the other leads.

14.1.7.2 In order to polarize the wiring of a permanently-wired device intended to be connected to a supply circuit rated at 125 V or 125/250 V or less, and employing an overcurrent-protective device other than an automatic control, one terminal or lead shall be identified for the connection of the grounded conductor of the supply circuit. See [14.1.7.1](#) for identification requirements. The grounded conductor or a terminal identified for this use shall be the one to which no overcurrent-protective devices of the single-pole type is connected.

14.2 Type 3 SPD – Cord connected

14.2.1 General

14.2.1.1 A metal strain-relief clamp or band without auxiliary protection is acceptable with a Type SJ, SJO, SJT, SJTO, SO, ST, STO, or equivalent cord. A metal strain-relief clamp or band is acceptable with a Type SP-3, SPT-3 or equivalent cord only if acceptable auxiliary mechanical protection that is not electrically conductive is provided over the cord.

14.2.1.2 The flexible cord shall be Type S, SO, ST, SJ, STO, SJO, SJT, SJTO or shall be a type at least as serviceable for the particular application. Outdoor use products shall include "W" suffix.

Exception: SPT-3 or SP-3 may be used on an SPD rated 15 A, or less, if marked in accordance with [85.16](#).

14.2.1.3 A cord set shall comply with the Standard for Cord Sets and Power-Supply Cords, UL 817.

14.2.1.4 The supply cord shall have a voltage rating not less than the rated voltage of the SPD, and shall have an ampacity not less than the current rating of the SPD. The power-supply cord of a cord-connected SPD must also comply with the power-supply cord gauge requirements in the Standard for Relocatable Power Taps, UL 1363.

Exception: An SPD employing one or two receptacles is not prohibited from having a smaller ampacity supply cord when the cord ampacity complies with the:

- a) Table for Allowable Ampacity for Flexible Cords and Cables in the National Electrical Code;*
- b) Temperature Test, Section [40](#);*
- c) Fault Current Test, Section [50](#); and*

d) *Overcurrent Test, Section [51](#).*

14.2.1.5 The length of a supply cord measured from the outside surface of the enclosure of an SPD to the plane of the face of the attachment plug shall not be less than 0.45 m (1.5 ft) or be more than 7.6 m (25 ft.).

Exception No. 1: SPDs with only one or two receptacles are not required to comply with the minimum supply cord length.

Exception No. 2: For an SPD intended for outdoor use, the length of the supply cord measured from the outside surface of the enclosure to the plane of the face of the attachment plug shall be not less than 0.15 m (6 in).

14.2.1.6 For an SPD employing an outlet cord as described in [16.1](#), the total length of the outlet cord including the receptacle shall not be more than 1.8 m (6 ft). The total length of a supply cord, measured from inlet to outlet including the body of the SPD, shall not be more than 7.6 m (25 feet).

14.2.1.7 A detachable power-supply cord shall not be used.

Exception: An SPD with one or two receptacles is able to employ a detachable power-supply cord when rated 12 amperes or less.

14.2.1.8 If the attachment plug is other than the non-polarity type, one of the circuit conductors in the flexible cord shall be identified for connection of the grounded supply conductor if the SPD is rated at 125 V or less or at 125/250 V or less (3 wires).

14.2.1.9 An attachment plug shall have a current rating not less than the rated current of the SPD, and a voltage rating consistent with the voltage rating of the SPD. An attachment plug shall comply with the applicable requirements in the Standard for Attachment Plugs and Receptacles, UL 498 and in accordance with Wiring Devices – Dimensional Specifications, ANSI/NEMA WD6.

14.2.1.10 An SPD that employs one or two receptacles is able to be provided with an IEC 320 attachment plug. An IEC 320 attachment plug shall comply with the applicable requirements in the Standard for Attachment Plugs and Receptacles, UL 498.

14.2.1.11 An SPD that employs one or two receptacles is able to be provided with a cord set with an IEC 320 attachment plug. The cord set shall comply with the Standard for Cord Sets and Power-Supply Cords, UL 817.

14.2.2 Strain relief

14.2.2.1 Strain relief shall be provided so that a mechanical stress on a supply cord is not transmitted to terminals, splices, or interior wiring.

14.2.2.2 Means shall be provided so that the supply cord cannot be pushed into the SPD through the cord-entry hole if such displacement is likely to subject the cord to mechanical damage or expose it to a temperature higher than that for which the cord is rated or if such displacement is likely to reduce spacings, such as to a metal strain-relief clamp, below the minimum acceptable values.

14.2.2.3 The strain-relief means shall comply with the Strain Relief and Push-Back Relief Test requirements, Sections [57](#) and [58](#).

14.2.2.4 A knot shall not be employed to provide strain relief.

14.3 Type 3 SPD – Direct plug-in

14.3.1 An SPD provided with blades for direct plug-in at a receptacle shall comply with applicable requirements in the Standard for Current Taps and Adapters, UL 498A.

14.3.2 An attachment plug shall have a current rating not less than the rated current of the SPD, and a voltage rating consistent with the voltage rating of the SPD. An attachment plug shall comply with the applicable requirements in the Standard for Attachment Plugs and Receptacles, UL 498 and in accordance with Wiring Devices – Dimensional Specifications, ANSI/NEMA WD6.

14.3.3 An SPD provided with two sets of line blades shall be constructed so that no electrical connection exists between the two sets of line blades associated with each outlet of the duplex receptacle.

15 Mounting

15.1 Type 1 or Type 2 SPD

15.1.1 Provisions shall be made for securely mounting an SPD to a supporting surface. A bolt, screw, or other part used to mount a component integral to the SPD shall not be used for securing the SPD to the supporting surface.

15.1.2 An SPD intended for connection using exposed wiring methods shall be provided with a bracket or similar means for mounting shall comply with the Strength of Mounting Test, Section [76](#).

15.2 Type 3 SPD – Cord connected

15.2.1 Cord-connected SPD shall not have means for permanent mounting.

Exception: A cord-connected Type 3 SPD, complying with the Standard for Furniture Power Distribution Units, UL 962A, may employ mounting means for securement to portable or stationary furniture.

15.2.2 Cord-connected SPDs may be provided with a means for temporary mounting. A tool shall not be required for dismounting.

15.2.3 A means for temporary mounting shall provide for secure positioning that requires a positive, deliberate action by the user to dismount it.

15.2.4 A keyhole slot, notch, or similar means for temporary mounting, shall be located so that the screw head, nail head, hook, or other supporting device is not accessible for further securing of the SPD once it is mounted.

Exception: A temporary mounting means that does not comply with the above requirement may be acceptable if investigated for the purpose.

15.2.5 If a temporary mounting means is provided, installation instructions shall be furnished with the product. If the mounting means requires special hardware, the hardware shall be provided with the product.

Exception: Installation instructions need not be furnished if it is determined that the mounting means is obvious.

15.2.6 The temporary mounting means shall comply with the construction requirements in [7.2.3](#), the Mounting Hole Barrier Test, Section [65](#), and the Adequacy of Mounting Test, Section [66](#).

15.2.7 A rack-mounted cord-connected Type 3 SPD is able to employ mounting means to secure the SPD to portable or stationary equipment.

15.3 Type 3 SPD — Direct plug-in

15.3.1 Direct plug-in SPDs shall not have a means for permanent mounting except as specified in the Exception to [7.3.1.1](#) for the mounting tab defined in [7.3.1.3](#).

15.3.2 A mounting tab shall not be provided with a unit unless all of the following conditions are met:

- a) The unit is intended for use on a 15 A, 125 V receptacle;
- b) A screw is provided and constructed so as to secure the mounting tab of the unit to a standard parallel-blade duplex receptacle cover-mounting screw;
- c) For a unit without a grounding pin, the mounting tab is constructed so that the unit may be mounted to both grounding and nongrounding receptacles; and
- d) Marking as specified in [85.14](#) is provided.

16 Receptacles

16.1 The receptacle outlets shall comply with the applicable requirements in the Standard for Attachment Plugs and Receptacles, UL 498 and in accordance with Wiring Devices – Dimensional Specifications, ANSI/NEMA WD6.

16.2 An SPD employing one or two receptacles is able to employ a maximum of two IEC 320 receptacles. The IEC 320 receptacles shall comply with the applicable requirements in the Standard for Attachment Plugs and Receptacles, UL 498.

16.3 An SPD is able to employ only one receptacle outlet at the end of a single cord set. The cord set shall comply with the requirements in the Standard for Cord Sets and Power-Supply Cords, UL 817. One or two cords may be provided.

16.4 A receptacle provided as part of an SPD shall be rated not more than the current rating of the SPD per [84.1](#) and a voltage rating consistent with the voltage rating of the SPD.

16.5 The receptacle outlets of cord-connected SPDs employing three or more receptacles shall have a current rating of 15 or 20 A and a voltage rating of 125 or 250 V.

16.6 The receptacle outlets of direct plug-in SPD shall comply with applicable requirements in the Standard for Current Taps and Adapters, UL 498A.

16.7 The contact components of a receptacle shall have a voltage and current rating equal to that of the attachment plug.

Exception: A 15A receptacle may be used with an SPD rated 20A with a 20A attachment plug.

16.8 A receptacle shall be of the grounding type if, and only if, the SPD is provided with a grounding-type attachment plug or other means for grounding. See Grounding, Section [17](#).

Exception: All of the receptacle outlets of cord-connected SPDs employing three or more receptacles shall be of the grounding type.

16.9 Receptacles may be of the same or different slot configurations (locking and non-locking).

16.10 The output receptacle(s) of a direct plug-in SPD shall be integral with the device (not cord-connected).

16.11 Each receptacle outlet provided in an SPD with mounting means or intended for use in a fixed application, having the 5-15 or 5-20 configuration specified in Wiring Devices – Dimensional Specifications, ANSI/NEMA WD6, shall comply with the Grounding Contact Test requirements specified in the Standard for Attachment Plugs and Receptacles, UL 498.

16.12 A receptacle used in an SPD intended for outdoor use shall be comply with the outdoor use requirements in the Standard for Attachment Plugs and Receptacles, UL 498.

16.13 A receptacle used in an SPD intended for outdoor use shall be provided with a receptacle hood which is weather-proof with an attachment plug cap inserted or removed.

17 Grounding

17.1 General

17.1.1 SPDs shall be provided with a means for grounding all exposed dead metal parts that might become energized.

17.1.2 The equipment grounding termination shall be connected by a clamp, bolt, screw, braze, weld or an equivalent positive means that cannot be loosened from the outside and may include a corrosion resistant strap or jumper. Mechanical connections shall be secured. A solder connection may be used if the grounding lead is mechanically secure to the enclosure in accordance with [11.13](#). The grounding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel.

17.1.3 The grounding continuity between the grounding pin, blade, or terminal and the accessible dead metal parts of the SPD that might become energized is to comply with the Grounding Continuity Test, Section [49](#).

17.1.4 An equipment-grounding conductor shall be of copper, copper alloy, or other material that has been investigated for use as an electrical conductor. A ferrous metal part in the grounding path shall be protected against corrosion.

17.1.5 Metal parts in a bonding path shall be galvanically compatible so as to reduce electrolytic action between dissimilar metals.

17.1.6 A bonding member shall:

- a) Be protected from mechanical damage;
- b) Not be secured by a removable fastener used for any purpose other than bonding unless the bonding conductor is not likely to be omitted after removal or replacement of the fastener; and
- c) Have the flexibility needed to withstand mechanical stress.

17.1.7 If a bonding means depends on screw thread, two or more screws shall be employed, or at least two full threads of a single screw shall engage metal.

17.1.8 A receptacle provided as part of an SPD shall have its grounding contact, if provided, conductively connected to the grounding means. See [16.8](#).

17.1.9 Connections in the grounding conductor path from the receptacle grounding contact to the grounding conductor shall be welded, bolted, mechanically secured and soldered, or made by equivalent positive means. A quick connect, or similar friction fit connector shall not be used in the grounding conductor path.

Exception: Grounding connectors/terminal blocks that comply with the requirements in UL 1059, the Standard for Terminal Blocks, and also comply with Part V – Protective Conductor Terminal Blocks (PCTB), shall be permitted. See [17.2.4](#) and [17.3.3](#) for details.

17.1.10 If a receptacle used is provided with a grounding screw, the grounding screw shall be used to provide the ground connection to the receptacle. The yoke or faceplate mounting screws of the receptacle shall not be used to provide or maintain the grounding means of the receptacle or enclosure of an SPD.

Exception: The yoke mounting screw of a Self-Grounding Receptacle (a receptacle which includes a spring clip or other part to provide for electrical continuity between the grounded device yoke and the yoke mounting screw) is able to be used to provide or maintain the grounding means of the receptacle or enclosure of an SPD. This Exception is applicable when the yoke mounting screw of a permanently-connected SPD is not able to be loosened from the outside, the mounting screw penetrates nonconductive coatings, such as paint and vitreous enamel, and the SPD complies with the Fault Current Test, Section [50](#), and the Overcurrent Test, Section [51](#).

17.1.11 A copper-base-alloy rivet that is used to secure parts in the grounding path, or that forms a part of the grounding path, shall contain not less than 80 percent copper.

17.1.12 The internal grounding wiring shall be at least of the same gauge (AWG) as the ungrounded wire.

Exception: Smaller wire may be used if the results of the Fault Current Test, Section [50](#) and the Overcurrent Test, Section [51](#), are acceptable using the smaller AWG size.

17.1.13 An SPD that has an equipment grounding conductor path through traces on a printed wiring board shall comply with the Fault Current Test, Section [50](#), and Overcurrent Test, Section [51](#).

17.2 Type 1 or Type 2 SPD

17.2.1 A wire-binding screw intended for the connection of a grounding conductor shall have a green-colored head that is hexagonal shaped, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly identified, such as by being marked "G," "GR," "GND," "Ground," "Grounding," or the like; or by a marking on a wiring diagram provided on the product. The wire-binding screw or pressure wire connector shall be so located that it is unlikely to be removed during normal servicing of the unit.

17.2.2 A terminal for connection of a grounding conductor shall be capable of securing a conductor of the size acceptable for the particular application, in accordance with the National Electrical Code, ANSI/NFPA 70, and shall be constructed as specified in [14.1.2.1](#) – [14.1.2.4](#).

17.2.3 A grounding terminal for 10 AWG (5.3 mm²) or smaller wire may consist of a threaded stud welded to the enclosure or equivalent. Such terminal shall be of acceptable material – for example, plated if of steel; and shall also comply with [17.2.1](#), [17.2.2](#) and [14.1.2.1](#) – [14.1.2.4](#).

17.2.4 A solder lug, a push-in (screwless) connector, or a quick-connect or similar friction-fit connector, shall not be used for the grounding terminal.

Exception: Grounding connectors/terminal blocks that comply with the requirements in UL 1059, the Standard for Terminal Blocks, and also comply with Part V – Protective Conductor Terminal Blocks (PCTB), shall be permitted. PCTB used in Type 1 SPD's shall be rated for Service applications. PCTB used in Type 2 SPD's shall berated for Service, Commercial, or Industrial applications.

17.2.5 A lead intended for the connection of a grounding conductor shall not be smaller than 14 AWG (2.1 mm²) and sized in accordance with the National Electrical Code, ANSI/NFPA 70. The surface of an insulated lead intended solely for the connection of an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other lead visible to the installer in the field in a field-wiring-terminal compartment shall be so identified.

17.2.6 A hinge on a metal enclosure shall not be relied upon as a suitable grounding connection for the cover. The cover shall be provided with a separate bonding conductor, sized in accordance with [17.2.5](#), connected from the grounding terminal to the cover.

17.3 Type 3 SPD – Cord connected

17.3.1 The grounding conductor of a flexible cord of a cord-connected SPD, that is required to be grounded, shall be conductively connected to a metallic enclosure or frame and to the ground terminal(s) of the output receptacle(s) of the SPD.

Exception No. 1: Dead metal parts that are isolated from grounded metal and are not a part of the enclosure need not be connected to the grounding conductor of the power-supply cord.

Exception No. 2: A small metal part, such as an adhesive-attached foil label, a screw, or the like, that is on the exterior of the enclosure and separated from all electrical components by grounded metal or is electrically isolated from all components need not be connected to the grounding conductor of the power-supply cord.

17.3.2 The grounding conductor in a power-supply cord shall be green with or without one or more yellow stripes and of at least the same size as the current-carrying conductors. No other lead in the power-supply cord shall be so identified.

17.3.3 The grounding conductor shall be welded, bolted, mechanically secured and soldered, or connected by other equivalent positive means to a metallic frame or enclosure such that it is not likely to be removed during ordinary servicing not involving the power-supply cord.

Exception: Grounding connectors/terminal blocks that comply with the requirements in UL 1059, the Standard for Terminal Blocks, and also comply with Part V – Protective Conductor Terminal Blocks (PCTB), shall be permitted. PCTB used in Type 3 SPD's shall be rated for Service, Commercial, or Industrial applications.

17.3.4 The grounding conductor shall be connected to the grounding blade or equivalent fixed contacting member of an attachment plug.

17.3.5 A cord-connected SPD (having a 125/250 V rating) shall not use the neutral circuit conductor as the grounding conductor.

17.3.6 The line and neutral conductor path shall not be connected to the grounding circuit conductor path.

Exception: Connections between the line or neutral circuit conductor path and the grounding conductor path are able to be made when the components are investigated for the application (such as certain capacitors permitted as detailed in Section [26](#) – Capacitors).

17.4 Type 3 SPD – Direct plug-in

17.4.1 A direct plug-in SPD required to be grounded shall be provided with a grounding pin as one of the attachment-plug contacts conductively connected to a metallic enclosure or frame and to the ground terminal(s) of the output receptacle(s) of the SPD.

Exception No. 1: Dead metal parts that are isolated from grounded metal and are not a part of the enclosure need not be connected to the grounding conductor of the power-supply cord.

Exception No. 2: A small metal part, such as an adhesive-attached foil label, a screw, or the like, that is on the exterior of the enclosure and separated from all electrical components by grounded metal or is electrically isolated from all components need not be connected to the grounding conductor of the power-supply cord.

18 Spacings

18.1 The spacings in an SPD shall not be less than those indicated in [Table 18.1](#).

Exception No. 1: Greater spacings may be required if the enclosure, because of its size, shape, or the material used, is not considered to be sufficiently rigid to warrant the minimum spacings.

Exception No. 2: As an alternative to [Table 18.1](#), lesser spacings may be acceptable when determined in accordance with the requirements for Clearance and Creepage Distances, Section [20](#).

Exception No. 3: The acceptability of the inherent spacings of a component shall be based on the requirements for the component.

Exception No. 4: Circuits that comply with the requirements for Isolated Secondary Circuits, Section [24](#) need not be evaluated for spacings. The spacing between these circuits and other circuits shall comply with [Table 18.1](#).

Table 18.1
Minimum Spacings

		Spacings, in mm (inches)		
		Between any uninsulated live part and an uninsulated live part of opposite polarity, and uninsulated grounded dead metal part other than the enclosure, or exposed dead metal part that is isolated (insulated) ^{e,f}	Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable ^{b,c,e,f}	
Product	Potential involved in volts-RMS (peak)	Through air or oil	Over surface	Shortest distance
Type 3 SPDs	0 – 50 (70.7 or less)	1.2 (3/64)	1.2 (3/64)	1.2 (3/64)
	51 – 125 (over 70.7 – 176.8)	1.6 (1/16)	1.6 (1/16)	6.4 (1/4)
	126 – 250 (over 176.8 – 353.5)	2.4 (3/32)	2.4 (3/32)	6.4 (1/4)
	251 – 600 (over 353.5 – 848.4)	9/5 ^d (3/8) ^d	12.7 ^d (1/2) ^d	12.7 (1/2)

Table 18.1 Continued on Next Page

Table 18.1 Continued

		Spacings, in mm (inches)		
		Between any uninsulated live part and an uninsulated live part of opposite polarity, and uninsulated grounded dead metal part other than the enclosure, or exposed dead metal part that is isolated (insulated) ^{e,f}		Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable ^{b,c,e,f}
Product	Potential involved in volts-RMS (peak)	Through air or oil	Over surface	Shortest distance
Type 1 or Type 2 SPDs	0 – 150 (212.1 or less)	3.2 ^a (1/8) ^a	6.4 (1/4)	12.7 (1/2)
	151 – 300 (over 212.1 – 424.3)	6.4 (1/4)	9.5 (3/8)	12.7 (1/2)
	301 – 600 (over 424.3 – 848.5)	9.5 (3/8)	12.7 (1/2)	12.7 (1/2)
	601 – 1000 (849.9 – 1414.2)	14 (.55)	21.6 (.85)	25.4 (1)
<p>^a The spacing between field wiring terminals of opposite polarity and between a wiring terminal and a grounded or exposed dead metal part shall not be less than 6.4 mm (1/4 inch) if short circuiting or grounding of such terminals may result from projecting strands of wire.</p> <p>^b For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce the spacing between the metal piece and uninsulated live parts.</p> <p>^c The spacing to a metal enclosure does not apply to the housing or frame of a device intended for installation with an end product enclosure.</p> <p>^d These spacings apply to the sum of the spacings involved whenever an isolated dead metal part is interposed.</p> <p>^e Reduced spacings in accordance with Section 20 may be acceptable on a printed wiring board provided with a conformal coating that complies with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E; and are judged based on the tests performed.</p> <p>^f A printed wiring board intended to be completely encapsulated in an acceptable potting compound or epoxy shall not have any spacing less than 0.8 mm (1/32 inch).</p>				

18.2 The spacing at wiring terminals is to be measured with wires representative of field wiring in place and connected to the terminals as in actual service.

18.3 All uninsulated live parts connected to different circuits shall be spaced from one another as though they were parts of opposite polarity, in accordance with the requirement in 18.5, and shall be investigated on the basis of the highest voltage involved.

18.4 For the purposes of these requirements any uninsulated live part that is completely encapsulated in an acceptable potting compound or epoxy shall be considered insulated for the purpose of accessibility of live parts.

18.5 A live screw head or nut on the underside of an insulating base shall be prevented from loosening and shall be insulated or spaced from the mounting surface. This may be accomplished by:

a) Countersinking such parts not less than 3.2 mm (1/8 inch) in the clear and then covering them with a waterproof, insulating sealing compound that does not soften at a temperature 15°C (27°F) higher than its normal operating temperature in the device, and not less than 65°C (149°F) in any case, or

b) Securing such parts and insulating them from the mounting surface by means of a barrier or the equivalent, or by means of through-air or over-surface spacings as required by Table 18.1.

18.6 In multicomponent equipment, the spacings from one component to another, from any component to the enclosure, or to other uninsulated dead metal parts excluding the component mounting surface, are based on the maximum voltage rating of the complete equipment and not on the individual component ratings. The inherent spacings within an individual component are investigated on the basis of the voltage used and controlled by the individual component. Spacings between metal oxide varistors, capacitors, and other components shall comply with the minimum spacing requirements in [Table 18.1](#).

Exception: Components that comply with the requirements in the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, need not comply with the minimum spacing requirements between components in [Table 18.1](#).

18.7 Spacings at a fuse and fuseholder are to be measured with a fuse in place that has the maximum standard dimensions for the rating, and such spacings are to not be less than those specified in [Table 18.1](#).

18.8 A barrier or liner of insulating material used in areas where spacings are otherwise insufficient, shall comply with the requirements for internal barriers outlined in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, it shall be resistant to moisture absorption, and shall be secured in place or its position fixed by space limitations. An adhesive used to position a barrier shall be investigated for the effects of temperature, humidity, and cyclic conditions outlined in the Standard for Polymeric Materials – Use in Electrical Equipment, Evaluations, UL 746C.

18.9 For open-type SPDs, the spacings between live parts and metal parts that may be grounded, such as the heads of mounting screws that pass through an insulating panel, shall be judged as if they were grounded parts within an enclosure. The spacing between uninsulated live parts and the surface on which the device may be mounted is to be judged as if the mounting surface were part of an enclosure.

19 SPDs Used in Higher Altitude

19.1 SPDs, rated for use in an altitude greater than 2000 m shall incorporate surge components that are not influenced by changes in outside air pressure and density anticipated at higher altitudes, such as semiconductor devices (MOVs, etc.), hermetically sealed devices (such as Gas Discharge Tubes) or be completely encapsulated.

Exception: SPDs that incorporate components that are influenced by changes in outside air pressure and density, such as open air gap devices, that are not installed within a hermetically sealed or encapsulated environment, shall be subjected to surge testing while installed within a Barometric Chamber at the pressure corresponding to the rated altitude as specified in IEC 60664-1.

19.2 SPDs, rated for use in an altitude greater than 2000 m, shall have through air (Clearance) spacings based on [Table 18.1](#) multiplied by the applicable altitude correction factors specified in IEC 60664-1.

Exception: When employing the alternative approach to the spacing requirements described in [20.1](#) for the spacing requirements specified in [18.1](#), the values obtained from UL 840 are also to be multiplied by the applicable altitude correction factors specified in IEC 60664-1.

19.3 SPDs rated for use in an altitude greater than 2000 m, shall comply with the High Altitude Conditioning Test, Section [78](#).

20 Clearance and Creepage Distances

20.1 As an alternative approach to the spacing requirements specified in [18.1](#), and other than as noted in [20.2](#) and [20.3](#), clearances and creepage distances are able to be evaluated in accordance with the

requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, as described in [20.4](#).

20.2 Clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable, shall be as noted in [Table 18.1](#). The clearances shall be determined by physical measurement.

20.3 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in Spacings, Section [18](#).

Exception: If the design of the field wiring terminals is such that it will preclude the possibility of reduced spacing due to stray strands or improper wiring installation, clearances and creepage distances at the field wiring terminal may be evaluated in accordance with the Standard for Insulation Coordination including Clearances and Creepage Distances for Electrical Equipment, UL 840.

20.4 In conducting evaluations in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, the following guidelines shall be used:

- a) The pollution degree within an SPD housing is pollution degree 2.
- b) SPD intended for installation as or with service entrance equipment shall be evaluated as Overvoltage Category III. Other SPD covered under this standard shall be evaluated as Overvoltage Category II;
- c) Pollution degree 2 exists on a printed wiring board between adjacent conductive material which is covered by any coating which provides an uninterrupted covering over at least one side and the complete distance up to the other side of conductive material;
- d) Any printed wiring board which complies with the requirements in the Standard for Printed Wiring Boards, UL 796, shall be considered to provide a Comparative Tracking Index (CTI) of 100, and if it further complies with the requirements for Direct Support in UL 796 then it provides a CTI of 175;
- e) For the purposes of compliance with the requirements for coatings of printed wiring boards used to achieve pollution degree 1 in accordance with UL 840, a coating which complies with the requirements for Conformal Coatings in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, complies with the requirements;
- f) Pollution degree 1 is also achievable at a specific printed wiring board location by application of at least a 0.79 mm (1/32 inch) thick layer of silicone rubber or for a group of printed wiring boards through potting, without air bubbles, in epoxy or potting material.
- g) Evaluation of clearances, only, to determine equivalence with current through air spacings requirements are able to be conducted in accordance with the requirements for Clearance A (Equivalency) of UL 840. An impulse test potential having a value as determined in UL 840 is to be applied across the same points of the device as would be required for the Dielectric Voltage-Withstand Test, Section [39](#);
- h) Evaluation of clearances and creepage distances shall be conducted in accordance with the requirements in UL 840 for Clearance B (Controlled Overvoltage), and Creepage Distances;
- i) The Phase-to-Ground Rated System Voltage used in the determination of Clearances shall be the equipment rated supply voltage rounded to the next higher value (in the table for determining clearances for equipment) for all points on the supply side of an isolating transformer or the entire product if no isolating transformer is provided. The System Voltage used in the evaluation of secondary circuitry is able to be interpolated with interpolation continued across the table for the Rated Impulse Withstand Voltage Peak and Clearance; and

j) Determination of the dimensions of clearance and creepage distances shall be conducted in accordance with the requirements for Measurement of Clearance and Creepage Distances of UL 840.

20.5 Insulation is required between traces on inner layers of PWBs and between traces of different layers in PWBs.

20.6 The insulation between adjacent tracks on the same layer shall be evaluated as either:

- a) Creepage distance for pollution degree 1; or
- b) Solid insulation evaluated by the Dielectric Voltage-Withstand Test, Section [39](#).

Note: Clearance is not considered for the inner layer where air does not exist.

20.7 Insulation between traces of different layers shall be evaluated by the Dielectric Voltage-Withstand Test, Section [39](#).

21 Switches

21.1 Each switch shall have voltage and current ratings of not less than the load it is intended to control.

21.2 A switch provided in an SPD shall comply with the requirements in the Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1. The switch shall have as a minimum a general use rating.

Exception No 1: A switch that complies with the requirements of the Standard for General-Use Snap Switches, UL 20, for a general-use ac switch shall be acceptable for use in an SPD.

Exception No. 2: A switch provided as part of a status indicator intended only to function when the SPD fails or when the SPD is removed need only be endurance rated/tested for 50 cycles/operations.

21.3 A switch shall open all ungrounded circuit conductors, and may, in addition, open the grounded circuit conductor.

21.4 Each switch shall indicate to the user when its associated circuit is energized. Such indication shall be by a means such as an integral pilot light, a separate pilot light adjacent to the switch, an on-off marking, or other readily understood visible indication of whether or not the switch is "on" or "off". See [85.18](#).

Exception: An SPD may be provided with indicator or pilot lights such as neon-series-resistor, LED type, or the like, to show which receptacles are live or to indicate that the unit is energized.

22 Printed Wiring Boards

22.1 A printed-circuit board shall comply with all requirements, including those for direct support and shall be marked with the triangle symbol as described in the Standard for Printed-Wiring Boards, UL 796. A printed-circuit board shall also be classed V-0, V-1, or V-2 and rated minimum 105°C (221°F) in accordance with the requirements for the tests for flammability of plastic materials for parts in devices and appliances, UL 94. For a material classed V-2 a closed bottom in the equipment beneath the material or barrier evaluated for the use shall be provided.

22.2 A resistor, capacitor, inductor, or other part that is mounted on a printed-circuit board to form a printed-circuit assembly shall be secured so that it cannot be displaced to cause a risk of electric shock or fire by a force likely to be exerted on it during assembly, operation, or servicing of the SPD.

Note: Consideration is to be given to a barrier or a partition that is part of the device and that provides mechanical protection and electrical insulation of a component connected to the printed-circuit board.

22.3 An SPD that has an equipment grounding conductor path through traces on a printed wiring board shall comply with the Fault Current Test, Section 50, and Overcurrent Test, Section 51.

22.4 A two-port SPD that has a load current-carrying circuit conductor path through traces on a printed wiring board shall comply with the Overcurrent Test, Section 51.

23 Electronic Circuits

23.1 Malfunction of a component such as a diode; a transistor; a thyristor; an electrolytic capacitor; an integrated circuit; an optical isolator or other solid-state device (any device whose operation is dependant upon any combination of optical, electrical, or magnetic phenomenal within a solid) that has not been investigated for reliability and determined to be reliable shall not result in a risk of fire, electric shock or injury to persons when subjected to the Component Breakdown Test, Section 56.

Exception No. 1: A component located in the following circuits need not be subjected to the Component Breakdown Test:

- a) Circuits that comply with the requirements for Isolated Secondary Circuits, Section 24,*
- b) A circuit that has been investigated to the requirements in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, for reliability and determined to be reliable.*

Exception No. 2: Resistors, non-electrolytic capacitors, inductors, transformers, electromechanical devices such as switches and relays, and optical isolators that comply with the applicable requirements, as specified, elsewhere in this Standard.

23.2 Compliance with 23.1 will require an analysis of the circuit to determine whether malfunction of a component could result in a risk of fire, electric shock or injury to persons. This analysis may require the opening and short circuiting of any component (electrolytic capacitor, transistor junction, and the like) and observation of the ultimate results of the simulated malfunction or breakdown. Only one condition of simulated malfunction or breakdown is to be imposed at a time. For Type 3 SPDs, compliance shall be determined with the input source connected as intended and also with Line-Neutral reversed.

23.3 A solid-state electronic circuit that operates and is relied upon for safe operation of the device during the Leakage Current Test, Section 38, the Surge Testing, Section 41, the Operational Voltage Test, Section 44, or the Current Testing, Section 45, shall be investigated and comply with the requirements of Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991.

Exception: A solid-state electronic circuit that operates during the Leakage Current Test, Section 38, the Surge Testing, Section 41, the Operational Voltage Test, Section 44, or the Current Test, Section 45, is not required to be investigated to UL 991 when the SPD is tested:

- a) With the circuit functioning as intended;*
- b) With the circuit open-circuited; and*
- c) With the circuit short-circuited*

during the Leakage Current Test, the Surge Testing, the Surge Current Test, the Operational Voltage Test, or the Current Test.

24 Isolated Secondary Circuits

24.1 General

24.1.1 In addition to the requirements for Separation of Circuits, Section [25](#), a secondary circuit shall comply with the requirements for one of the following types of secondary circuits:

- a) A Class 2 circuit;
- b) A Limited Voltage/Current circuit;
- c) A Limited Energy circuit; or
- d) A Limiting Impedance circuit.

24.1.2 Secondary circuits intended for interconnection to Information Technology Equipment, such as keyboards, monitors, mice and the like, shall comply with the spacing, isolation, and transformer requirements in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1.

24.1.3 An optical isolator that is relied upon to provide isolation between primary and secondary circuits or between other circuits as required by this standard shall be constructed in accordance with the Standard for Optical Isolators, UL 1577, and shall be able to withstand for 1 minute, without breakdown, an ac dielectric voltage withstand potential equal to 1000 V plus twice rated voltage between the input and output circuits.

24.1.4 A power switching semiconductor device that is relied upon to provide isolation to ground shall be constructed in accordance with the Standard for Electrically Isolated Semiconductor Devices, UL 1557. The dielectric voltage withstand tests required by UL 1557 shall be conducted at a dielectric potential of 1000 V plus twice rated voltage for 1 minute.

24.1.5 An electromechanical relay that is relied upon to provide isolation between primary and secondary circuits or between other circuits, as required by this standard, shall be constructed in accordance with the Standard for Industrial Control Equipment, UL 508, and shall be able to withstand for 1 minute, without breakdown, an ac dielectric voltage withstand potential equal to 1000 V plus twice rated voltage between the input and output circuits.

24.2 Difference between the level of evaluation required within each type of secondary circuit

24.2.1 The following applies to secondary circuits that comply with the Class 2 (see [24.3](#)) or the Limited Voltage/Current (see [24.4](#)) circuit requirements:

- a) Components located within these circuits need not be evaluated.
- b) Spacings located within these circuits and from these circuits to earth ground or to the enclosure need not be evaluated. However, spacings from these circuits to other circuits shall be in accordance with Spacings, Section [18](#).
- c) These circuits can be accessible from outside the enclosure.

24.2.2 The following applies to secondary circuits that comply with the Limited Energy (see [24.5](#)) circuit requirements and that involve open circuit potentials less than or equal to 30 V ac or 42.4 V peak:

- a) Components located within these circuits need not be evaluated.

Exception: Printed wiring boards shall be evaluated in accordance with Printed Wiring Boards, Section 22. Wiring shall be evaluated in accordance with Internal Wiring, Section 11.

- b) Spacings located within these circuits and from these circuits to earth ground or to the enclosure need not be evaluated. However, spacings from these circuits to other circuits shall be in accordance with Spacings, Section 18.

- c) These circuits cannot be accessible from outside the enclosure. Therefore, if these circuits provide power to components that extend through the enclosure (such as displays, keypads, and the like), then the ability of these components to serve as an enclosure will need to be evaluated.

24.2.3 The following applies to secondary circuits that comply with the Limited Energy (see 24.5) circuit requirements and that involve open circuit potentials in excess of 30 V ac or 42.4 V peak:

- a) Printed wiring boards shall be evaluated in accordance with Printed Wiring Boards, Section 22. Wiring shall be evaluated in accordance with Internal Wiring, Section 11. The effects of heat generating power components on adjacent components such as printed wiring boards and wiring shall be evaluated in accordance with the temperature requirements in Temperature Test, Section 40.

Exception: Components located within these circuits need not be evaluated.

- b) Spacings located within these circuits need not be evaluated. However, spacings from these circuits to earth ground or to the enclosure and spacings from these circuits to other circuits shall be in accordance with Spacings, Section 18.

- c) These circuits shall not be accessible from outside the enclosure. Therefore, if these circuits provide power to components that extend through the enclosure (such as displays, keypads, and the like), then the ability of these components to serve as an enclosure will need to be evaluated.

24.2.4 The following applies to secondary circuits that comply with the Limiting Impedance (see 24.6) circuit requirements in this section:

- a) Components located within these circuits need not be evaluated.

- b) Spacings located within these circuits and from these circuits to earth ground or to the enclosure need not be evaluated. However, spacings from these circuits to other circuits shall be in accordance with Spacings, Section 18.

- c) These circuits can be accessible from outside the enclosure.

Exception: Circuits supplied from a limiting impedance that complies with Exception No. 1 to 24.6.2 cannot be accessible from outside the enclosure. Therefore, if these circuits provide power to components that extend through the enclosure (such as displays, keypads, and the like), then the ability of these components to serve as an enclosure will need to be evaluated.

24.3 Class 2 circuit requirements

24.3.1 A Class 2 circuit shall be supplied by an isolating source that complies with the requirements for Class 2 Power Units, UL 1310, or the requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

24.4 Limited voltage/current circuit requirements

24.4.1 A limited voltage/current circuit shall be supplied by an isolating source such that the maximum open circuit voltage potential available to the circuit is not more than 30 V ac or 42.4 V peak and the current available is limited to a value not exceeding 8 amperes measured after 1 minute of operation. The secondary winding of an isolating type transformer may be used to comply with this requirement. The transformer shall comply with the requirements in the appropriate UL Standards for Transformers.

24.4.2 With reference to these secondary voltage and current limits, these measurements are to be made as follows:

- a) The input to the source of that secondary is to be connected as intended. For Type 3 SPDs, the input source shall be connected as intended and also with Line-Neutral reversed;
- b) The maximum open circuit voltage potential available to the secondary circuit under consideration is to be measured across the source of that secondary; and
- c) The current available to the secondary circuit under consideration is to be measured by connecting a variable resistive load across the source of that secondary and then varying the load until an available current of 8 amperes can be obtained for 1 minute of operation. If an available current of 8 amperes cannot be obtained under any condition of loading, up to and including a short circuit, then the test can be discontinued for that circuit.

24.4.3 For a transformer, only one secondary circuit of a multiple secondary transformer is to be tested at a time and all other secondaries not under test are to be loaded as intended. The voltage and current measurements can be made directly across the secondary output terminals of the transformer. When a tapped transformer winding is used to supply a full-wave rectifier, the measurements are to be made from either end of the winding to the tap. When the transformer is used as part of a switching-type power supply, the voltage and current measurements are to be made after the transformer secondary winding rectification means.

24.4.4 A secondary fuse or other such secondary circuit protective device used to limit the available current in accordance with [24.4.1](#), shall be rated at not more than the values specified in [Table 24.1](#).

Table 24.1
Rating for Fuse or Circuit Protective Device

Open circuit volts (peak)	Amperes
0 – 20	5.0
Over 20 – 30	100/V ^a

^a V is defined as the peak open circuit voltage.

24.4.5 The secondary circuit protective device referenced in [24.4.4](#) may also be provided in the primary circuit. When provided in the primary circuit, there are no restrictions on the current rating of the protective device as long as it limits the available secondary current in accordance with [Table 24.1](#).

24.4.6 When a protective device is used as specified in [24.4.4](#) or [24.4.5](#), this protective device shall comply with the requirements in Spacings, Section 18, and shall be provided with an adjacent replacement marking and replacement instructions that include the required voltage and current rating. The printed wiring board, wiring, and spacings prior to the point at which the voltage and current are suitably limited shall comply with the requirements of this Standard.

24.4.7 A fixed impedance (such as a component or grouping of components in the same circuit) or a regulating network (such as used in a switching type power supply) may be provided to limit the voltage

and/or the available current in accordance with [24.4.1](#). Such a fixed impedance or regulating network shall be able to function under single component fault conditions.

24.5 Limiting energy circuit requirements

24.5.1 A limited energy circuit shall be supplied by an isolating source such that the maximum volt-ampere capacity available to the circuit is 200 volt-amperes or less at a maximum open circuit voltage potential of 100 V ac. The secondary winding of an isolating type transformer may be used to comply with this requirement. The transformer shall comply with the requirements in the appropriate UL Standard for Transformers.

24.5.2 With reference to the secondary voltage and volt-ampere capacity limits, the measurements are to be made as follows:

- a) The input to the source of that secondary is to be connected as intended. For Type 3 SPDs, the input source shall be connected as intended and also with Line-Neutral reversed;
- b) The maximum open circuit voltage potential available to the secondary circuit under consideration is to be measured across the source of that secondary; and
- c) The maximum volt-ampere capacity available to the secondary circuit under consideration is to be measured by connecting a variable resistive load across the source of that secondary and then measuring the voltage and current while varying the resistive load from open circuit to short circuit in 1-1/2 to 2-1/2 minutes. The maximum available volt-ampere capacity is then calculated by multiplying the simultaneously measured values of secondary voltage and secondary current.

24.5.3 For a transformer, only one secondary circuit of a multiple secondary transformer is to be tested at a time and all other secondaries not under test are to be loaded as intended. The voltage and volt-ampere capacity measurements can be made directly across the secondary output terminals of the transformer. When a tapped transformer winding is used to supply a full-wave rectifier, the measurements are to be made from either end of the winding to the tap. When the transformer is used as part of a switching-type power supply, the voltage and volt-ampere capacity measurements are to be made after the transformer secondary winding rectification means.

24.5.4 A primary or secondary circuit fuse or other such circuit protective device may be used to limit the maximum available volt-ampere capacity in accordance with [24.5.1](#). While there are no restrictions on the current rating of this protective device as long as it limits the available secondary volt-ampere limit in accordance with [24.5.2](#), the protective device shall comply with the requirements of this standard and shall be provided with an adjacent replacement marking or replacement instructions that includes the required voltage and current rating. The printed wiring board, wiring, and spacings prior to the point at which the voltage and volt-ampere capacity are suitably limited shall comply with the requirements of this Standard.

24.6 Limiting impedance circuit requirements

24.6.1 A Limiting Impedance circuit shall be supplied by an impedance that complies with the following. For Type 3 SPDs, Limiting Impedance shall be evaluated with the input source connected as intended and also with Line-Neutral reversed:

- a) The calculated power dissipation of the impedance, as the result of a direct short applied across the circuit downstream of the impedance, does not exceed the power rating of the impedance; and
- b) The power dissipation of the impedance shall be less than 15 watts.
- c) There does not exist a risk of shock, as defined in [3.41](#), downstream of the impedance.

Exception: A Limiting Impedance circuit may be supplied by an impedance that complies with the following:

- a) The impedance shall be rated such that the calculated power dissipation of the impedance, as the result of a direct short applied across the circuit downstream of the impedance, exceeds the power rating of the impedance but is still less than 15 watts; and*
- b) The impedance shall not open or short when subjected to the effects of a direct short applied across the circuit downstream of the impedance. The method for setting up this limiting impedance test is the same as the method for setting up the Breakdown of Components Test, Section [56](#).*
- c) There does not exist a risk of shock, as defined in [3.41](#), downstream of the impedance.*

24.6.2 The limiting impedance referred to in [24.6.1](#) shall be able to function under single component fault conditions.

Exception No. 1: If the circuit limited by this impedance is enclosed, then this limiting impedance need not function under single component fault conditions.

Exception No. 2: A single resistor serving as a limiting impedance is considered to comply with this requirement without further investigation.

Exception No. 3: A single capacitor serving as a limiting impedance is considered to comply with this requirement without further investigation if the capacitor complies with requirements in the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14.

25 Separation of Circuits

25.1 An SPD employing circuit conductors intended for connection to telephone communication, data communication, fire alarm, antenna/cable or isolated secondary circuits, shall be provided with a barrier, physically secured by means other than friction, that separates the ac power circuit conductors from the conductors of the other circuits. Bonding of the equipment grounding conductor and the referenced conductors of the telecommunication circuits is permissible.

Exception No. 1: A barrier is not required between conductors that are separated by a minimum spacing of 2 inches, including lead dress.

Exception No. 2: Conductors that are acceptably insulated for the maximum ac power circuit voltage involved need not be separated from the ac power circuit conductors, provided that breakage or loosening of a conductor at a terminal in either circuit cannot result in contact between uninsulated live parts of one circuit and uninsulated or inadequately insulated live parts of the other circuit.

Exception No. 3: For conductors other than appliance wiring material, such as traces on a printed wiring board, terminals mounted on insulating blocks, and the like, the minimum separation between conductors of the ac power circuit and conductors of other circuits shall be in accordance with [Table 18.1](#).

26 Capacitors

26.1 Capacitors other than those employed in a secondary circuit shall comply with the Dielectric Voltage-Withstand Test, Section [39](#), Insulation Resistance Test, Section [54](#), and Capacitor Endurance Test, Section [55](#).

Exception No. 1: Capacitors evaluated to the Dielectric Voltage-Withstand Test, Insulation Resistance Test and Capacitor Endurance Test of the Standard for Electromagnetic Interference Filters, UL 1283 are not required to be subjected to these tests.

Exception No. 2: Capacitors that comply with the requirements in the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14 and are rated for the intended application, including operating voltage, subclass, Upper and Lower Temperature rating as follows:

- a) X Capacitors can be used in L-L and L-N applications only without additional testing per [26.1](#).*
- b) Y Capacitors can be used in L-L, L-N, L-G and N-G applications without additional testing per [26.1](#).*

Exception: Two X capacitors in series, may be substituted for a Y capacitor providing that each capacitor is rated $1.36 / 2 = .68$ times the voltage rating required for a Y capacitor.

NOTE: Since the endurance testing of Y capacitors is at 1.7 times the rated voltage and the endurance testing for X capacitors is at 1.25 times the rated voltage, the X capacitor needs to be rated at 1.36 times the rating of the Y capacitor ($1.25U_{RX} = 1.7U_{RY}$; $U_{RX} = 1.36U_{RY}$). Therefore, with two X capacitors in series, each capacitor would need to be rated $1.36 / 2 = .68$ times the operating voltage at the point of installation.

- c) Duration of the damp-heat test (21 or 56 days) does not need to be considered.*
- d) Passive flammability category does not need to be considered.*
- e) Overvoltage Class and Peak Surge Voltage properties do not need to be considered provided that the capacitors are tested as part of the SPD during the end-product SPD Surge Testing per UL 1449 Section [41](#).*

Exception No. 3: Capacitors employed in Type 1 and Type 2 SPDs and not intended to function as an EMI filtering feature, as defined in the glossary of this standard, that comply [26.3](#), need not comply with the Capacitor Endurance Test.

26.2 A capacitor shall comply with spacings of [Table 18.1](#) between the case and legs, and any other uninsulated live parts.

Exception: For a capacitor that complies with the requirements of the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, spacings of [Table 18.1](#) do not apply.

26.3 Capacitors employed in Type 1 SPDs shall comply with the Fault-Current Test in the Standard for Capacitors, UL 810 at the short circuit current rating of the SPD.

Exception No. 1: UL 810 capacitors that have not been subjected to the Fault-Current Test in accordance with UL 810 at the short circuit current rating of the SPD shall be subjected to the Capacitor Failure Test, Section [73](#). The Capacitor Failure Test shall be applied at all test current levels required by the Current Testing in [45.2](#), [45.3](#) and [45.4](#) that are higher than the Fault Current Rating of the UL 810 Capacitor including the SCCR of the SPD.

Exception No. 2: Capacitors that have not been subjected to the Fault-Current Test in accordance with UL 810 shall be subjected to the Capacitor Failure Test, Section [73](#) at all current levels of the Current Testing detailed in [45.2](#), [45.3](#) and [45.4](#).

26.4 A discharge means, such as a bleeder resistor, shall be provided to drain the charge stored in a capacitor if necessary to comply with the requirements in the Capacitor Discharge Test, Section [69](#).

27 Electromagnetic Interference Filters

27.1 An SPD provided with an EMI filtering feature, as defined in the glossary of this standard, shall comply with the applicable requirements in the Standard for Electromagnetic Interference Filters, UL 1283.

27.2 Suppression elements may be removed when conducting the Dielectric Voltage-Withstand Testing.

28 Protectors for Communication and Fire Alarm Circuits

28.1 Secondary protector circuits, employed in Type 2 or Type 3 SPDs, intended for use in telecommunication networks shall comply with the applicable requirements in the Standard for Secondary Protectors for Communication Circuits, UL 497A, and shall be marked in accordance with [85.23](#).

Exception: A secondary protector circuit that complies with the applicable requirements from UL 497A bi-directionally is not required to be marked in accordance with [85.23](#).

28.2 Protector circuits, employed in Type 2 or Type 3 SPDs, intended for use in data communication, coaxial connections and fire alarm circuits shall comply with the applicable requirements in the Standard for Protectors for Data Communication and Fire Alarm Circuits, UL 497B.

28.3 Primary protector circuits, employed in Type 1 SPDs intended for use on communication circuits as defined in article 800 of the National Electrical Code, NFPA 70, shall comply with the applicable requirements of Protectors for Paired-Conductor Communications Circuits, UL 497.

28.4 Primary protector circuits, employed in Type 1 SPDs, intended for use on coaxial communication circuits and network-powered broadband communications systems as defined in article 830 of the National Electrical Code, NFPA 70, shall comply with the applicable requirements of Protectors for Coaxial Communications Circuits, UL 497C.

29 Antenna Connections for Audio-Video Products

29.1 Outdoor antenna lead-in connections, employed in SPDs, shall comply with the applicable requirements in the Standard for Antenna-Discharge Units, UL 452, and the Standard for Audio-Video Products and Accessories, UL 1492 or the Standard for Audio, Video, and Similar Electronic Apparatus-Safety Requirements, UL 60065.

29.2 The antenna connections shall be subjected to the Internal Resistance and Discharge Tests outlined in the Standard for Antenna-Discharge Units, UL 452, and the Voltage Surge Test outlined in the Standard for Audio-Video Products and Accessories, UL 1492 or the Surge Test outlined in the Standard for Audio, Video, and Similar Electronic Apparatus-Safety Requirements, UL 60065.

Exception: Coaxial protectors complying with the requirements in Protectors for Coaxial Communications Circuits, UL 497C for primary protection and the Standard for Protectors for Data Communication and Fire Alarm Circuits, UL 497B for secondary protection satisfy this requirement.

30 SPDs Intended for Use on Ungrounded Systems, Impedance Grounded Systems, or Corner Grounded Delta Systems

30.1 SPDs for use on ungrounded systems, impedance grounded systems, or corner grounded delta systems shall have surge protective elements that are connected from line to ground rated for maximum line to line voltage.

30.2 SPDs for use on ungrounded systems shall have a cautionary marking in the instruction manual as specified in [86.1\(e\)](#).

31 Uninterruptible Power Supply Equipment

31.1 Uninterruptible power supply equipment employed in SPDs shall comply with the applicable requirements in the Standard for Uninterruptible Power Supply Equipment, UL 1778.

32 SPD/Panelboard Extension Modules

32.1 SPD/Panelboard Extension Modules shall also comply with the applicable requirements in the Standard for Panelboards, UL 67.

33 Molded Case Surge Protective Devices

33.1 Molded Case SPDs shall additionally comply with the requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures, UL 489. The investigation will include, but is not limited to:

- a) Spacings evaluation, such as electrical spacings, wiring space, and wire bending space.
- b) Openings in enclosures or the deadfront when the classified SPD is placed in a specified panelboard and is used with filler plates or other circuit breakers.
- c) Accessibility of wiring terminals with the classified SPD installed in a specified panelboard.
- d) Other construction requirements in this standard.
- e) Connectability features that are equivalent to a specified circuit breaker, including wiring terminal temperature rating, and field wiring conductor temperature rating and type.

33.2 Molded Case SPDs of the Pullout design shall additionally comply with the following:

- a) The Pullout Module shall not be insertable into a Pullout Base of the same manufacturer that has a different voltage rating, or for which it is not intended for use.
- b) The Pullout Module and Pullout Base case insulating material shall comply with the Base and Support – Insulating Material requirements in the Standard for Panelboards, UL 67.
- c) Spacings shall comply with the Standard for Panelboards, UL 67.

Exception: Spacings inside the Pullout Module shall comply with the spacing requirements for Surge Protective Devices, Section 18 of UL 1449.

- d) The enclosure of a Pullout SPD shall enclose completely all current-carrying parts, whether dead or alive, when the pullout module is installed. A pullout module shall be so constructed that no live part will be exposed to unintentional contact by the operator when the pullout module is in any position. See Standard for Pullout Switches, UL 1429 – Operating Mechanism.

e) The Pullout Base shall fit closely with the opening in the panelboard deadfront in accordance with the Standard for Panelboards, UL 67.

f) Pullout SPDs shall be subjected to and comply with the Pullout Insertion and Withdrawal Test, Section [72](#).

34 Interchangeability of Metal Oxide Varistors (MOVs)

34.1 The following requirements shall be applied when substituting discrete component Type 5 MOVs within SPDs:

a) Interchangeability of MOVs shall be applicable to Type 1, Type 2, or Type 1, 2, component assemblies and Type 4 component assemblies. Also, Type 3, Type 3 component assemblies where the MCOV of the MOVs is greater than the Current Testing voltage in [Table 45.1](#).

b) Replacement MOV shall have the same orientation and location as the original MOV.

c) Replacement MOV shall comply with the requirements in this standard.

d) Replacement MOV shall have the same MCOV as the original MOV with a maximum tolerance of $\pm 4\%$.

e) Replacement MOV disk diameter shall be equal to the original MOV or the geometric area shall be equal, i.e. when replacing a round MOV with a square one with a tolerance of $\pm 10\%$.

f) Replacement MOV shall have the following test specification data equivalent to the original MOV:

1) Nominal Discharge Current, (I_n)

i) Replacement MOV shall have an equal or greater I_n rating as the original MOV.

2) Measured Limiting Voltage (MLV)

i) Replacement MOV MLV shall be less than 110% of the original MOV.

Exception: If replacement MOV(s) has a MLV rating, greater than 110%, conduct Determination of Voltage Protection Rating Test, [41.6](#) on the SPD with the replacement MOV installed. If the average limiting voltage measured is less than or equal to, but not greater than 10% of the average limiting voltage measured using the original MOV(s), then the replacement MOV is considered to comply with this requirement.

3) Nominal Varistor Voltage

i) Replacement MOV nominal varistor voltage (V_n) shall be within $\pm 4\%$ of the original MOV's nominal varistor voltage (V_n).

g) The coating of the replacement MOV shall be of the same generic material, such as epoxy powder coating, as the original MOV.

35 Supplementary Circuit

35.1 A supplementary charging circuit provided in a Type 3 SPD shall comply with the requirement of the Standard for Class 2 Power Units, UL 1310 or the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1.

35.2 Type 3 SPDs that employ supplementary circuitry as specified in [1.15](#) evaluated by UL 60950-1 shall be marked as specified in [85.32](#) to warn the user of the limited application.

36 Rechargeable Battery Pack

36.1 A rechargeable battery pack provided in cord-connected and direct plug-in Type 3 SPDs shall comply with the requirements in the Standard for Household and Commercial Batteries, UL 2054.

36.2 Cord-connected and direct plug-in Type 3 SPDs provided with a non-replaceable rechargeable battery shall be marked as specified in [85.33](#).

36.3 Cord-connected and direct plug-in Type 3 SPDs provided with a replaceable rechargeable battery shall be marked as indicated in [85.34](#) and provided with instructions as noted in [86.3](#).

TEST PROGRAM

37 General

37.1 General

37.1.1 [Figure 37.1](#) (Flowcharts 1 – 4) and [Table 37.1](#) (SPD Test Matrix) identify the primary tests to be conducted on SPDs. The tests identified in Flowchart 1 are Surge Tests as detailed in Section [41](#). The tests shown in Flowcharts 2 – 4 identify the Current Tests which include the Short Circuit Current Rating Test as well as the Intermediate Current Test and the Limited Current Abnormal Overvoltage Test. These tests are detailed in Section [45](#). The tests identified in Section [38](#) (Leakage Current), Section [39](#) (Dielectric), Section [40](#), (Temperature), and Section [44](#) (Operational Voltage Test), as well as Section [49](#) (Grounding Continuity), are required at specified points and on specified SPD Types throughout the Test Program.

37.2 Test environment and general sample discussion

37.2.1 Unless otherwise specified, tests performed on an SPD shall be conducted under the following standard test conditions:

Relative Humidity:	Less than 85 percent
Altitude or Pressure:	Less than 2000 m (6562 ft) or pressure of 80 – 106 kPa
Ambient Temperature:	25 ±5°C
AC Operating Voltage:	Nominal System Voltage or manufacturers normal operating voltage rating, whichever is greater

37.2.2 Tests on an SPD shall be performed on an unaltered unit except where specifically stated in this standard.

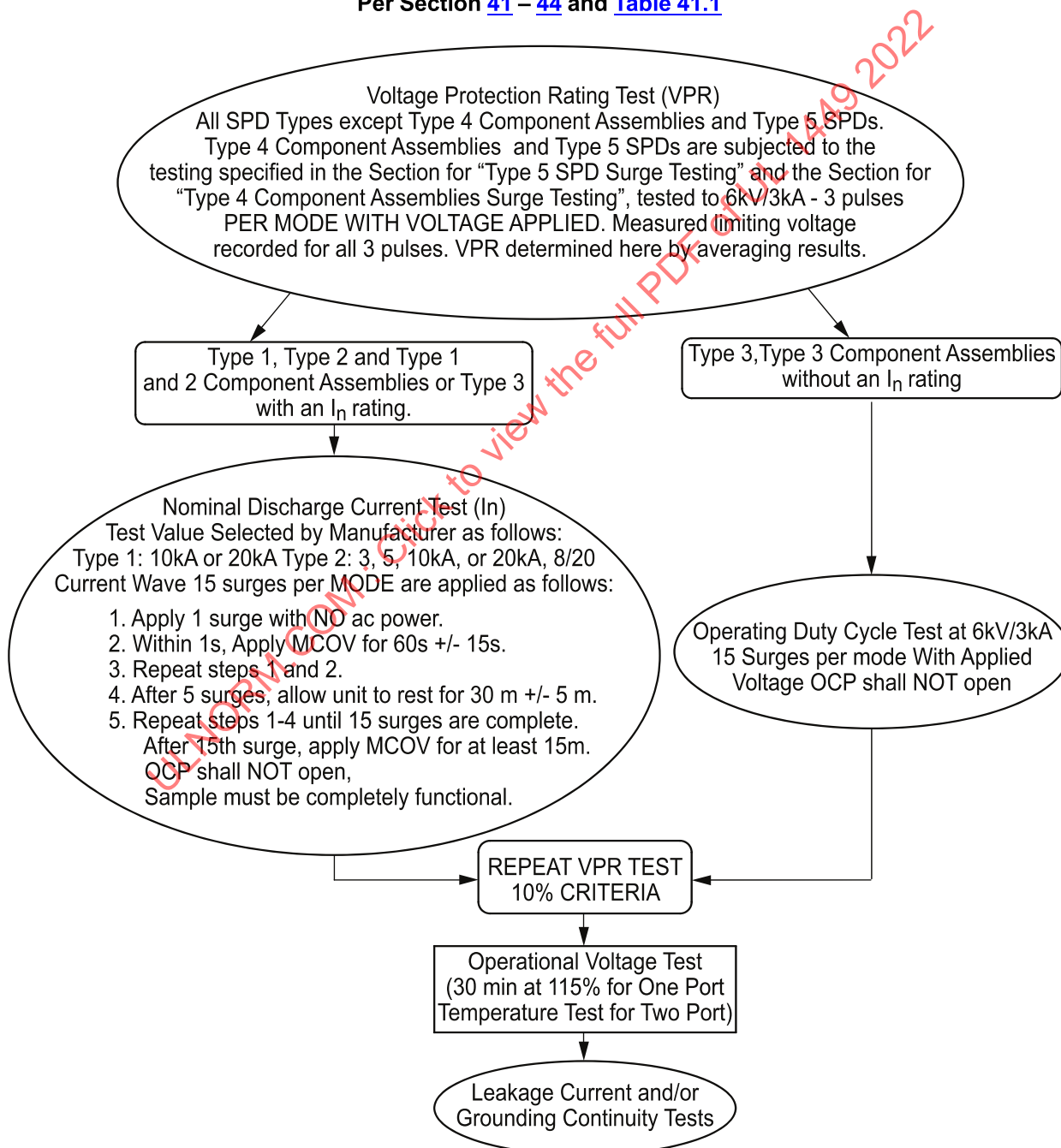
37.2.3 Unless otherwise specified, new and clean representative devices of an SPD shall be selected for testing. The minimum number of representative devices, and the tests or sequence of tests to be conducted, shall be in accordance with [Figure 37.1](#), Test program flow charts 1 – 4.

Exception: Tests may be combined and conducted on fewer representative devices if agreeable to all concerned.

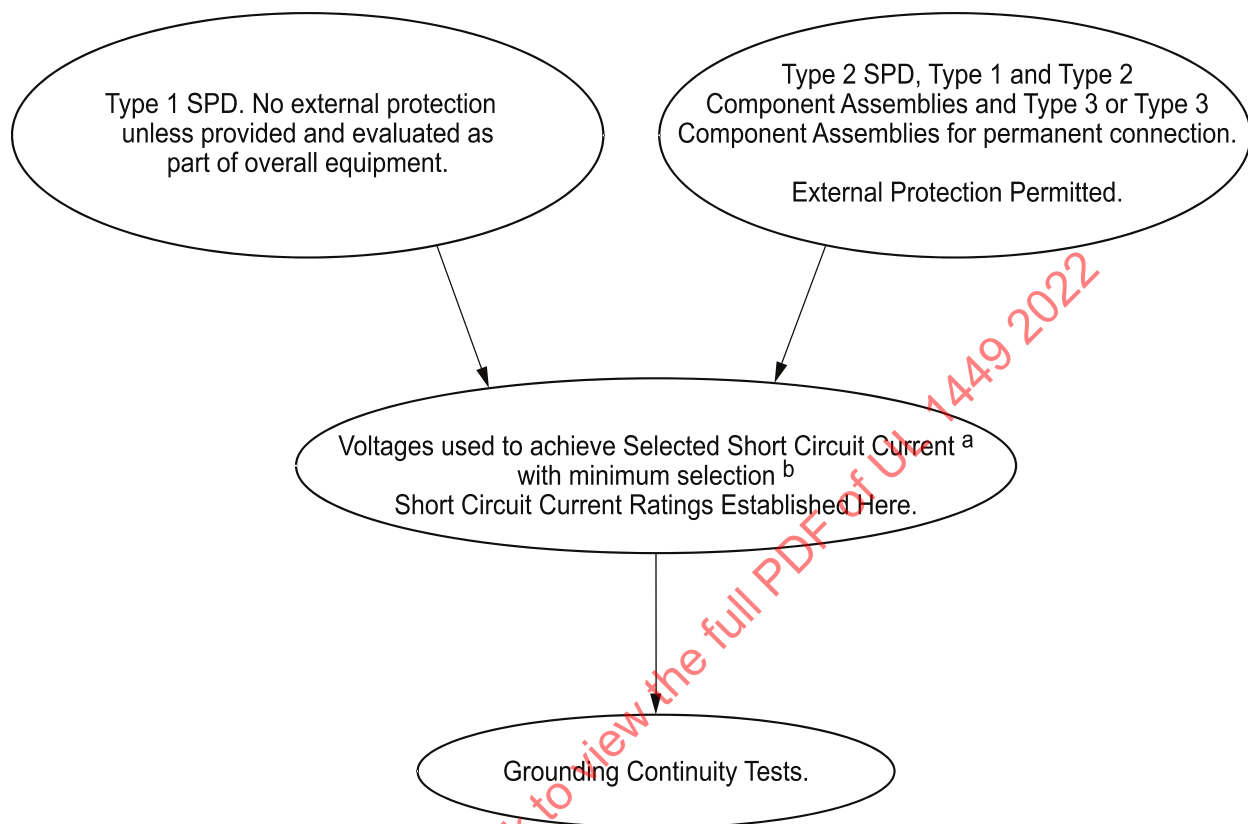
37.2.4 When the use of cheesecloth is specified, the cloth to be used is to be bleached cheesecloth running 14 – 15 yd²/lb (approximately 26 – 28 m²/kg) and having what is known as a count of 32 by 28, that is, for any square inch, 32 threads in one direction and 28 threads in the other direction (for any square centimeter, 13 threads by 11 threads).

37.2.5 When the use of tissue paper is specified, the paper shall be white wrapping paper of grammage generally between 12 g/m² and 30 g/m².

Figure 37.1
Test Program Flow Chart 1
Per Section 41 – 44 and Table 41.1



Test Program Flow Chart 2
Short Circuit Current Test
Per [45.2](#) and [Table 12.1](#) and [Table 12.2](#)

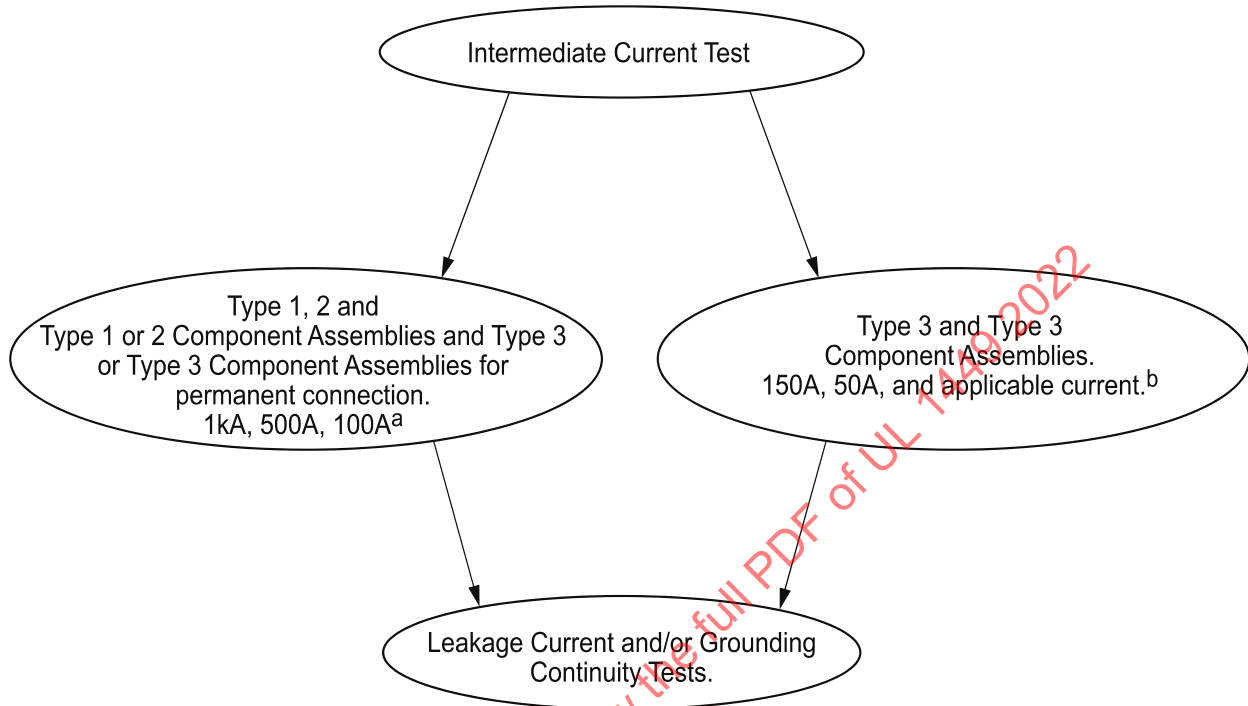


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a – Per [Table 12.2](#)

b – Per [Table 12.1](#)

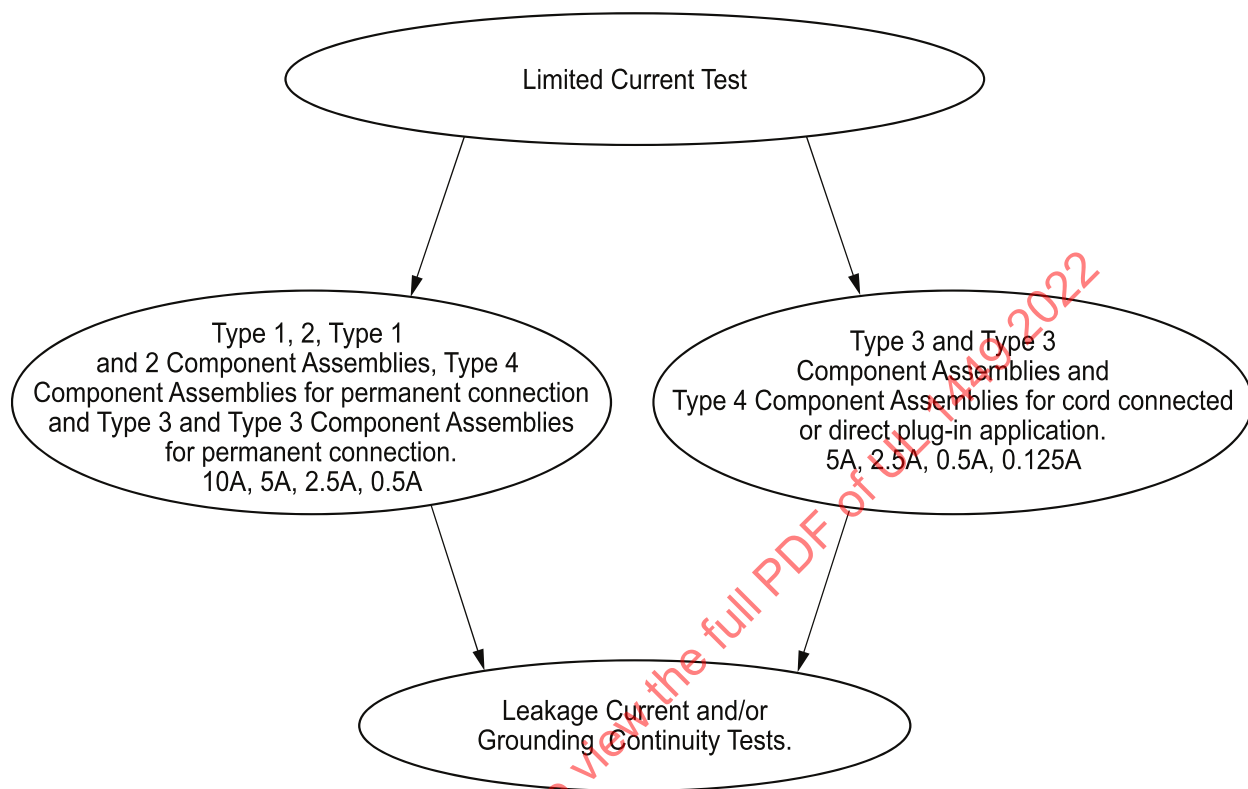
NOTE: Additional non-sequential test requirements are specified in various sections throughout the standard. These include: Sections [31](#), [32](#), [34](#), [41](#), [45](#), [49](#), [51](#), [52](#), [54](#), and [61](#).

Test Program Flow Chart 3**Intermediate Current Test**Per [45.3](#) and [Table 45.2](#) and [Table 45.3](#)

su0193c

a – Per [Table 45.2](#)b – Per [Table 45.3](#)

NOTE: Additional non-sequential test requirements are specified in various sections throughout the standard. These include: Sections [31](#), [32](#), [34](#), [41](#), [45](#), [49](#), [51](#), [52](#), [54](#), and [61](#).

Test Program Flow Chart 4**Limited Current Test**Per [45.4](#) and [Table 45.4](#)

su0194c

NOTE: Additional non-sequential test requirements are specified in various sections throughout the standard. These include: Sections [31](#), [32](#), [34](#), [41](#), [45](#), [49](#), [51](#), [52](#), [54](#), and [61](#).

**Table 37.1
SPD Testing Matrix**

Test	Section reference	SPD Type			
		Type 1	Type 2	Type 3	Type 1, 2, 3 component assemblies
Temperature	40	A ^a	A ^a	A ^a	A ^a
Leakage Current	38	NA	NA	A ^d	A ^d
Dielectric Voltage Withstand	39	A	A	A	A
Surge Test for VPR	41	A	A	A	A
Nominal Discharge Current (I _n)	41	A	A	NA ^b	A for Type 1 or 2 applications
Operating Duty Cycle	41	NA	NA	A	A for Type 3 application or ^b
Repeat Surge Test	41	A	A	A	A
Operational voltage	44	A	A	A	A
Grounding Continuity	49	A	A	A	A
Current tests at short circuit current rating, intermediate and limited short circuit current levels	45	A	A	A (Applies to Permanently Connected Only)	A, NA for Type 5 SPDs. Limited Current only for Type 4 Component Assemblies. Short circuit, intermediate and limited for Type 1, 2, 3 Component Assemblies
Fault and Overcurrent Tests only as required by Exception No. 2 of 11.18 and 11.19 or by 22.3 or 22.4 .	50 , 51	A	A	A	A
Withstand	52	A ^c	A ^c	NA ^c	A – Type 1 or 2 application ^c
Insulation Resistance and Capacitor Endurance	54 , 55	A	A	A	A
Component Breakdown as required by 23.1	56	A	A	A	A
Strain Relief	57	NA	NA	A	O
Push-back Relief	58	NA	NA	A	O
Conductor Secureness	59	A	A	NA	O
Snap-On Cover	60	A	A	A	O
Non-Metallic Enclosure Conduit Connection	61	A	A	NA	O
Enclosure Impact	62	A	A	A	O
Crushing	63	NA	NA	A	O
Mold Stress-Relief Distortion	64	A	A	A	O
Mounting Hole Barrier	65	A	A	A	O
Adequacy of Mounting	66	NA	NA	A	O
Accessibility	67	NA	NA	A	O
Permanence of Cord Tag	68	NA	NA	A	O
A – Applicable NA – Non-applicable O – Only as applicable					

Table 37.1 Continued on Next Page

Table 37.1 Continued

Test	Section reference	SPD Type			
		Type 1	Type 2	Type 3	Type 1, 2, 3 component assemblies
^a – Applicable to one-port SPDs with heat generating components, such as inductors, resistors, etc., and all two-port SPDs.					
^b – I _n test is applicable per Exception to 41.8.1 .					
^c – Applicable to two-port SPDs intended for permanently connected applications.					
^d – Applicable to Type 3 SPDs intended for cord-connected and direct plug-in applications.					

Table 37.2
Testing for Type 5 and Type 4 Component Assemblies

Test	Section reference	Type 5 ^a	Type 4 component assemblies ^a
Temperature	40	O ^a	O ^a
V_n (before and after I_n)	70	A	A
Nominal Discharge Current (I_n)	42 , 43	A	A
Disconnect	46 , 47 , 48	NA	A
Limited Current	45	NA	A
Dielectric Voltage Withstand (for discrete components the test is performed with foil wrapped around epoxy disc)	39	A	A
Grounding Continuity	49	O	O
Fault and Overcurrent Tests only as required by Exception No. 2 of 11.18 and 11.19 or by 22.3 or 22.4	50 , 51	O	O
Withstand	52	O ^b	O ^b
Insulation Resistance and Capacitor Endurance	54 , 55	O	O
Component Breakdown as required by 23.1	56	O	O
A – Applicable NA – Non-applicable O – Only as applicable ^a – Applicable to one-port SPDs with heat generating components, such as inductors, resistors, etc., and all two-port SPDs. ^b – Applicable to two-port SPDs.			

38 Leakage Current Test – Type 3 SPDs Only

38.1 When tested in accordance with [38.4](#) – [38.9](#), the leakage current of Type 3 and Type 4, intended for Type 3 applications, cord-connected or direct-plug-in SPDs shall not be more than 0.5 mA.

Exception No. 1: Cord-connected or direct plug-in SPDs marked in accordance with [85.9](#) shall not have leakage current more than 3.5 mA.

Exception No. 2: For SPDs intended to be employed between line and ground as a component of a cord-connected product, the leakage current shall be measured through the SPD.

38.2 Leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed surfaces of an SPD and ground or other exposed surfaces of an SPD.

38.3 An SPD provided with solid-state electronic circuit that operates and is relied upon for safe operation of the device during this test shall be tested as follows during the test:

- a) With the circuit functioning as intended;
- b) With the circuit open-circuited; and
- c) With the circuit short-circuited.

Exception: A solid-state electronic circuit that has been investigated and found to comply with the requirements of the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, is not required to be tested as described in (a) – (c).

38.4 All exposed surfaces and the receptacle grounding contact, if provided, are to be tested for leakage current. The leakage currents from these surfaces, and a grounding contact, are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are to be considered exposed surfaces unless guarded by an enclosure considered acceptable for protection against electric shock as defined in Accessibility of Live Parts, Section 13. Surfaces are to be considered simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time.

38.5 If a surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using metal foil having an area of 10 × 20 cm (4 × 8 inches) in contact with the surface. If the surface is less than 10 × 20 cm (4 × 8 inches), the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the SPD.

38.6 The measurement circuit for leakage current is to be as shown in Figure 38.2 for three-phase SPDs. The measurement instrument is defined in (a) – (d) of this paragraph. The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

- a) The meter is to have an input impedance of 1500Ω resistive shunted by a capacitance of 0.15 μF.
- b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of the voltage across the resistor or current through the resistor.
- c) Over a frequency range of 0 – 100 kHz, the measurement circuitry is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500Ω resistor shunted by a 0.15 μF capacitor to 1500Ω. At an indication of 0.5 mA and 5 mA, the measurement is to have an error of not more than 5 percent.
- d) Unless the meter is used to measure leakage from one part of an SPD to another, the meter is to be connected between accessible parts and the grounded supply conductor.

38.7 A sample of the SPD is to be tested for leakage current starting with the as-received condition – as received being without prior energization except as may occur as part of the production-line testing – but with its grounding conductor circuit open at the test receptacle. An SPD intended for outdoor use shall additionally be subjected to the leakage current test following a 48 hour humidity conditioning of air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F). Immediately following the humidity conditioning, the sample is to be removed from the humidity chamber and tested as noted below. The supply voltage is to be adjusted to:

- a) 120 V for an SPD rated between 110 and 120 V;
- b) 240 V for an SPD rated between 220 and 240 V; and
- c) The rated voltage marked on the SPD for any other voltage.

The test sequence with reference to the appropriate measuring circuit is to be as follows:

d) For single-phase SPDs,

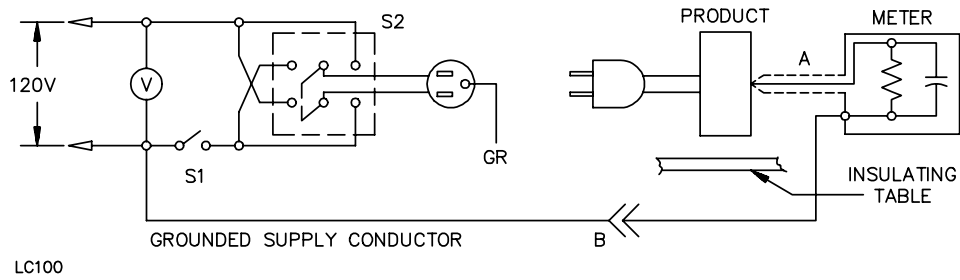
- 1) Using the appropriate circuit from [Figure 38.1](#) and, with switch S1 open, the SPD is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2.
- 2) Switch S1 is then to be closed energizing the SPD and, within a period of 5 seconds, the leakage current is to be measured using both positions of switch S2.
- 3) The leakage current is to be monitored until the leakage current stabilizes or decreases. Both positions of switch S2 are to be used in determining this measurement.

e) For three-phase SPD, the measurements are to be made when the leakage current has stabilized using [Figure 38.2](#), with each of the switches S_A, S_B and S_C open in turn and the other two switches closed. The SPD enclosure or other dead metal parts intended to be grounded are not to be connected to ground, except through the measuring circuit during the test.

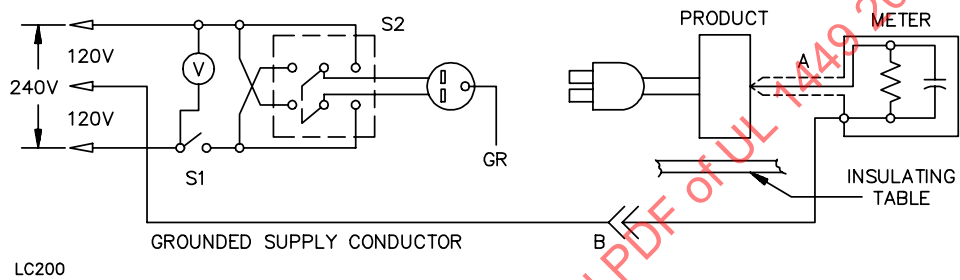
Exception: For products known to be sensitive to instantaneous changes in polarity, the leakage current test shall be repeated in the reverse polarity condition.

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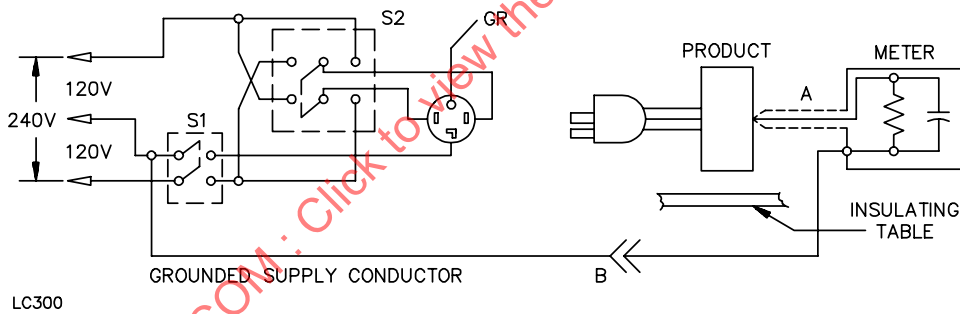
Figure 38.1
Leakage-Current Measurement Circuit



Product intended for connection to a 120-V power supply.



2-wire product intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.

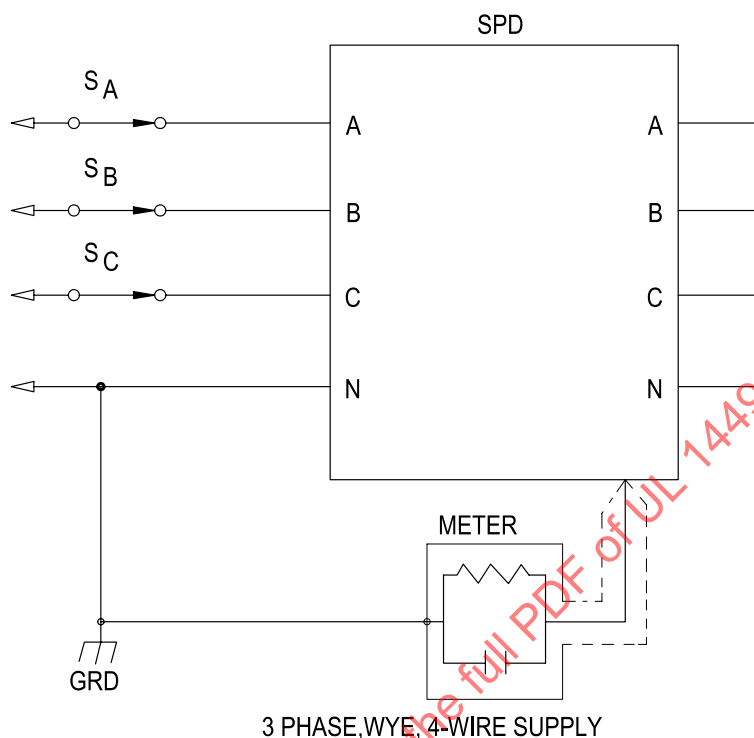


3-wire product intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.

A – Probe with shielded lead.

B – Separated and used as clip when measuring currents from one part of product to another.

Figure 38.2
Three-Phase Leakage-Current Measurement Circuit



SB1791c

38.8 A representative device of the SPD is to be tested for leakage current starting with the as-received condition – as received being without prior energization except as may occur as part of the production-line testing – but with its grounding conductor circuit open at the test receptacle. A two-port SPD incorporating heat dissipating circuit components electrically in series with the load shall also be operated at rated load until temperatures stabilize, and then be subjected to the leakage current test while still in a well heated condition.

38.9 The test representative device is to be installed in a manner so that all parallel ground paths are eliminated.

39 Dielectric Voltage-Withstand Test

39.1 Primary circuits

39.1.1 An SPD shall withstand a 60 Hz sinusoidal potential of 1000 V plus twice maximum rated supply voltage without breakdown for 1 minute between the following:

- a) Uninsulated live metal parts and the enclosure. A nonconductive enclosure is to be wrapped in conductive foil. For discrete components, such as MOVs, the component may be tested with the nonconductive enclosure or coating embedded in No. 7-1/2 lead or steel shot or smaller that is to serve as the outer electrode.
- b) Terminals of opposite polarity.
- c) Uninsulated live metal parts and accessible dead metal parts.

- d) Uninsulated live metal parts and grounding contacts of grounding type receptacles.
- e) Primary and isolated secondary circuits.

39.1.2 Across-the-line connected components (that is, varistors, diodes, capacitors, and the like) that would interfere with the test are to be disconnected or removed during this test.

39.1.3 Capacitors rated more than 250 V connected across the line or line to ground, shall withstand a DC dielectric potential of 1414 V plus 2.828 times maximum rated supply voltage without breakdown for 1 minute between the terminals of the capacitor and between terminals and foil wrapped around the case of the capacitor. For capacitors rated 250 V or less, the DC test potential is to be 1414 V.

Exception: A capacitor that complies with the requirements the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, is not required to be subjected to the test potential specified in [39.1.3](#).

39.1.4 The test potentials mentioned in [39.1.1](#) and [39.1.3](#) are to be obtained from any convenient source of sufficient capacity – at least 500 VA, except that a lower capacity source may be employed if the meter is connected in the output circuit – to maintain the potential except in the case of breakdown. The voltage is to be gradually increased until the required test level is reached and is to be held at that value for one minute. The increase in the applied potential is to be at a uniform rate as rapid as is consistent with its value being correctly indicated by a voltmeter.

39.2 Isolated secondary circuits

39.2.1 The test potential indicated in [Table 39.1](#) is to be applied between:

- a) Secondary circuits and grounded metal – with grounded secondary windings of transformers disconnected; and
- b) Between secondary circuit parts of opposite polarity.

A 60-Hz essentially sinusoidal source is to be used for testing alternating-current circuits. A direct-current source may be used for testing a direct-current circuit but, if possible, the transformer in the appliance should be employed to supply the alternating current to the rectifier (or substitute high voltage rectifier, if necessary) for the opposite polarity test on direct-current circuits.

Exception: A secondary circuit derived from a Class 2 power source is not required to be subjected to this test.

Table 39.1
Magnitude of Test Potential

Maximum voltage in circuit	Test voltage
0 – 1000 volts	3V (500 minimum)
Over 1000 volts	1.25V + 1750

39.2.2 All selector or other operating switches are to be adjusted to the various operating positions which ensure the connection of these parts in the circuit under test. Bleeder resistors, electrolytic capacitors, transistors, and other power consuming devices are to be opened at the common return side of the circuit.

40 Temperature Test

40.1 General – This test is conducted on all two-port SPDs.

Exception: This test need not be conducted if the manufacturer elects to have temperatures measured during the test conducted in Section 44, Operational Voltage Test. In either case, the measured temperatures shall not exceed the maximum acceptable temperatures as shown in Table 40.1.

40.2 One representative device of the SPD shall be tested under conditions of maximum rated voltage, current load and frequency. It shall not attain a temperature at any point high enough to affect adversely any materials employed or exhibit higher temperatures at specific points than indicated in Table 40.1.

Table 40.1
Maximum Acceptable Temperatures

Material and components		°C	°F
1.	Varnished-cloth insulation	85	185
2.	Fuses other than Class CC, G, J, T	90 ^g	194 ^g
3.	Fuses Class C, CC, G, J, T		
	Tube	125	257
	Ferrule or blade	110	230
4.	Fiber employed as electrical insulation	90	194
5.	Wood and other similar insulation	90	194
6.	Any point on or within a terminal box	90 ^a	194 ^a
7.	Any external surface not intended to be contacted in normal use	90	194
8.	Enclosure surfaces at risk of being contacted in normal use including operating devices and handles		
	Metallic	60	140
	Nonmetallic	85	185
9.	Class 105 insulation system on coils or windings:		
	Thermocouple method	90 ^b	194 ^b
	Resistance method	110 ^b	230 ^b
10.	Class 130 insulation system on coils or windings:		
	Thermocouple method	110 ^b	230 ^b
	Resistance method	130 ^b	266 ^b
11.	Class 155 insulation system on coils or winding:		
	Thermocouple method	135	275
	Resistance method	145	293
12.	Class 180 insulation systems on coils or windings:		
	Thermocouple method	150	302
	Resistance method	160	320
13.	Phenolic composition employed as electrical insulation or as a part whose malfunction results in a fire or an electrical shock condition	f	f
14.	Insulated wires and cords	60 ^g	140 ^g
15.	On the surface of a capacitor casing:		
	Electrolytic	65 ^d	149 ^d
	Other types	85 ^e	194 ^e

Table 40.1 Continued on Next Page

Table 40.1 Continued

Material and components		°C	°F
16.	Epoxy	f	f
17.	Metal Oxide Varistor Casing	85 ^h	194 ^h
18.	Receptacle outlet and male plug blade contacts	55	131
19.	Printed wiring board	i	i
<p>^a See 85.11.</p> <p>^b See 40.2.</p> <p>^c The limitations on phenolic composition and on wire insulations do not apply to compounds that have been investigated and found to have heat-resistant properties.</p> <p>^d A capacitor operating at a temperature higher than 65°C (149°F) is able to be investigated on the basis of its marked temperature rating or, if not marked with a temperature rating, is able to be investigated to determine whether it meets requirements for use at the higher temperature.</p> <p>^e A capacitor operating at a temperature higher than 85°C (194°F) is able to be investigated on the basis of its marked temperature limit.</p> <p>^f See the requirements in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.</p> <p>^g A fuse that has been investigated and found to meet requirements for use at a higher temperature is able to be used at that temperature.</p> <p>^h An MOV operating at a temperature higher than 85°C is able to be investigated to determine whether it meets requirements for use at the higher temperature.</p> <p>ⁱ A printed wiring board shall not exceed the temperature ratings for which the board has been evaluated. See 22.1.</p>			

40.3 Ordinarily, coil or winding temperatures are to be measured by thermocouples unless the coil is inaccessible for mounting these devices – for example, a coil enclosed in sealing compound – or unless the coil wrap includes thermal insulation or more than two layers, 0.8 mm (1/32 inch) of cotton, paper, rayon, or the like. At any point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by means of a thermocouple may be 15°C (27°C) higher than the maximum indicated in items 10 or 11 of [Table 40.1](#) if the temperature of the coil, as measured by the resistance method, is not higher than specified in [Table 40.1](#).

40.4 When the change-in-resistance method is used, determination of the temperature rise of a winding is to be calculated by the following formula:

$$\Delta t = \frac{R_2}{R_1}(K + t_1) - (K + t_2)$$

in which:

Δt is the temperature rise in °C;

R_2 is the resistance of the coil in ohms at the end of test;

R_1 is the resistance of the coil in ohms at the beginning of the test;

t_1 is the ambient temperature in °C at the beginning of the test;

t_2 is the ambient temperature in °C at the end of the test; and

K is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined.

40.5 When necessary, the value of R at shutdown is able to be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after shutdown. A curve of the resistance values and the time is to be plotted and extrapolated to give the value of R at shutdown.

40.6 Measurements are to be made until thermal equilibrium is attained. Thermal equilibrium is to be considered to exist if three successive readings indicated no change when taken at the conclusion of each of three consecutive equal intervals of time, the duration of each interval being whichever of the following is longer:

- a) 5 minutes; or
- b) 10 percent of the total test time elapsed previous to the start of the first interval.

40.7 All values in [Table 40.1](#) are based on an assumed ambient room temperature not higher than 25°C (77°F). A test may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F), and the observed temperature corrected for a room temperature of 25°C (77°F).

40.8 Equipment intended specifically for use where the prevailing ambient temperature is consistently 40°C (104°F) or more is to be tested at such higher ambient temperature and shall not exceed the maximum acceptable temperatures in [Table 40.1](#), see [85.10](#).

40.9 If acceptable to all concerned, the equipment described in [40.7](#) may be tested within the range of 10 – 40°C (50 – 104°F) and corrected for a room ambient temperature the equipment is intended to be used. For example, equipment ambient is 50°C (122°F) and is tested in a 25°C (77°F) ambient. To determine the maximum acceptable temperatures on components and materials in the equipment, the values in [Table 40.1](#) are to be reduced by 25°C (77°F).

40.10 Thermocouples consisting of 30 AWG (0.05 mm²) iron and constantan wire and a potentiometer-type instrument are to be used whenever referee temperature measurements by thermocouples are necessary.

40.11 The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform to the requirements for Special Tolerances thermocouples as listed in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

40.12 A thermocouple junction and the adjacent thermocouple lead wire are to be securely held in good thermal contact with the surface of the material whose temperature is being measured. In most cases, acceptable thermal contact results from securely taping or cementing the thermocouple in place but, if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

40.13 To facilitate conducting the test on totally enclosed SPDs, thermocouples are to be attached to coils and capacitors prior to the addition of potting materials and are to be routed through holes made in the enclosure for this purpose.

40.14 Temperatures on receptacle outlet contacts are obtained using a standard mating attachment plug with rigidly attached solid blades. The thermocouples should be attached to the male plug blades at points as close as possible to the face of the receptacle and to the wiring terminals of the receptacle if they are accessible for the mounting of thermocouples.

40.15 Molded Case SPDs, subjected to the Temperature Test, shall additionally comply with the Temperature Test requirements Section 7.1.4 of UL 489.

40.16 Open-type SPDs, subjected to the Temperature Test, shall be mounted in an enclosure considered representative of the intended use. The maximum enclosure dimensions are to be determined by one of the following methods:

- a) 150 percent of the dimensions of the device – that is, length, width, and height;
- b) Dimensions needed to meet the wire-bending space specified in UL 508, Table 6.8;
- c) The intended enclosure, such as a standard outlet box; or
- d) The intended enclosure, which may be larger than indicated in [40.16](#) (a) – (c) provided the size is marked on the device, detailed in the installation instructions or provided on a separate stuffer sheet. (See [85.36](#)).

40.17 Direct Plug-In SPDs are to be connected to the test circuit by means of a 300 mm (12 inch) or greater length of Type TW, Type RH, or equivalent building wire. The lead-in wires are to be soldered to the male plug blades. The wire size and type are to be determined using the appropriate value for the device's current rating from Table 310-16 of the National Electrical Code, ANSI/NFPA 70, as follows:

- a) Ampacities for copper conductors temperature rated at 60°C (140°F) for a receptacle rated 100A or less for use on copper conductors only.
- b) Ampacities for copper conductors temperature rated at 75°C (167°F) for a receptacle rated greater than 100 A for use on copper conductors only.

41 Surge Testing

41.1 General

41.1.1 These tests are conducted to verify that SPDs are able to operate in surge environments and comply with the criteria outlined in [41.8.3](#). Different tests are conducted for the different SPD Types:

- a) Type 1, Type 1 Component Assemblies, Type 2, Type 2 Component Assemblies and Type 3 intended for outdoor use, are subjected to a Nominal Discharge Current Test (I_n) as described in [41.7](#). ([Figure 37.1](#), Flowchart 1).
 - 1) The sample undergoing the Nominal Discharge Current Test is first subjected to a 6 kV/3 kA Combination Wave Surge Test to establish the benchmark measured limiting voltage. From this benchmark measured limiting voltage the voltage protection rating (VPR) is also determined in accordance with [84.2](#).
 - 2) The VPR is based on the measured limiting voltages recorded after the first set of 6 kV/3 kA Combination Wave Surge Tests. The measured limiting voltages with the average no signal noise as specified in [41.2.6](#) subtracted are averaged per mode. The per mode average is the VPR and is verified after the second set of 6 kV/3 kA Combination Wave Surge Tests.
- b) Type 3 intended for indoor use and Type 3 Component Assemblies are subjected to the Operating Duty Cycle Test.
 - 1) The sample undergoing the Operating Duty Cycle test is first subjected to a 6 kV/3 kA Combination Wave Surge Test to establish a voltage protection rating (VPR).
 - 2) The measured limiting voltage with the average no signal noise as specified in [41.2.6](#) subtracted is recorded for the 6 kV/3 kA Combination Wave Surge Tests before and after the Operating Duty Cycle Test and the Voltage Protection Rating is determined and verified as described above.

41.1.2 In all cases, the Voltage Protection Rating (VPR) shall not exceed the manufacturer's marked voltage protection rating selected from [Table 84.1](#). In addition, no individual measured limiting voltage may exceed the voltage protection rating I by 10 percent.

41.1.3 All SPD types are then subjected to an Operational Voltage Test, Section [44](#), a Grounding Continuity Test, Section [49](#), and a Leakage Current Test, Section [38](#) (for Type 3 SPDs).

41.1.4 [41.2](#) – [41.5](#) provide detailed requirements for the Test Equipment and Test Procedures that shall be followed.

41.1.5 Three representative samples of the SPD are subjected to the tests identified in [41.6](#) – [41.9](#) and in accordance with the surge parameters shown in [Table 41.1](#).

Table 41.1
Surge Test Parameters

SPD type	Surge Test (using the calibrated short circuit current from a combination wave generator) ^a to establish VPR		Nominal discharge current (using the calibrated impressed current through the SPD) ^b or the Operating Duty Cycle (using the combination wave generator) ^a	
	Peak voltage (kV _p)	Peak current (kA _p)	Peak voltage (kV _p)	Peak current (kA _p)
Type 1, 2 SPDs and Type 1, 2 Component Assemblies	6	3	Voltage needed to obtain I_n Operating duty cycle ^{a,c}	b Operating duty cycle ^{a,c}
Type 3 SPD and Type 3 Component Assemblies	6	3	6	3
Type 4 Component Assemblies and Type 5 SPD – Surge tested in accordance with Sections 42 , 43 . ^a Combination 1.2/50 μ s, 8/20 μ s Voltage/Current surge waveform. For specifications and tolerances, refer to Annex A , "Surge Waveforms". ^b See 41.7 for details of the 8/20 Nominal Discharge Current levels ^c See 41.8 for details of the Operating Duty Cycle Test.				

41.1.6 An SPD provided with a solid-state electronic circuit that operates and is relied upon for safe operation of the device during the testing of Section [45](#), Current Testing, shall additionally be tested as follows during the test:

- a) With the circuit open-circuited; and
- b) With the circuit short-circuited.

Exception: A solid-state electronic circuit that has been investigated and found to comply with the requirements of the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, is not required to be tested as described in (a) and (b).

41.2 Test equipment

41.2.1 Surge generator

41.2.1.1 The surge generator(s) (including its means of connection to the EUT) used for testing shall be capable of delivering the surges specified in [Table A1.1](#) of Annex [A](#) to the EUT ac power interface at the specified phase angle of the ac voltage sine wave.

41.2.1.2 Impedance and inductance should be minimized between the generator output, and the connection to the SPD. Noise also should be minimized. If open wires are used, they should be kept straight and close together, and the length should be as short as possible. It shall be verified, using the methods specified in [41.5](#), that the characteristics of the surge appearing at the ac power interface to the EUT complies with [Table 41.1](#) and is within the tolerances permitted by [Table A1.1](#) of Annex [A](#).

41.2.1.3 Surges should be prevented from being fed back onto the ac power circuit during powered testing (which could result in loading of the surge generator and/or damage to other equipment in the facility). An acceptable backfilter should be connected between the ac power interface where the surges are being applied, and any equipment located upstream on the ac power circuit. The backfilter should effectively isolate the ac power system from the surges while allowing power follow and specified fault current to flow to the EUT. Any effect that the backfilter may have on the amplitude or waveforms of the surges specified in [Table 41.1](#) shall be limited to the tolerances permitted by [Table A1.1](#) of Annex [A](#).

41.2.1.4 The generator shall employ a series coupling/decoupling network as defined in Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits, ANSI/IEEE C62.45.

Exception: A generator employing a shunt coupling/decoupling network, as defined in ANSI/IEEE C62.45 may be employed when testing devices which permit follow current.

41.2.1.5 The generator shall have an ungrounded output. This is commonly referred to as a "floating" output.

Exception: For higher capacity generators it may be necessary to ground the output.

41.2.1.6 In order to facilitate the connection of the surge generator and the measuring equipment leads to the EUT, plug blades, receptacle contacts, or lead terminations, specially prepared receptacles, plugs, and terminal block wiring devices, respectively, may be used. The surge generator and measuring equipment leads can be connected to the terminals of these devices. When such devices are used, they shall be so designed (for example, conductor "length", spacings, and the like) as to have no observable or measurable effect on the applied surge, as determined by including the devices when performing any calibration measurements on the test setup.

41.2.2 Source of supply (used to energize sample)

41.2.2.1 The surges specified in [Table 41.1](#) shall be superimposed on the ac power line with the EUT energized (powered testing).

41.2.2.2 An SPD that does not permit follow current, such as a metal-oxide varistor or a voltage limiting device in series with a voltage switching device, shall be tested on an ac or dc power source having sufficient current source capability that during the flow of current the crest value of the power frequency voltage or the dc voltage, measured at the SPD terminals, does not fall below the crest or dc rated voltage of the SPD by more than 10 percent.

Exception No. 1: The available short-circuit current (SCC) may be determined by measuring the open circuit voltage (V_{oc}) under no load conditions and by measuring the closed circuit voltage (V_{cc}) and current (I) with the circuit loaded with an approximate 20A resistive load. The short circuit current is determined using the following equation:

$$SCC = \frac{(V_{oc} \times I)}{(V_{oc} - V_{cc})}$$

For ac power sources, the power factor (pf) is determined by measuring the power, in watts, dissipated by the resistive load (P_{load}) and using the following equation:

$$pf = \frac{P_{load}}{(V_{cc} \times I)}$$

Note: All voltage, amperage and wattage measurements are made using true rms voltage, ampere and watt meters respectively.

Exception No. 2: For I_n testing as specified in [41.7](#), the test sample shall be connected to a voltage source. The impedance of the power source shall be such that during the flow of follow current the crest value of the power frequency voltage or the dc voltage, measured at the SPD terminals, does not fall below the crest value of its MCOV by more than 10 percent.

Exception No. 3: The available short circuit current is measured to be 100A or greater.

41.2.2.3 An SPD that permits follow current, such as a gas tube, shall be tested on an ac power line with an available short-circuit fault current as specified in [Table 12.1](#), with a power factor as specified in [Table 53.1](#), determined in accordance with Instrumentation and Calibration of High-Capacity Circuits, Section 53. When testing of the Neutral-Ground mode is required by [41.4.1](#), the Nominal Discharge Current test in [41.7](#) shall be conducted at the rated L-G voltage or N-G MCOV, whichever is greater, or the Operating Duty Cycle in [41.8](#) shall be conducted at the Line-Ground voltage.

Exception: The Neutral-Ground mode only of a Type 1 or 2 SPD is able to be tested using a source of supply as indicated in [41.2.2.2](#) when the component SPD that permits follow current is not in series with the load.

41.2.3 Oscilloscope

41.2.3.1 The peak voltage shall be determined with the use of an acceptable storage-type oscilloscope, with a minimum single shot bandwidth or effective bandwidth (in cases where high or enhanced resolution is used) of 20 MHz and, if digital, be capable of displaying the entire response of the SPD to the surge. Measurements shall be made using the automatic peak measurement function of the oscilloscope. The time base (seconds per division) of the oscilloscope shall be set to 10 microseconds per division or less ($\leq 10 \mu\text{s}/\text{div}$). A minimum effective sampling rate* of 5,000,000 samples per second (5 MS/s) shall be used. At 10 $\mu\text{s}/\text{div}$, this results in displaying a minimum of 500 samples (data points) per division or 50 samples per microsecond, for example. Additionally, the scope vertical channels shall have input impedance of 1 M Ω (with an optional 50 Ω input) and the capability to conduct differential measurements.

*Note: The effective sampling rate accounts for the minimum number of data points displayed during measurement. This may vary from the actual sampling rate of the oscilloscope due to the use of "high resolution" or "enhanced resolution" settings (averaging or filtering) as a built in function of the oscilloscope.

41.2.3.2 All measurements are to be made with the oscilloscope in differential mode (Example: if channel 1 is connected to the line conductor and channel 2 is connected to the neutral conductor, channel 1 will be in normal mode and channel 2 will be inverted. Differential mode adds these channels together resulting in the combination of both lines).

41.2.3.3 The vertical channels of the oscilloscope are to be set in dc coupling mode.

41.2.3.4 Oscilloscopes that are equipped with noise filtering capabilities (commonly referred to as "high resolution" or "enhanced resolution") may be set to produce effective sampling rates and bandwidths (see [41.2.3.1](#)) to aid in the mitigation of erroneous noise on the displayed waveforms.

41.2.4 High voltage probes

41.2.4.1 To determine Voltage Protection Ratings, a differential connection of two probes that are determined to be equivalent to two Tektronix, model P6015A high voltage probes with 10 foot cables shall be used. Equivalency is determined by:

- a) Ensuring the probes have a peak pulse input voltage rating of 20 kV at 10 MHz, an input impedance of 100M Ω and an input capacitance of 3 pF with 1000:1 attenuation, and by
- b) Conducting comparison testing with the Tektronix, model P6015A probes, for the specific test set-up (generator, fixturing and the like) and EUT type (SPD employing a MOV, SPD employing a MOV with a capacitor, SPD employing a filter and the like).

Exception: A differential high voltage probe other than specified above may be used for all other surge testing including VPR testing when used to check for degradation provided that they are used within the probe manufacturer's declared specifications.

41.2.4.2 Each high voltage probe is to be compensated, to the oscilloscope channel it is intended to be installed in, in accordance with the high voltage probe manufacturer's specifications.

41.2.4.3 The ground leads of the probes may be removed or connected together but are not to be connected to the EUT nor to any other point of the test setup.

41.2.4.4 The probe cables that connect the oscilloscope to the SPD are to be routed close together or twisted to minimize loop area.

41.2.4.5 The probes are to be connected to the EUT, positioned as close together as possible and perpendicular to the current flow.

41.2.4.6 No modification is to be made to the high voltage probes, nor are leads to be used to connect the probes to the EUT.

Exception: Alligator clips may be soldered or welded to the probe tip to reduce noise.

41.2.4.7 The procedure described in [41.2.6](#) shall be used to measure the level of erroneous (no signal) noise in the system setup.

41.2.4.8 For additional guidance reference should be made to the IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits, ANSI/IEEE C62.45.

41.2.5 Current monitor

41.2.5.1 The short-circuit current shall be measured using a current monitor suitable for the maximum peak current and current-time characteristics to be measured.

41.2.5.2 The useable rise time of the current monitor shall not exceed 800 ns.

41.2.5.3 The current monitor is to be rated for use with either a 1M Ω , 50 Ω or 75 Ω termination.

41.2.5.4 The current monitor with or without an attenuator shall have a maximum ± 1 percent tolerance.

41.2.6 Determination of no signal noise during determination of voltage protection rating

41.2.6.1 The noise associated with each surge test setup shall be measured and recorded. The noise shall be subtracted from the actual measurement when determining the resultant amplitude associated with a test.

41.2.6.2 Connect the SPD to the surge generator in accordance with [41.5](#) and [41.6](#). Connect the voltage probes in accordance with [41.2.4](#).

41.2.6.3 Set the oscilloscope in accordance with [41.2.3](#) using the appropriate voltage scale settings (volts/division) for the expected result. If the voltage scale settings are modified during the test, repeat this procedure using the new voltage scale setting.

41.2.6.4 Without applying a surge, trigger the oscilloscope and record the voltage (math) maximum. This is the no signal noise. Repeat five times recording the amplitude each time.

41.2.6.5 Average the five no signal noise measurements to compute the average no signal noise for the determination of the voltage protection rating.

41.2.6.6 This value is to be derived for and subtracted from the measured limiting voltage during the determination of the voltage protection rating (see [41.6](#)).

41.2.7 Determination of no signal noise for current

41.2.7.1 The noise associated with each surge test setup shall be measured and recorded. The noise shall be subtracted from the actual measurement when determining the resultant amplitude associated with a test.

41.2.7.2 With the current monitor described in [41.2.5](#) in place, connect a suitable short circuit between the connection points at the output of the surge generator normally used to connect the SPD to the generator. An example of a suitable short circuit would be a 6 AWG wire of minimal length.

41.2.7.3 Set the oscilloscope in accordance with [41.2.3](#) using the appropriate voltage scale settings (volts/division) for the expected result. If the voltage scale settings are modified during the test, repeat this procedure using the new voltage scale setting.

41.2.7.4 Without applying a surge, trigger the oscilloscope and record the voltage (math) maximum. This is the no signal noise. Repeat five times recording the amplitude each time.

41.2.7.5 Average the five no signal noise measurements to compute the average no signal noise for current.

41.2.7.6 This value is to be derived for and subtracted from the current measured during the calibration of the surge generator for the determination of the voltage protection rating and the nominal discharge current test.

41.3 Surge generator calibration

41.3.1 General – Surge waveform calibration

41.3.1.1 Measurements shall be made on the amplitude, rise and decay time of the waveform. The following steps shall be taken in order to ensure proper calibration of the combination impulse surge waveforms specified in [Table 41.1](#) and is within the tolerances permitted by [Table A1.1](#) of Annex A.

Oscillograms of the waveform shall be obtained. The line voltage is not to be applied during waveform calibration.

41.3.1.2 Oscilloscopes that are equipped with noise filtering capabilities (commonly referred to as "high resolution" or "enhanced resolution") may be set to produce effective sampling rates and bandwidths (see [41.2.3](#), [41.2.6](#), and [41.2.7](#)) to aid in the mitigation of erroneous noise on the displayed waveforms to ensure accuracy when determining the calibration characteristics. This clause applies to all sub-clauses of [41.3](#).

41.3.2 Short circuit current (SCC)

41.3.2.1 Amplitude (Peak, I_p) – To ensure consistent and accurate results, the short circuit current amplitude is to be calibrated to the value specified with a tolerance of +10 percent only. This is to be done by connecting the generator output to the supply connections of the EUT as specified in [41.6](#) using as short a length of wire, as possible, to make all connections. (Using leads that are too long effects the parameters of the SCC waveform, especially Amplitude and Rise Time). The generator leads are to be disconnected from the EUT, and the current monitor is to be inserted over the output lead. The output leads are to be shorted together using a reliable, very low impedance method (that is, terminal block, heavy-duty clamp, and the like).

41.3.2.2 With the current monitor connected to the oscilloscope, the vertical scale is to be set to read the specified amplitude and the horizontal scale set for 5 $\mu\text{s}/\text{div}$. The surge is then to be applied. If the amplitude of the SCC is within +10 percent of the specified value, the rise time measurement is to be performed.

41.3.2.3 If the short circuit current measurement is too low it may be necessary to either shorten the leads from the surge generator to the EUT and/or increase the voltage adjustment on the generator. It may be necessary to repeat the above steps several times to ensure the proper output short circuit current. Increasing the high voltage adjustment on the generator may increase the open circuit voltage measurement of the generator beyond the voltage waveform parameters. It is preferable to increase the generator current output by decreasing the length of the generator leads to the supply connections or leads of the EUT as specified in [41.6](#).

41.3.2.4 Decay Time (Duration) – Decay time is the time between the virtual origin of the waveform and the time where the amplitude has decreased to 50 percent of the peak value. The decay time of the waveform shall be $\geq 16 \mu\text{s}$ and $\leq 28 \mu\text{s}$.

41.3.2.5 Rise Time (Front Time) – The rise time is 1.25 times the time difference between the 10 percent and 90 percent amplitude points on the leading edge of the waveform. The time difference is to be measured between the 10 percent and 90 percent points of the peak amplitude and multiplied by 1.25. The rise time shall be $\geq 5.5 \mu\text{s}$ and $\leq 9 \mu\text{s}$.

41.3.2.6 For I_n testing specified in [41.7](#), use the method in [41.3.2.1](#) with the EUT in the circuit to measure and adjust, if necessary, the amplitude of I_n .

41.3.3 Open circuit voltage (OCV)

41.3.3.1 When making the OCV measurements, the generator peak open-circuit voltage is not to be readjusted since that will affect the short circuit current adjustment which has previously been made.

41.3.3.2 Amplitude (Peak, V_p) – The test leads are to be separated from the point with which they were shorted and remove the current transformer from the test circuit. The probes are to be connected from channels x and y of the oscilloscope to the high and low output leads of the generator, respectively, at the point where the leads are to be connected to the EUT. The scope is to be set in differential mode set for dc

coupling with channel x normal and channel y inverted. The scope is to be set for 1V/div (or greater if measuring over 6kV). The surge is then to be applied.

41.3.3.3 If the amplitude of the surge applied falls within +10, -5 percent of the value specified, the decay time measurements are to be performed (higher values may be used if agreeable to all concerned).

41.3.3.4 If the measured voltage is greater than the tolerances allowed, SCC calibration is to be performed again and the lead length is to be decreased from the generator to the EUT. The SCC is to be recalibrated by decreasing the peak open-circuit voltage. This may bring the output voltage into the proper tolerances.

41.3.3.5 If the measured voltage is below the tolerances allowed, it may be possible to bring the voltage into proper tolerances by first increasing the peak open-circuit voltage of the generator and then rechecking the amplitude of the OCV. The SCC is to be rechecked. It may be necessary to increase the lead length from the generator to the EUT. It is important to note that substantially increasing the lead length from the generator to the EUT may also effect the rise and decay time parameters of the waveform. (This method will only work if the voltage waveform is slightly below the tolerances specified for the waveform).

41.3.3.6 Decay Time (Duration) – Decay time is the time between virtual origin and the time where the voltage has decreased to 50 percent of the peak level. The decay time of the waveform shall be $\geq 40 \mu\text{s}$ and $\leq 60 \mu\text{s}$.

41.3.3.7 Rise Time (Front Time) – The rise time is 1.67 times the time between the 30 percent and 90 percent amplitude points on the leading edge of the waveform. The time difference is to be measured between the 30 percent and 90 percent points of the peak amplitude and multiplied by 1.67. The rise time must be $\geq 0.84 \mu\text{s}$ and $\leq 1.56 \mu\text{s}$.

41.4 Test procedure – Application and measurement points

41.4.1 The surges specified in [Table 41.1](#) are to be applied at the intended ac power interface of the SPD (that is, plug blades of a cord and plug or direct plug-in connected SPD; terminals or leads of a permanently wired SPD). The combinations of blades, terminals, leads, and the like to be tested shall be in accordance with [Table 41.2](#). Testing is to be performed on the SPD on all pairs of available conductors where SPD components are connected. The SPD shall be connected to a power source with a voltage configuration that is suitable to the application of the SPD. The SPD is powered as in its normal configuration where no ac voltage is imposed on the neutral-to-ground mode.

Exception: For 600V applications, testing may be performed at 480V.

41.4.2 The measured limiting voltage shall be determined using the data points captured in the initial 100 μs of the oscillogram recorded during the application of the specified surge. The electrical point of measurement shall be in accordance with [Table 41.2](#), and the physical point as described in [41.4.4](#) and [41.4.5](#).

Table 41.2
Points of Surge Application and Measurement of Limiting Voltage

SPD ac supply/surge test	Connection of surge generator and measurement point of limiting voltage ^a				
	G	N	L ₁	L ₂	L ₃
Single phase, 2-wire + ground:					
Test-1 ^b	–	L	H	–	–
Test-2	L	H	–	–	–
Test-3	L	–	H	–	–
Single phase, 3-wire + ground:					
Test-1	–	L	H	–	–
Test-2	–	L	–	H	–
Test-3	L	H	–	–	–
Test-4	L	–	H	–	–
Test-5	L	–	–	H	–
Test-6	–	–	L	H	–
Three phase, 4-wire + ground: ^c					
Test-1	–	L	H	–	–
Test-2	–	L	–	H	–
Test-3	–	L	–	–	H
Test-4	L	H	–	–	–
Test-5	L	–	H	–	–
Test-6	L	–	–	H	–
Test-7	L	–	–	–	H
Test-8	–	–	L	H	–
Test-9	–	–	–	L	H
Test-10	–	–	L	–	H

^a SPD conductors: G = ground, N = neutral (grounded circuit conductor), L₁ / L₂ / L₃ = line conductors (ungrounded circuit conductors).
Surge generator connections: L = low, H = high by coupling capacitor C.

^b Also applies to two-conductor SPD.

^c Also applies to three phase, 3-wire + ground (such as a Delta connection), conduct tests 5 – 10.

41.4.3 Not all combinations indicated in [Table 41.2](#) need be tested if one test can be considered representative of another. In deciding whether or not one test is representative of another, it is necessary to consider any differences in component surge protective devices, layout, wiring, and the like, that may affect the measured limiting voltage.

41.4.4 Application and Measurement Points – One-port SPD:

- For a permanently-connected device, the surge is to be applied at the point where the device leads extend 15 cm (6 inches) as measured from the point where the leads exit from the device enclosure (or conduit connector, if provided).
- For a cord-connected or direct plug-in device, the surge is to be applied to the attachment plug.
- For a meter-socket adapter SPD, the surge shall be applied to the input of the SPD.
- For a one-port SPD, the measurement shall be made at the ac power interface (that is, at the same leads, plug blades, and similar locations) where the surge was applied as described above.
- For Type 1, 2, 3 and 4 Component Assemblies and Type 5 SPDs the surge is to be applied at the leads or terminals provided with the component. No additional lead length is to be added.

Exception No. 1: Leads may be added to facilitate connection of the SPD, however, measurement should be made at or as close as possible to the leads/terminals provided with the component.

Exception No. 2: If terminals are provided within an enclosure, the application and measurement point shall be as indicated in (a) above.

Exception No. 3: If pigtail leads are provided, the application and measurement point shall be as indicated in (a) above. Pigtail leads greater than 15 cm (6 in.) are to be shortened to 15 cm (6 in.).

41.4.5 Application and Measurement Points – Two-port SPD:

- a) The surge should be applied at the point where the ac power is introduced to the device (e.g. input terminals).
- b) For cord-connected and direct plug-in devices, the surge will be applied to the attachment plug.
- c) For a panelboard device, the surge will be applied on the line side of the main circuit breaker.
- d) For a two-port SPD, the measurement shall be made at the output port (that is, receptacle contacts, leads, terminals, and similar locations, that are provided on the SPD for the purpose of being electrically connected to the equipment to be protected) electrically closest to the input port (supply connections of device).

41.5 Representative device – Sample preparation

41.5.1 The performance characteristics of components employed in the three previously untested specimens shall conform to the component manufacturer specifications, if those characteristics are critical to the surge response of the SPD.

41.5.2 SPDs intended for use with circuit breakers or fuses shall be tested with the manufacturer's specified circuit breaker or fuse protection in the circuit.

Exception: For Type 1, 2, 3 and 4 Component Assemblies and Type 5 SPDs the circuit breakers or fuses need not be in the circuit for VPR/MLV measurement, but shall be included for Nominal Discharge and Operating Duty Cycle Testing.

41.5.3 The length and arrangement of conductors (internal and external wiring), printed circuits, and the like, of the specimen tested shall be representative of production.

41.5.4 A permanently connected one-port SPD employing wiring leads or terminals for connection to the ac power system (a service panel mounted type SPD with leads or terminals) shall be tested with 15 cm (6 inch) leads, as measured from the point where the leads exit the enclosure. If provided with leads to be installed, leads are to be routed with the greatest amount of internal lead length allowed by the manufacturer's installation instructions. For leads provided integral to the representative device, leads shall be routed with either the greatest amount of internal lead length allowed in the manufacturing of the device, in accordance with the manufacturer's installation instructions, or both. Additionally, the leads shall be of the smallest wire diameter to be provided integrally, or included with the device, and/or as specified by the manufacturer's installation instructions.

Exception: Where leads are not provided, the sample shall be prepared so that 15 cm (6 inches) leads shall be installed in accordance with the manufacturers' specifications and the surge applied at the point where the leads extend 15 cm (6 inches) from the point where the leads exit from the device enclosure.

41.5.5 The length of the power supply cord of a cord connected SPD shall be representative of the minimum cord length provided by the manufacturer.

41.5.6 Test Setup and Apparatus (Nominal discharge current and Operating duty cycle test) – The representative devices shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative device is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

41.6 Determination of voltage protection rating (VPR)

41.6.1 General – A 6 kV/3kA Combination Wave Surge is used to determine the Voltage Protection Rating and to benchmark the sample prior to the Nominal Discharge Current (I_n) Test described in [41.7](#).

41.6.2 Each of the three representative devices shall be subjected to three (3) x 6 kV/ 3 kA impulse surges specified in [Table 41.1](#), with the open-circuit voltage and the output of the surge generator calibrated as specified in [41.3](#). The surge generator (including its means of connection to the SPD), ac power line, and measuring equipment shall be as described in [41.2](#) – [41.4](#).

41.6.3 The impulse surges shall be applied and the limiting voltage measured as specified in [41.4](#) with the representative devices connected to the ac power line. The surge shall be initiated at a phase angle of 90 ± 10 degrees.

41.6.4 A recording or print out shall be obtained of the resultant waveform. The voltage protection ratings are derived. The VPR shall be assigned for each mode of protection provided. This value is obtained by comparing the measured limiting voltage obtained in [41.6](#) to a higher value in [Table 84.1](#). The average of the measured limiting voltage as specified in [41.6](#) with the average no signal noise as specified in [41.2.6](#) subtracted shall not exceed the manufacturer's marked VPR rating from [Table 84.1](#). In addition, no individual measured limiting voltage with the average no signal noise as specified in [41.2.6](#) subtracted may exceed the marked VPR by more than 10 percent. The VPR is verified during the repeat VPR test conducted in [41.9](#).

41.7 Nominal discharge current – For Type 1 and Type 2 SPDs and Type 1, 2 component assemblies

41.7.1 The manufacturer shall specify (declare) the value of the Nominal Discharge Current (I_n) to which the sample will be tested. The value of the Nominal Discharge Current (I_n) selected by the manufacturer shall be: 10 kA or 20 kA for Type 1 SPDs and 3 kA, 5 kA, 10 kA or 20 kA for Type 2 SPDs. With the SPD in the circuit the surge generator voltage shall be adjusted to ensure that the value of I_n (selected by the manufacturer) is impressed through the SPD. The resultant waveshape is permitted to deviate from the initial short circuit calibration of the 8 x 20 μ s waveshape providing that the front time is a maximum of 9 μ s and the duration is a minimum of 16 μ s.

Exception: A generator that can be calibrated to produce an 8 x 20 μ s waveform with the EUT in the circuit is considered acceptable.

41.7.2 Type 1, Type 1 Component Assemblies, Type 2 SPDs and Type 2 Component Assemblies shall be subjected to the Nominal Discharge Current (I_n) Test as specified in [Table 41.1](#). The same three representative devices that were subjected to the 6 kV/3 kA combination wave in the Voltage Protection Rating Test, shall then be subjected to fifteen (15) x 8/20 short circuit current surges, per mode. The surges are to be applied at the application points specified in [41.4](#).

41.7.3 During the application of these surges the samples are unenergized. Surges shall be applied in three groups of five surges. Within 1 second after the application of each surge, the manufacturer's specified (declared) MCOV shall be applied for 60 seconds ± 5 seconds. A maximum of 1 minute ± 15

seconds between surges is permitted. After each group of 5 surges, the sample shall rest for 30 minutes ± 5 minutes. After the 15th surge, the MCOV shall be re-applied for at least 15 minutes.

Exception No. 1: After each group of 5 surges, the sample may rest for less than 30 minutes if agreeable to all concerned.

Exception No. 2: SPDs that permit follow current, such as gas tubes and air gap devices (see [41.2.2.3](#)), shall be tested with the unit energized by applying the surge initially at 0 degrees on the AC voltage waveform and then incrementing the angle by 30 degrees for each of the 15 surges.

41.7.4 All tests shall be performed on each mode of protection; however, if some modes of protection have identical circuitry, one single test can be performed on the mode of protection which represents the most vulnerable configuration, using new samples each time. If components of the same type and parameters are connected in parallel, they shall be tested as one current path. The manufacturer shall provide samples prepared according to the requirements in [41.5](#).

41.7.5 For multimode devices (e.g. 3 phase SPDs) in which the protective component circuitry is identical, the testing of each of the modes (e.g. three phases) can satisfy the three sample requirement.

41.7.6 Pass Criteria – During and following the Nominal Discharge Current Test, the following conditions shall not result:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (preexisting or created as a result of the test) in the product.
- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.
- c) Ignition of the enclosure.
- d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#).
- e) Supplementary protective devices, internal or external to the SPD, opening.

41.8 Operating duty cycle test – For Type 3 SPDs and Type 3 component assemblies

41.8.1 Type 3 SPDs and Type 3 Component Assemblies, shall be energized and subjected to the Operating Duty Cycle Test while connected to a rated power source. The same three representative devices that were subjected to the 6 kV/3 kA Combination Wave Surge, shall be subjected to fifteen (15) x 6 kV/3 kA combination wave surges, per mode, as specified in [Table 41.1](#), applied at the application points specified in [41.4](#). Eight (8) surges shall be positive polarity at a phase angle of 90 (+0, -15) degrees and 7 shall be negative polarity at a phase angle of 90 (+0, -15) degrees. The surges are to be conducted in succession with a maximum 60 second period between each surge.

Exception: Type 3 SPDs may be subjected to the I_n test of [41.7](#) as per Type 2 requirements. If tested as required for Type 2, at a minimum I_n level of 3 kA, the marking specified in [85.4](#) may be omitted.

41.8.2 These tests are carried out on three samples. An SPD with at least three identical terminals satisfies this sample requirement.

41.8.3 Pass Criteria – During and following the Nominal Discharge Current Test and the Duty Cycle Test, the following conditions shall not result:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.

- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.
- c) Ignition of the enclosure.
- d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#).
- e) Supplementary protective devices, internal or external to the SPD, opening.

41.9 Repeated voltage protection rating test

41.9.1 Following the testing in [41.6](#), [41.7](#), [41.8](#), the SPDs shall be allowed to cool to room temperature and then be subjected to the 6 kV/3 kA combination wave as described in [41.6](#). The resulting average measured limiting voltage per sample shall not deviate more than 10 percent from the original average value for the same sample measured in [41.6](#).

Exception: For Gap Type SPDs including gas tubes, a deviation of 20% is permitted.

42 Type 5 SPD Surge Testing

42.1 3 samples shall be subjected to the following sequence:

- a) For discrete varistors only, V_n as specified in [70](#).
- b) For discrete gas tubes only, breakdown voltage as specified in [74](#).
Exception: Where the gas pressure and composition is controlled, this test need not be conducted.
- c) Apply 15 surges at a selected nominal discharge current (I_n) as follows: (.01, .05, .1, .15, .25, .5, 1, 1.5, 2, 2.5, 3, 5, 10 or 20 kA).
- d) Apply MCOV between surges (as done for Type 1 and 2 SPDs in [41.7.3](#)).
- e) Measure MLV, see [41.6](#), during each surge and compute the average of the 45 values to obtain the MLV rating (rounding to the nearest 10 V).
- f) For discrete varistors only, the repeat V_n as specified in Section [70](#) shall be within 10% of the initial value.
- g) For discrete gas tubes only, if required by (b), the repeat breakdown voltage as specified in [74](#) shall be within 20% of the initial value.
- h) For all other SPDs, where V_n is not provided, such as SPDs with thermal protection, capacitors, etc., each MLV shall be within 10% of the average of the 15 MLVs for that sample.

Exception: For gas type SPDs where breakdown voltage is not provided or applicable, a deviation of 20 % is permitted.

- i) Operational Voltage Test in Section [44](#).

42.2 Type 5 SPDs with rated operating temperature above 85°C shall comply with [42.1](#) with the Aging Test in Section [71](#) conducted during the [42.1](#) sequence following the V_n @ 1mA DC test in [42.1\(a\)](#) or for gas discharge tubes the breakdown voltage test in [42.1\(b\)](#). Immediately following completion of the Aging Test, while the samples are still in a heated condition, the samples are to be subjected to the nominal discharge current in [42.1\(a\)](#).

43 Type 4 Component Assemblies Surge Testing

43.1 Surge testing as specified in Section [42](#) for Type 5 SPDs plus the limited current tests in [45.4](#) and the disconnect testing as appropriate.

43.2 The 10A for permanently connected SPD's, or 5A for cord connected SPD's, limited current test shall be performed on the samples tested in Section [42](#).

Exception No. 1: AC, DC and DC PV SPDs that have been evaluated to Section [47](#) are not required to be additionally subjected to the test sequence in [43.2](#).

Exception No. 2: AC SPDs that do not rely on a disconnect to comply with [45.4](#) are not required to be additionally subjected to the test sequence in [43.2](#).

Exception No. 3: For DC and PV SPDs that have not been evaluated to Section [47](#) and rely on modified samples per [SA8.3](#), [SA8.4\(a\)](#), [SA8.3](#) and [SA8.4\(a\)](#) to insure conduction of test current during the Limited Current Test, prior to conducting limited current tests in [45.4](#) as per [43.2](#), the modified samples are to be subjected to In testing with no voltage applied, per [SA10.2](#) and [SB10.1](#).

44 Operational Voltage Test

44.1 Following the repeated VPR Test (6 kV/3 kA Combination Wave Surge), the SPD shall be subjected to an overvoltage, on all protection modes, of 115 percent of the rated supply voltage (to simulate the upper tolerance of the supply voltage) for 30 minutes. The SPD must remain operational and shall meet the pass criteria as specified in [44.5](#). For SPDs intended for use on ungrounded systems, impedance grounded systems, or corner grounded delta systems, the line-to-ground modes shall be tested at 115 percent of the rated line-to-line voltage.

Exception: If the SPD was tested at 115 percent of the rated supply voltage (or greater) during the I_n test in [41.7](#), this test need not be performed.

44.2 Two-port SPDs employing heat dissipating components (for example, inductors) electrically in series with the load, shall be operated at rated load or testing may be conducted inside an oven maintained at the maximum temperature measured during the Temperature Test, Section [40](#). Following the overvoltage test, two-port SPDs shall be operated for 7 hours at rated voltage and load.

44.3 Test Setup and Apparatus – The representative devices shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative device is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

44.4 Following the overvoltage test, the same samples shall be subjected to and comply with the Grounding Continuity Test, Section [49](#). Cord Connected and Direct Plug-in Devices shall also comply with the Leakage Current Test requirements of Section [38](#).

44.5 Pass Criteria – During and following the overvoltage tests the following conditions shall not result:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.
- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.

c) Ignition of the enclosure.

d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section 13.

e) Supplementary protective devices, internal or external to the SPD, opening.

45 Current Testing

45.1 General

45.1.1 The Short Circuit Current Rating Test (45.2), the Intermediate Current Test (45.3), and Limited Current Abnormal Overvoltage Tests (45.4) shall be performed as identified in Figure 37.1, Flowcharts 2 – 4.

45.1.2 The voltages in Table 45.1 shall be applied during the Limited Current Abnormal Overvoltage Test. During the Short Circuit Current Rating Test and the intermediate Current Tests, the voltages in Table 45.1 may be used if Exception to 45.2.3 is not applied.

Table 45.1
Test Voltage Selection Table

Nominal voltage rating	Phase	Minimum test voltage ^{a,c}
0 – 109V	Single	Twice Rated Voltage
110 – 219V	Single	240
220 – 229V	Single	380
230 – 239V	Single	400
240 – 345V	Single	480
346 – 399V	Single	600
400 – 499V	Single	690
500 – 1000V	Single	Twice Rated Voltage Up to Max 1000V
110 – 120/220 – 240V	Split	240
120/208V	3-WYE	208
220/380V	3-WYE	380
230/400V	3-WYE	400
220 – 240/380 – 415V	3-WYE	415
240/415V	3-WYE	415
254 – 277/440 – 480V	3-WYE	480
346/600V	3-WYE	600
400/690V	3-WYE	690
120/240V	High leg delta	240
240/480V	High leg delta	480
0 – 1000	Delta	b

^a For device voltage ratings not specified in this table, the test voltage shall be the maximum phase voltage (if available) or twice the conductor pair voltage rating up to 1000Vmax.

^b SPDs rated for use on a Delta power distribution system shall be subjected to the Short circuit current rating and Intermediate current tests, with a minimum test voltage \geq the full phase (L-L) voltage. The Limited current abnormal overvoltage test is not required to be conducted on SPDs rated for use on a Delta power distribution system.

^c The test voltage may be increased beyond the minimum values when agreed upon by all concerned parties.

45.1.3 SPDs shall be subjected to the tests described in [45.2](#) (Short Circuit Current Rating Test), [45.3](#) (Intermediate Current Test) and [45.4](#) (Limited Current Abnormal Overvoltage Test) without resulting in any of the conditions described in [45.1.10](#).

Exception: The neutral to ground mode is only tested for 120 VAC Single Phase Type 3 SPDs.

45.1.4 Requirements [45.1.4](#) – [45.1.8](#) cover general test apparatus and sample preparation. The representative devices used for each of the tests described in [45.2](#) – [45.4](#) may be previously untested.

45.1.5 When agreed upon by all concerned parties, fewer samples than those specified in [45.2.1](#) – [45.4.2](#) shall be used for testing.

45.1.6 When agreed upon by those concerned, the same samples may be used for more than one mode.

45.1.7 The representative devices shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative device is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

Exception: For totally enclosed devices, having provisions for conduit connection(s), the cheese cloth shall be kept away from the conduit opening. This is accomplished by installing a length of conduit that directs venting away from the cheesecloth. Alternatively, when conduit is not installed, a 2 inch cheesecloth margin is to be maintained around the conduit opening.

45.1.8 Cord-connected, direct plug-in, permanently connected receptacle and other SPD types intended for connection to common outlet boxes (such as raceways, multiple outlet assembly types) shall be tested in accordance with [45.3](#) in both normal and reversed polarity.

45.1.9 An SPD provided with solid-state electronic circuit that operates and is relied upon for safe operation of the device during this test shall be tested as follows during the test:

- a) With the circuit functioning as intended;
- b) With the circuit open-circuited; and
- c) With the circuit short-circuited.

Exception: A solid-state electronic circuit that has been investigated and found to comply with the requirements of the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991 is not required to be tested as described in (a) – (c).

45.1.10 Pass criteria – During and following the tests described in [45.2.1](#) – [45.4.2](#), the following conditions shall not result:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.
- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.
- c) Ignition of the enclosure

- d) Creation of any openings in the enclosure that result in accessibility of live parts, when evaluated in accordance with the accessibility of live parts test in [67.2](#). For open-type SPDs only, this applies to parts intended to be installed through an opening in or as part of an enclosure.
- e) Loss of structural integrity to a degree that the equipment collapses or experiences such displacement of parts that there is a risk of short-circuiting or grounding of current-carrying parts.
- f) Opening (external to the SPD) of the smallest gauge wire specified in [45.2.2](#).

45.1.11 Following the tests described in [45.2](#), [45.3](#), and [45.4](#), the same representative devices are to be subjected to and comply with the tests below according to their Type:

- a) Type 3 SPDs, except receptacle SPDs, SPD Type 3CA and SPD Type 4 component assemblies intended for cord-connected or direct plug-in applications, shall be subjected to the Leakage Current Test requirements in Section [38](#). The Leakage Current Test shall be conducted within 5 minutes of the end of the Current Tests.
- b) All SPD Types, including all SPD Type Component Assemblies (except Type 5) shall be subjected to the Grounding Continuity Test requirements in Section [49](#) when a grounding and/or bonding path is present.
- c) Molded Case SPDs of the Pullout design shall be subjected to and comply with the Pullout Insertion and Withdrawal Test, Section [72](#), only on each of the samples subjected to the tests described in [45.2](#), [45.3](#), and [45.4](#).

45.1.12 Operation of the ac power line circuit breaker or fuse internal or external to the SPD, or operation of an acceptable overcurrent or overtemperature protective device provided as part of the SPD is considered acceptable.

45.1.13 When an SPD is marked for use with a series circuit breaker or fuse, in accordance with [85.13](#), the test circuit is to include the circuit breaker or fuse. Type 1 SPDs shall be tested without any external protection. For two-port SPDs the ampere rating of such a circuit breaker or fuse shall not be less than 125 percent of the SPD ampere rating. For one- port SPDs the ampere rating of the circuit breaker or fuse shall be based on the manufacturer's specifications.

45.1.14 Compliance is able to be determined by performing this test with either a test limiter or a fuse. A test limiter shall be evaluated to the Standard for Low-Voltage Fuses – Part 16: Test Limiters, UL 248-16. A fuse shall be sized in accordance with [45.2.4](#) and shall have an interrupting rating not less than the maximum available fault current of the circuit. A Class CC, CD, G, H, J, L, R, or T fuse evaluated to the UL 248 series of standards shall be chosen such that its peak let-through current and clearing I^2t and not less than the maximum value for the size and class of fuse that is intended to be used with the device under test.

45.1.15 When used for the test, a circuit breaker is to be sized in accordance with [45.1.13](#). The interrupting rating of the circuit breaker is to be at least the available fault current of the circuit to which it is to be connected.

Exception No. 1: A circuit breaker with a lower interrupting rating is able to be used when the combination is evaluated and subjected to the appropriate requirements of the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489.

Exception No. 2: Testing with a specific circuit breaker meets the intent of this requirement when the manufacturer and catalog number of the circuit breaker is marked on the device or specified in the installation instructions.

45.1.16 Two (split phase) or three conductor pairs (A-N, B-N, C-N) or (A-G, B-G, C-G) shall be permitted to be combined for the tests described in [45.2](#), Short circuit current rating test, or [45.3](#), Intermediate current test.

45.1.17 Molded Case SPDs shall be subjected to the tests described in [45.2](#) (Short Circuit Current Rating Test), [45.3](#) (Intermediate Current Test), and [45.4](#) (Limited Current Abnormal Overvoltage Test), and installed in a panelboard as described in the Standard for Panelboards, UL 67. Additional circuit breakers specified by the panelboard manufacturer are to be used to surround the Molded Case SPD under test as required by UL 67.

Exception: Testing may be conducted without installing the Molded Case SPD in a panelboard, provided the test is conducted with the Molded Case SPD wrapped with a double layer of cheesecloth and determining that none of the conditions detailed in [45.1.10](#) result.

45.1.18 Molded Case SPDs, intended for use in other manufacturer's panelboards, shall be subjected to the tests described in [45.2](#), (Short Circuit Current Rating Test), [45.3](#) (Intermediate Current Test), and [45.4](#) (Limited Current Abnormal Overvoltage Test), with the Molded Case SPD installed in a panelboard as described in the Standard for Panelboards, UL 67. Additional circuit breakers specified by the panelboard manufacturer, as well as those that may be specified by other manufacturers, are to be used to surround the Molded Case SPD under test as required by UL 67.

Exception: Testing may be conducted without installing the Molded Case SPD in a panelboard, provided the test is conducted with the Molded Case SPD wrapped with a double layer of cheesecloth and determining that none of the conditions detailed in [45.1.10](#) result.

45.2 Short circuit current rating test – For Type 1 and Type 2 SPDs and permanently connected Type 3 SPDs

45.2.1 One representative device of the SPD, for each conductor pair tested in accordance with VPR Test (6 kV/3 kA Combination Wave), Section [41](#), is to be subjected to the application of the test voltage as specified in [Table 45.1](#). The ac power source shall have an available short-circuit (fault) current (I_{sc}) as specified in [Table 12.2](#) with a minimum level as specified in [Table 12.1](#) and with the power factor as specified in [Table 53.1](#), determined in accordance with Instrumentation and Calibration of High-Capacity Circuits, Section [53](#).

Exception: The neutral to ground mode is only tested for 120 VAC Single Phase Type 3 SPDs.

45.2.2 The SPD shall be connected to the AC power source with the smallest gauge wire specified by the manufacturer in the installation instructions.

45.2.3 For each representative device, the overvoltage is to be applied for 7 hours, or until the SPD becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device).

Exception: For permanently connected (Type 1, Type 2 and Type 3 SPDs) devices that do not conduct current (beyond leakage current) when subjected to the test, any one of the following options, or any combination thereof, shall be implemented and the test described in [45.2.1](#) repeated:

- a) Short out any voltage switching components with solid wire that shall not open during this test;*
- b) Increase the test voltage above the values in [Table 45.1](#) until disconnection occurs; or*
- c) Use lower voltage rated nonlinear voltage limiting and/or voltage switching components. Test at the maximum voltage specified in [Table 45.1](#) until disconnection occurs.*

1) Voltage limiting components may be replaced with lower voltage rated components from the same manufacturer and product family with identical chemical composition.

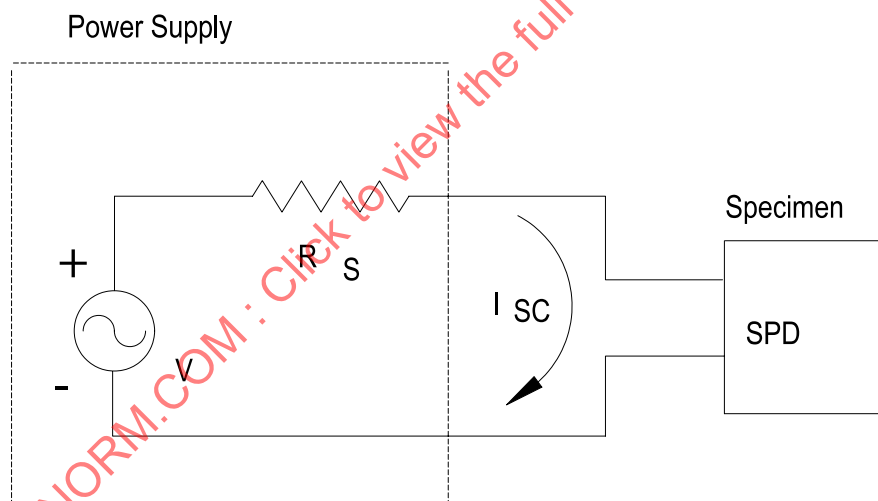
2) Voltage switching devices may be replaced with lower voltage rated (breakdown voltage is lower than the peak of the test voltage) components from the same manufacturer and product family with identical physical dimensions.

3) For combination type SPDs with voltage limiting components in series with voltage switching devices, voltage limiting components may be replaced with lower voltage rated components from the same manufacturer and product family with identical chemical composition and voltage switching devices may be replaced with lower voltage rated (breakdown voltage is lower than the peak of the test voltage) components from the same manufacturer and product family with identical physical dimensions to achieve conduction.

d) For voltage switching-type SPDs, a combination waveform surge shall be applied on the AC power source at a voltage level to turn on the SPD.

45.2.4 The Short Circuit Current Rating Test Circuit is shown in [Figure 45.1](#). The Short Circuit Current Ratings (Fault Current) Tables are shown in [Table 12.1](#) and [Table 12.2](#).

Figure 45.1
Short-Circuit Current Test Circuit



S3765c

V = Test voltage

I_{sc} = Maximum available fault current as specified in [Table 12.1](#) measured without the SPD in the circuit.

45.2.5 When the test is terminated by any of the following conditions, the test is to be conducted two more times using new components or an additional sample of the device for each test:

- a) Opening of a printed wiring board fuse trace; or
- b) Opening of an integral overcurrent or over temperature device including a thermal responsive device used above its short circuit current rating, or any circuit component not previously evaluated.

The test results after each test shall comply with [45.1.10](#).

45.2.6 Permanently connected receptacle and other type SPDs intended for mounting in boxes shall be tested in the smallest standard metal box, with a non-metallic faceplate, in accordance with the National Electrical Code, ANSI/NFPA 70.

45.3 Intermediate current test

45.3.1 One representative device of the SPD, for each conductor pair tested in accordance with the VPR Test (6 kV/3 kA combination wave) Section [41](#), is to be subjected to the application of the test voltage as specified in [Table 45.1](#). The ac power source shall have an available short-circuit (fault) current (I_{sc}) as specified in [Table 45.2](#) and [Table 45.3](#), determined in accordance with Instrumentation and Calibration of High-Capacity Circuits, Section [53](#).

Exception No. 1: For intermediate current level testing where the SPD conducts current for 7 hours AND does not become disconnected from the ac source, the test results are also representative of testing at the lower currents.

Exception No. 2: The neutral to ground mode is only tested for 120 VAC Single Phase Type 3 SPDs.

45.3.2 For each representative device, the overvoltage is to be applied for 7 hours, or until the SPD becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device).

Exception: For permanently connected devices that do not conduct current (beyond leakage current) nor exhibit any conditions described in [45.1.10](#) when subjected to the test, any one of the following options, or any combination thereof, shall be implemented and the test described in [45.3.1](#) repeated:

- a) Short out any voltage switching components with solid wire that shall not open during this test;*
- b) Increase the test voltage above the values in [45.1](#) until disconnection occurs; or*
- c) Use lower voltage rated nonlinear voltage limiting and/or voltage switching components. Test at the maximum voltage specified in [45.1](#) until disconnection occurs.*
 - 1) Voltage limiting components may be replaced with lower voltage rated components from the same manufacturer and product family with identical chemical composition.*
 - 2) Voltage switching devices may be replaced with lower voltage rated (breakdown voltage is lower than the peak of the test voltage) components from the same manufacturer and product family with identical physical dimensions.*
 - 3) For combination type SPDs with voltage limiting components in series with voltage switching devices, voltage limiting components may be replaced with lower voltage rated components from the same manufacturer and product family with identical chemical composition and voltage switching devices may be replaced with lower voltage rated (breakdown voltage is lower than the peak of the test voltage) components from the same manufacturer and product family with identical physical dimensions to achieve conduction.*
- d) For voltage switching-type SPDs, a combination waveform surge shall be applied on the AC power source at a voltage level to turn on the SPD.*

45.3.3 [Table 45.2](#) and [Table 45.3](#) below, provide the Available Fault test currents for the Intermediate Current tests for Type 1, Type 2 and Type 3 SPDs respectively. The test circuit used for these tests is the same as shown in [Figure 45.1](#), Short Circuit Current Rating Test Circuit.

Table 45.2
Intermediate Current Test – Available Fault Current from AC Source of Supply for Type 1 and Type 2 SPDs and Permanently Connected Type 3 SPDs

Test No.	Current (amps)	Power factor ^b
1	1000 ± 5%	0.7 – 1
2	500 ± 5%	0.7 – 1
3	100 ± 5%	0.8 – 1
4	Short circuit current rating ^a	See Table 53.1
^a Current from Table 12.2 , but not less than specified in Table 12.1 .		
^b Power factor may be less.		

Table 45.3
Intermediate Current Test – Available Fault Current from the AC Source of Supply for Type 3 SPDs^b

Test No.	Current (amps)	Power factor ^c
1	a	See Table 53.1
2	150 ± 5%	0.8 – 1
3	50 ± 5%	0.8 – 1
^a Current from Table 12.1 . For receptacle SPDs, 5kA shall be applied.		
^b Also applies to permanently connected receptacle SPDs.		
^c Power factor may be less.		

45.3.4 When the test is terminated by any of the following conditions, the test is to be conducted two more times using new components or an additional sample of the device for each test:

- a) Opening of a printed wiring board fuse trace; or
- b) Opening of an integral overcurrent or over temperature device, including a thermal responsive device, used above its short circuit current rating, or any circuit component not previously evaluated.

The test results after each test shall comply with [45.1.10](#).

45.3.5 Permanently connected receptacle and other type SPDs intended for mounting in boxes shall be tested in the smallest standard metal box, with a non-metallic faceplate, in accordance with the National Electrical Code, ANSI/NFPA 70.

45.4 Limited current abnormal overvoltage test

45.4.1 Four previously untested representative devices of the SPD for each combination of conductor pairs that were tested in accordance with Section [41](#), are to be connected to an ac power supply having an open circuit voltage equal to the test voltage specified in [Table 45.1](#). The power supply is to incorporate a series variable resistor that can be adjusted to obtain the short-circuit current (I_{sc}) specified below. See [Figure 45.2](#). In the case of a two-port SPD, no load is to be connected. The variable resistor is to be adjusted such that I_{sc} equals the values specified in [Table 45.4](#). The four representative devices are to be energized for 7 hours, or until current to, or temperatures within the SPD attain equilibrium, as specified in [40.6](#), and temperatures do not exceed the values specified in [Table 40.1](#), or until the SPD becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device). See [Figure 45.2](#).

Exception No. 1: When this test is performed at a current level specified above and results in neither: any condition specified in [45.1.10](#) nor operation of any overcurrent or thermal device, then the test results are also representative of testing of the device at lower current levels.

Exception No. 2: L-L modes in single phase or three-phase wye configuration devices are excluded from this test.

Exception No. 3: For Type 4 Component Assemblies the test must be energized for 7 hours for currents of .5 amps or less. The test may be stopped prior to 7 hours if all parties agree.

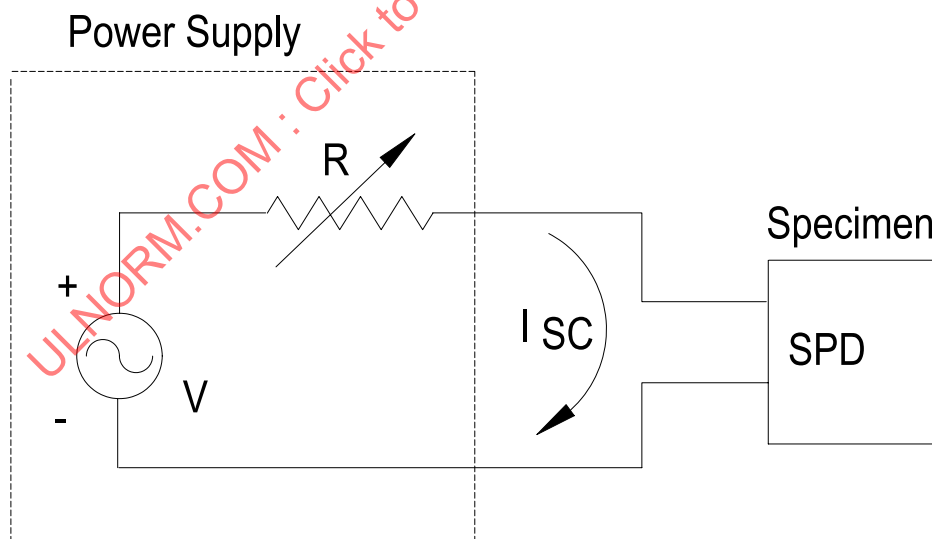
Exception No. 4: The neutral to ground mode is only tested for 120 VAC Single Phase Type 3 SPDs and SPD Type 4 Component Assemblies for cord-connected and/or direct plug-in applications.

Table 45.4
Limited Available Short Circuit Current (A)

Limited available short circuit current (amps)	
Permanently connected SPDs	Cord connected or direct plug-in SPDs
10 ± 10%	5 ± 10%
5 ± 10%	2.5 ± 10%
2.5 ± 10%	0.5 ± 15%
0.5 ± 15%	0.125 ± 20%

Figure 45.2

Limited Current Abnormal Overvoltage Test Circuit



S3766c

V = Test voltage as per [Table 45.1](#).

I_{sc} = 5A, 2.5A, 0.5A, 0.125A, (1st, 2nd, 3rd, and 4th representative device separately) measured without the SPD in the circuit.

45.4.2 Permanently-connected receptacle and other type SPD intended for mounting in boxes are to be mounted in the smallest standard non-metallic box, with a non-metallic faceplate in accordance with the National Electrical Code, ANSI/NFPA 70.

45.4.3 Type 4 Component Assemblies shall be tested based on the intended application, permanently connected or cord connected/direct plug-in, as detailed in [Table 45.4](#).

46 Thermal Responsive Device Testing

46.1 Temperature withstand

46.1.1 Three samples of the SPD shall be placed in an oven maintained at the maximum rated ambient temperature or 40°C, whichever is greater, or the maximum temperatures measured on the disconnect for two port SPDs for 24 hours. The thermal-link shall not operate during this test.

46.2 Repeat limited current test

46.2.1 The limited current tests shall be repeated at the levels where the thermal-link device opened to disconnect the power.

47 Thermal Responsive Device Testing Not In-Series with a Load

47.1 Each specimen group consists of one test sample and is to be conducted for each limited available short circuit current test level, as detailed in [Table 45.4](#), that the disconnect means is being relied to comply with [45.4](#).

Table 47.1
Thermal Disconnect Testing

UL Standard	Test	Specimens							
		A	B	C	D	E	H	I	J
60691	Temperature and Humidity Cycle Conditioning ^a	X	X	X					
60691	Dielectric Strength (if applicable) ^b	X	X	X					
60691	Insulation Resistance (if applicable) ^b	X	X	X					
1449	Surge Testing Sequence	X	X				X		
60691	Temperature Tests – Aging – Step 1, 21 days ^a					X	X	X	X
1449	Limited Current Abnormal Overvoltage Test ^{d,e}	X	X	X	X	X	X	X	X
60691	Dielectric Strength (if applicable) ^b	X	X	X	X	X	X	X	X
60691	Insulation Resistance (if applicable) ^b	X	X	X	X	X	X	X	X

^a The Temperature & Humidity Cycle Conditioning is conducted as detailed in UL 60691 except that 24 hour Temperature Conditioning is conducted at 60°C, the maximum rated Ambient Air Temperature or the maximum temperature measured on the disconnect means, during the Temperature Test of Section 40 of UL 1449, whichever is greater. Temperature Conditioning of component assemblies with a varistor shall be conducted at minimum 85°C unless the Metal Oxide Varistors are limited to an end-use temperature between 60°C and 84°C. Testing may be conducted in a test chamber with a ±2°C temperature tolerance.

^b If Acceptable Results are obtained between Disconnection Means (between open contacts) for both the Dielectric Strength and Insulation Resistance Tests, a discrete component "board level" Type 4 Component Assemblies does not need to comply with the Dielectric Strength and Insulation Resistance Testing requirements, between Live Part and the body of the discrete component (wrapped in foil) provided the conditions of use indicate that there was dielectric breakdown between live parts and the body of the

Table 47.1 Continued on Next Page

Table 47.1 Continued

UL Standard	Test	Specimens							
		A	B	C	D	E	H	I	J
discrete component (wrapped in foil).As such, proper spacings will need to be maintained between the discrete component, other live parts and dead-metal parts.									
° Step 1 of the Aging portion of the Temperature Tests is conducted as detailed in UL 60691 except that 100% of the specimens shall not have functioned and Aging is conducted at 60°C, the maximum rated Ambient Air Temperature or the maximum temperature measured on the disconnect means, during the Temperature Test of Section 40 of UL 1449, whichever is greater. Aging of component assemblies with a varistor shall be conducted at minimum 85°C unless the Metal Oxide Varistors are limited to an end-use temperature between 60°C and 84°C. Testing may be conducted in a test chamber with a ±2°C temperature tolerance.									
° To be conducted for each Limited available short circuit current test level, as detailed in Table 45.4 of UL 1449, that the disconnect means is being relied to comply 45.4.									
° The samples shall not be disturbed until they have been allowed to cool for 15 minutes maximum or cool down to within 10°C of ambient.									
Note 1 – Eight additional samples are required for the test program for each Limited available short circuit current test level, as detailed in Table 45.4 of UL 1449, that the disconnect means is being relied to comply with 45.4.									
Note 2 – If the identification of the thermal element material has not been previously determined by UL, then the material will need to be subjected to the Differential Scanning Calorimeter test for identification.									
Note 3 – Special Samples for testing may be required. Specifically, if the SPD employs status circuitry or other non-SPD discrete components, that would conduct during the Dielectric Strength and Insulation Resistance Tests, those components may be omitted for these tests.									
Note 4 – Unless Sequence H is being conducted as representative of the as-received Nominal Discharge Current Testing. Nominal Discharge Current Testing of sequences A, B and H can be conducted without applying MCOV.									

48 Thermal Responsive Device Testing In-Series with a Load

48.1 The test program in Table 48.1 shall be conducted, in the sequences detailed (based on Table 1 of UL 60691), when conducting an investigation of an integral thermal-link feature employed in an SPD. Each Specimen Group consists of 3 test samples.

Table 48.1
Test Program

UL Standard	Test		Specimen Groups									
			A	B	C	D	E	F	G	H	I	J
60691	Temperature and Humidity Cycle Conditioning ^a		X	X	X			X	X			
60691	Dielectric Strength (if applicable) ^c		X	X	X			X	X			
60691	Insulation Resistance (if applicable) ^c		X	X	X			X	X			
60691	Interrupting Current ^b							X	X			
1449	Surge Testing and Operational Voltage Sequence		X	X						X		
60691	Temperature Tests											
60691	Check of T _f ^d		X		X							
60691	Check of T _m ^f				X	X						
60691	Ageing			X			X			X	X	X
	Step 1 (optional)	21 days										
	Step 2 (mandatory)	21 days										
	Step 3 (mandatory)	14 days										
	Step 4 (mandatory)	7 days										

Table 48.1 Continued on Next Page

Table 48.1 Continued

UL Stand ard	Test		Specimen Groups									
			A	B	C	D	E	F	G	H	I	J
	Step 5 (mandatory)	7 days										
	Step 6 (mandatory)	24 hours										
60691	Dielectric Strength (if applicable) °		X	X	X	X	X	X	X	X	X	X
60691	Insulation Resistance (if applicable) °		X	X	X	X	X	X	X	X	X	X

^a The Temperature & Humidity Cycle Conditioning is conducted as detailed in UL 60691 except that 24 hour Temperature Conditioning is conducted at the highest temperature of any of the following:

(a) At 60°C (140°F), or

(b) The maximum rated Ambient Air Temperature, or

(c) The maximum temperature measured on the disconnect means, during the Temperature Test of Section 40 of UL 1449.

Temperature Conditioning of Type 1, 2, 3 or 4 component assemblies with a varistor shall be conducted at minimum 85°C (185°F) unless the varistors are limited to an end-use temperature between 60°C (140°F) and 84°C (183°F). Testing may be conducted in a test chamber with a ±2°C (±3.6°F) temperature tolerance.

^b If the conditions of voltage, power and current in the Interrupting Current Tests of UL 60691 are not covered by one test, a minimum of three samples should be used for each condition. Power Factor shall be 0.75 to 0.8 for SPDs for cord-connected and direct plug-in applications. Power Factor shall be 0.6 for SPDs for permanently connected applications. For SPDs not rated nor intended to carry current, other than surge current, the samples shall be subjected to the Limited Current Abnormal Overvoltage Test at the 10A level, in lieu of the Interrupting Current Test

^c If Acceptable Results are obtained between Disconnection Means (between open contacts) for both the Dielectric Strength and Insulation Resistance Tests, "board level" Type 4 component assemblies do not need to comply with the Dielectric Strength and Insulation Resistance Testing requirements, between Live Part and the body of the discrete component (wrapped in foil) provided conditions of use indicate that there was dielectric breakdown between live parts and the body of the discrete component (wrapped in foil). As such, proper spacings need to be maintained between the discrete component, other live parts and dead-metal parts.

^d For Type 3 SPDs connected in series with the load, the thermal-link may open at a temperature less than T_F-10°C, provided the opening temperature is greater than the maximum declared end-use temperature.

^e Step 1 of the Aging portion of the Temperature Tests is conducted as detailed in UL 60691 except that Aging is conducted at the maximum declared end-use temperature. If the measured end-use temperature exceeds the declared value, then the test shall be conducted at 10°C higher than this measured temperature. Testing may be conducted in a test chamber with a ±2°C temperature tolerance.

^f The Dielectric Strength and Insulation Resistance Tests following the Maximum Temperature Test shall be conducted with the samples at room temperature.

Note 1 – The Surge Testing Sequence is conducted instead of the Transient Overload Current Test (UL 60691) as the requirements in UL 1449 are more severe and demonstrate that the thermal-link feature is NOT damaged by the normal surges that an SPD is intended to be subjected to.

Note 2 – 30 Samples are required for the test program.

Note 3 – If the identification of the thermal element material has not been previously determined by UL, then the material will need to be subjected to the Differential Scanning Calorimeter test for identification.

Note 4 – Unless Sequence H is being conducted as representative of the as-received Nominal Discharge Current Testing. Nominal Discharge Current Testing of sequences A, B and H can be conducted without applying MCOV.

49 Grounding Continuity Test

49.1 A representative device of an SPD provided with means for grounding shall be tested to determine that the impedance between the grounding pin, terminal, or lead and the accessible dead metal parts of the SPD that are likely to become energized, is not more than 0.1Ω when measured in accordance with 49.2. The grounding pin of a receptacle, or other means for grounding on the load side, shall be included in this test.

49.2 Compliance with [49.1](#) is to be determined by measuring the voltage drop when a current of 25 A, derived from a 60 Hz source with a no-load voltage not exceeding 6 V, is passed between the point of connection of the grounding means and the metal part in question.

50 Fault Current Test

50.1 If required by Exception No. 2 of [11.18](#) and [11.19](#) or by [22.3](#), three representative devices of previously untested SPD are to be subjected to the Fault Current Test as described in [50.3](#) and [50.4](#). The SPD shall comply with the requirements in [50.4](#) and [50.5](#). Each representative device shall be tested once.

50.2 The representative devices shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative device is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

Exception: For totally enclosed devices, having provisions for conduit connection(s), the cheese cloth shall be kept away from the conduit opening. This is accomplished by installing a length of conduit that directs venting away from the cheesecloth. Alternatively, when conduit is not installed, a 2 inch cheesecloth margin is to be maintained around the conduit opening.

50.3 Each representative device shall be tested on a circuit with an available short circuit (fault current) current of minimum 1000A or greater, in accordance with [Table 12.1](#), with a power factor as specified in [Table 53.1](#), determined in accordance with Instrumentation and Calibration of High-Capacity Circuits, Section [53](#). The grounding or bonding circuit is to be connected in series with a circuit breaker or time delay non-current limiting fuse rated for the maximum ampacity of the circuit the SPD is intended to be installed in, suitable for branch circuit protection directly to the test circuit. The circuit breaker or fuse shall open when the test circuit is closed.

50.4 During and following the Fault Current Test, the following conditions shall not result:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.
- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.
- c) Ignition of the enclosure.
- d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#).
- e) There shall be no evidence of degradation or separation of the trace from the printed-wiring board.

50.5 Following the fault current test, the representative devices shall be subjected to and comply with the Grounding Continuity Test, Section [49](#).

51 Overcurrent Test

51.1 If required by Exception No. 2 of [11.18](#) and [11.19](#) or by [22.3](#) or [22.4](#), three previously untested representative devices of SPD are to be subjected to the Overcurrent Test as described in [51.3](#) – [51.7](#). The SPD shall comply with the requirements on [51.7](#) and [51.8](#). Each SPD shall be tested once.

51.2 The representative devices shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative device is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

Exception: For totally enclosed devices, having provisions for conduit connection(s), the cheese cloth shall be kept away from the conduit opening. This is accomplished by installing a length of conduit that directs venting away from the cheesecloth. Alternatively, when conduit is not installed, a 2 inch cheesecloth margin is to be maintained around the conduit opening.

51.3 All integral supplementary protection devices are to be shunted out of the circuit for this test.

51.4 The resistance of each circuit conductor path as specified in [51.1](#) shall be determined by measuring the voltage drop when a current of 25 A, derived from a 60 Hz source with a no-load voltage not exceeding 6 V is passed between the input port and output port connectors of conductor path.

51.5 The SPD shall be mounted so as to provide free air flow around all sides and the top. The ambient temperature shall be $25 \pm 5^{\circ}\text{C}$ ($77 \pm 9^{\circ}\text{F}$). The load current and time duration shall be as indicated in [51.6](#). Rated frequency shall be used. Any voltage not higher than the rated voltage may be used.

51.6 For an SPD with integral overcurrent protection, the overload current is to be 200 percent of the overcurrent device rating. For an SPD without integral overcurrent protection, the overload current is to be 200 percent of the current rating of the maximum size branch circuit to which the SPD is intended to be connected. The overload test current is to be applied for 2 minutes.

51.7 During and following the Overcurrent Test, the following conditions shall not result:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.
- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.
- c) Ignition of the enclosure.
- d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#).
- e) There shall be no evidence of degradation or separation of the trace from the printed-wiring board.

51.8 After the representative device has cooled to room temperature, the resistance of each circuit conductor path shall be determined as specified in [51.4](#). The resistance of each conductor path shall not increase by more than 10 percent. Additionally, the resistance of the grounding circuit shall not exceed 0.1Ω .

52 Withstand Test

52.1 A two-port SPD, intended for use in permanently-connected applications, shall be subjected to testing in accordance with [52.2](#) – [52.11](#). The SPD shall withstand the designated current levels until the overcurrent protective device(s) opens and:

- a) The fuse mentioned in [52.11](#) shall not open;

- b) There shall be no breakage to the extent that the integrity of the mounting of live parts is impaired; and
- c) There shall be no ignition of a double layer of cheesecloth, draped over the SPD so that the cloth is within 3.2 mm (1/8 inch) of any openings in the enclosure.

Exception: The above is not required for a permanently wired receptacle type SPD intended for use on branch circuits.

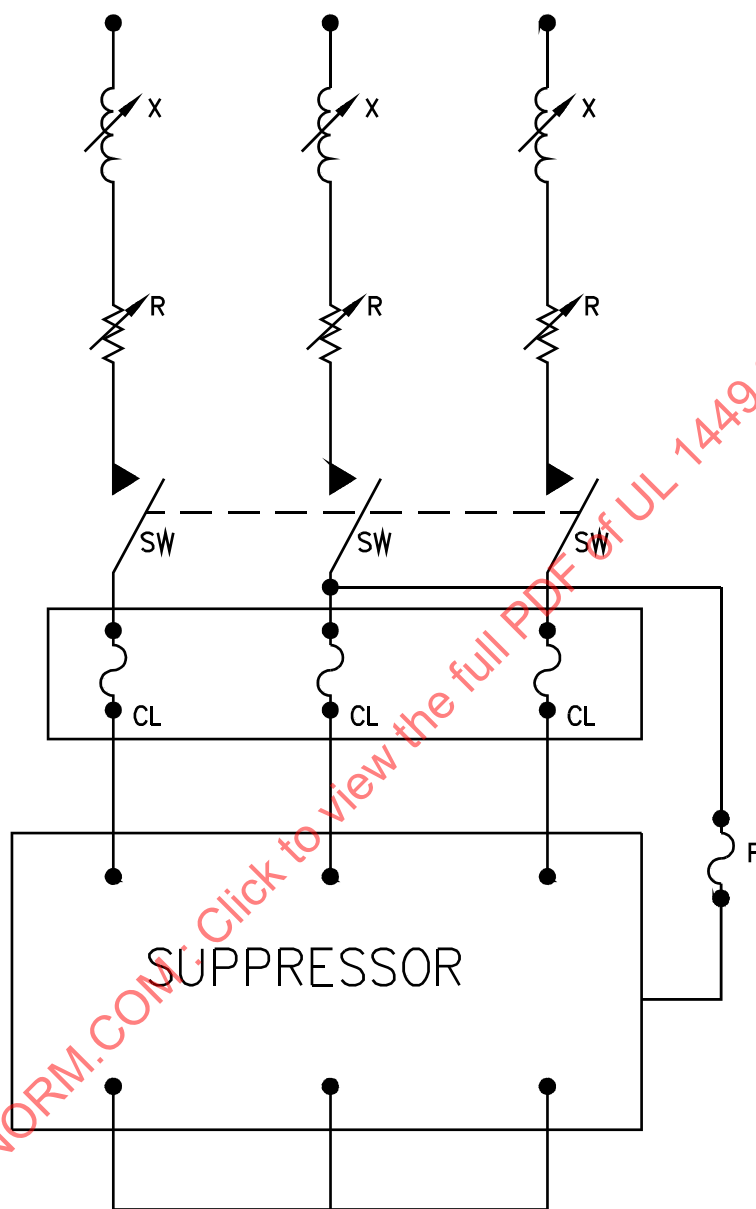
52.2 The overcurrent protective device(s) specified in [52.1](#) shall be an externally connected circuit breaker or fuse(s), as marked on the SPD. See [85.13](#). The ampere rating of such circuit breakers or fuse(s) shall not be less than 125 percent of the SPD ampere rating.

52.3 The test specified in [52.1](#) may be performed without overcurrent protective device(s) if it can be shown that the test circuit current was maintained for a minimum 3 cycles.

52.4 If fuses are used for tests at current levels greater than 10,000 A, a fuse is to be installed in each conductor. The fuses are to be external to the SPD as shown in [Figure 52.1](#).

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Figure 52.1
Circuit Withstand Tests



SB0801B

Supply – Rated Voltage, 3-Phase

X – Variable-tap air-core reactor

R – Variable resistor

SW – Closing switch, may be located as shown or ahead of limiting impedance

F – Enclosure fuse

CL – Protective fuses, if needed

52.5 When used for the test, a fuse is to be sized in accordance with [52.2](#). A Class CC, CD, G, H, J, L, R, T, or K fuse is to be selected such that, when tested on a single-phase circuit, the peak let-through current and clearing I^2t are not less than the maximum value established for the fuse – see the UL 248 series of standards – that is intended to be used with the device being tested. A Class H or K fuse shall not be used if the fault current marked on the device as indicated in [85.13](#) is greater than 10kA. For a fuse with I_p and I^2t limits established for several different short-circuit current levels, the test fuse is to be selected to have at least the maximum values of the current corresponding to the available fault current rating of the circuit to which the device is intended to be connected.

Exception: A test limiter evaluated to the Standard for Low-Voltage Fuses – Part 16: Test Limiters, UL 248-16, is able to be used in place of the fuses.

52.6 If fuses are used for tests at current levels of 10,000A or less, they shall comply with the limits specified for high-interrupting-capacity Class K fuses. The fuses shall be connected as described in [52.4](#).

52.7 When used for the test, a circuit breaker is to be sized in accordance with [45.1.13](#). The circuit breaker to be used is to be selected from commercially available units of the molded-case type having essentially the same characteristics with respect to let-through (I^2t) and peak let-through (I_p) and current-limiting features. The interrupting rating of the circuit breaker is to be at least the available fault current rating of the circuit to which the device is intended to be connected. Testing conducted using a circuit breaker with a particular interrupting rating is representative of testing with a circuit breaker of a lower interrupting rating.

52.8 An SPD shall be tested with alternating current at rated frequency on a circuit as indicated in [Figure 52.1](#). The test is to be performed in accordance with the following:

- a) The open-circuit voltage of the power supply circuit shall not be less than the maximum rated voltage of the SPD.
- b) The available short-circuit current in rms symmetrical amperes at the test source terminals shall not be less than the marked available fault current, see [85.12](#) and [Table 12.1](#) and [Table 12.2](#).
- c) The test source circuit shall include the necessary measuring equipment and the fuse mounting means if necessary.
- d) The power factor of the circuit shall be as specified in [Table 53.1](#). Lower power factors may be used if agreeable to those concerned.
- e) The test source terminals are to be included in the circuit to permit the connections described in [52.10](#) to be made. For determining the available short-circuit current of the circuit, these terminals, as well as the fuse-mounting means, shall be short-circuited in each instance by bus bars.

52.9 The reactive components of the impedance in the line shown in [Figure 52.1](#) may be parallel if one of the air-core type, but no reactance is to be connected in parallel with resistances except that an air-core reactor(s) in any phase may be shunted by resistance determined as follows:

The shunting resistance used with an air-core reactor having negligible resistance may be calculated from the formula:

$$R = 167 \frac{E}{I}$$

in which:

E is the voltage across the air-core reactor with current I flowing as determined by:

Oscillographic measurement during the short-circuit calibration, or

By proportion, from meter measurements at some lower current.

52.10 For the performance of the test, the line terminals of the representative device are to be connected to the corresponding test-circuit terminals by short wire leads, each of which is to have an ampacity consistent with the rating of the device. The load terminals are to be similarly connected to a short-circuiting bus bar.

52.11 An SPD intended for use on circuits having one conductor grounded shall be tested with the metal enclosure, or the grounding terminal, bus bar, etc., for SPDs not provided with a metal enclosure, connected to the grounded conductor through a 30-A, nontime-delay Class RK5 or K5 cartridge fuse having a voltage rating not less than that of the SPD. If the SPD is intended for use on other types of circuits, the metal enclosure and/or grounding terminal, etc. shall be connected through the fuse mentioned above to the live pole least likely to strike to ground. This connection is to be made with 10 AWG (5.3 mm²) copper wire having a length of 1.2 – 1.8 m (4 – 6 ft).

52.12 Test Setup and Apparatus – The representative devices shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative device is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

53 Instrumentation and Calibration of High-Capacity Circuits

53.1 General

53.1.1 The available current capacity of the circuit is to be at least the value required for the short-circuit-withstand rating of the SPD. The frequency of the test circuit is to be 60 ±1.2 Hz.

53.2 Available current of 10,000 amperes or less

53.2.1 For an alternating-current circuit intended to deliver 10,000 amperes or less, the current and power factor shall be as specified in [Table 53.1](#) and are to be determined as follows:

a) For a 3-phase test circuit, the current is to be determined by averaging the rms values of the first complete cycle of current in each of the three phases; the voltage to neutral is to be used to determine the power factor.

b) For a single-phase test circuit, the current is to be the rms value of the first complete cycle – see [Figure 53.1](#) – when the circuit is closed to produce an essentially symmetrical current waveform. The direct-current component is not to be added to the value obtained when measured as illustrated. In order to obtain the desired symmetrical waveform of a single-phase test circuit, controlled closing is recommended although random closing methods may be used. The power factor is to be determined by referring the open-circuit voltage wave to the two adjacent zero points at the end half of the first complete current cycle by transposition through a suitable timing wave. The power factor is to be computed as an average of the values obtained by using these two current zero points.

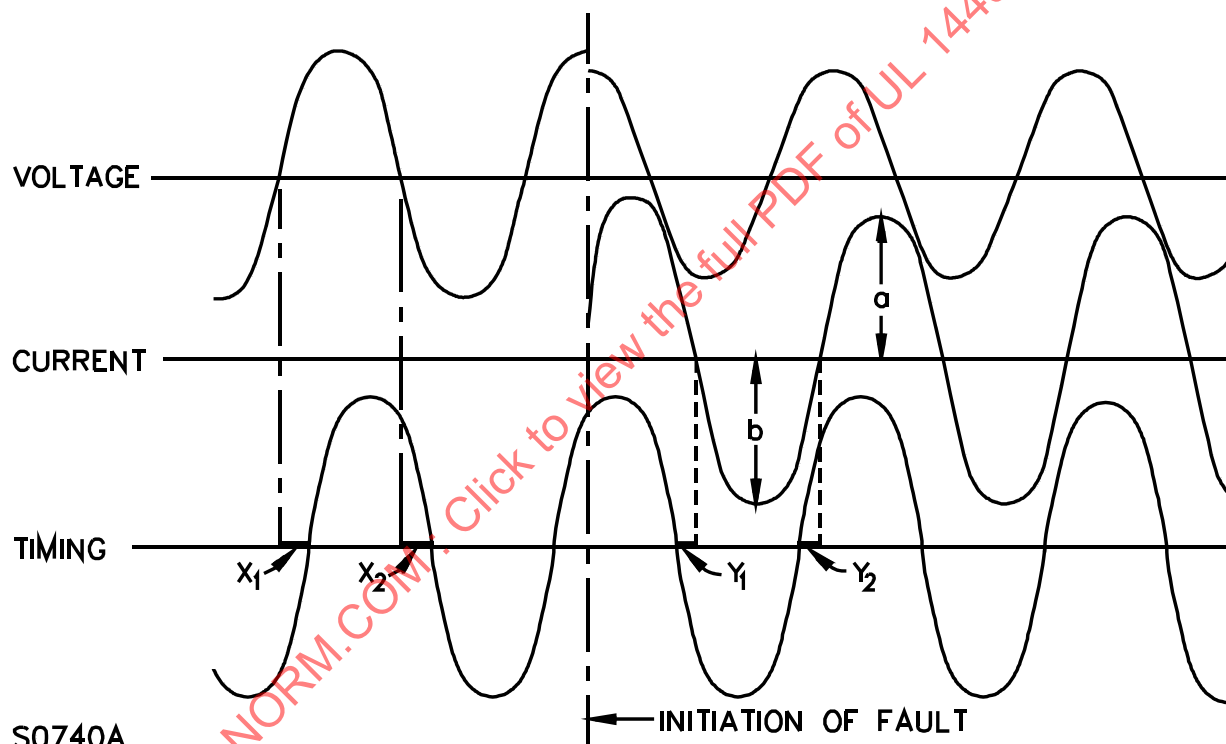
Table 53.1
Power Factor

Available fault current	Power factor ^a
200 A	0.80 – 1.0
1000 A	0.70 – 0.80
2000 – 10,000 A	0.40 – 0.50
10,001 – 20,000 A	0.25 – 0.30
>20,000 A	≤0.20

^a Power factor may be less.

Figure 53.1

Determination of Current and Power Factor for Circuits of 10,000 Amperes and Less



$$rms \text{ Current} = \left(\frac{a+b}{\sqrt{2} \times 2} \right) \text{ (rms calibration of instrument element)}$$

$$Power \text{ factor} = \frac{\cos [(Y_1 + X_1) (180^\circ)] + \cos [(Y_2 + X_2) (180^\circ)]}{2}$$

in which:

X_1 , X_2 , Y_1 , and Y_2 values are fractions of the 1/2-cycle distance in which they occur.

53.3 Available current more than 10,000 amperes

53.3.1 For circuits intended to deliver more than 10,000 amperes, the current and power factor are to be determined in accordance with the requirements in [53.3.2](#) – [53.3.8](#). Instrumentation used to measure test circuits of over 10,000 amperes is to comply with the requirements in [53.4.1](#) – [53.4.11](#).

53.3.2 The rms symmetrical current is to be determined, with the supply terminals short-circuited by measuring the alternating-current component of the wave at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the initiation of the short circuit. The current is to be calculated in accordance with the Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis, ANSI/IEEE C37.09.

53.3.3 For a 3-phase test circuit, the rms symmetrical current is to be the average of the currents in the three phases. The rms symmetrical current in any one phase is not to be less than 90 percent of the required test current.

53.3.4 The test circuit and its transients are to be such that 3 cycles after initiation of the short circuit, the symmetrical alternating component of current will not be less than 90 percent of the symmetrical alternating component of current at the end of the first 1/2 cycle, or the symmetrical alternating component of current at the time at which the overcurrent-protective device will interrupt the test circuit is at least 100 percent of the rating for which the controller is being tested. In 3-phase circuits, the symmetrical alternating component of current of all three phases is to be averaged.

53.3.5 The power factor is to be determined at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the short circuit occurs. The total asymmetrical rms amperes are to be measured in accordance with [53.3.2](#) and the ratio M_A or M_M is to be calculated as follows:

$$M_A (3 \text{ phase}) = \frac{\text{Av. 3 phases - Asymmetrical RMS Amperes}}{\text{Av. 3 Symmetrical RMS Amperes}}$$

$$M_M (1 \text{ phase}) = \frac{\text{Asymmetrical RMS Amperes}}{\text{Symmetrical RMS Amperes}}$$

Using ratio M_A or M_M , the power factor is to be determined from [Table 53.2](#).

Table 53.2
Short-Circuit Power Factor

Short-circuit power factor, percent	Ratio M_M^a	Ratio M_A^a	Short-circuit power factor, percent	Ratio M_M^a	Ratio M_A^a
0	1.732	1.394	30	1.130	1.066
1	1.696	1.374	31	1.121	1.062
2	1.665	1.355	32	1.113	1.057
3	1.630	1.336	33	1.105	1.053
4	1.598	1.318	34	1.098	1.049
5	1.568	1.301	35	1.091	1.046
6	1.540	1.285	36	1.084	1.043
7	1.511	1.270	37	1.078	1.039

Table 53.2 Continued on Next Page

Table 53.2 Continued

Short-circuit power factor, percent	Ratio M_M^a	Ratio M_A^a	Short-circuit power factor, percent	Ratio M_M^a	Ratio M_A^a
8	1.485	1.256	38	1.073	1.036
9	1.460	1.241	39	1.068	1.033
10	1.436	1.229	40	1.062	1.031
11	1.413	1.216	41	1.057	1.028
12	1.391	1.204	42	1.053	1.026
13	1.372	1.193	43	1.049	1.024
14	1.350	1.182	44	1.045	1.022
15	1.330	1.171	45	1.041	1.020
16	1.312	1.161	46	1.038	1.019
17	1.294	1.152	47	1.034	1.017
18	1.277	1.143	48	1.031	1.016
19	1.262	1.135	49	1.029	1.014
20	1.247	1.127	50	1.026	1.013
21	1.232	1.119	55	1.015	1.008
22	1.218	1.112	60	1.009	1.004
23	1.205	1.105	65	1.004	1.002
24	1.192	1.099	70	1.002	1.001
25	1.181	1.093	75	1.0008	1.0004
26	1.170	1.087	80	1.0002	1.00005
27	1.159	1.081	85	1.00004	1.00002
28	1.149	1.075	100	1.00000	1.00000
29	1.139	1.070			

^a See 53.3.5.

53.3.6 The power factor of a 3-phase circuit may be calculated by using controlled closing so that upon subsequent closings a different phase will be caused to have maximum asymmetrical conditions. The power factor of each phase could then be determined using the method described for single-phase circuits in 53.3.5. The power factor of the 3-phase circuit is considered to be the average of the power factors of each of the phases.

53.3.7 The recovery voltage is to be at least equal to the rated voltage of the controller. The peak value of the recovery voltage within the first complete half cycle after clearing and for the next five successive peaks is to be at least equal to 1.414 times the rms value of the rated voltage of the controller. Each of the peaks is not to be displaced by more than ± 10 electrical degrees from the peak values of the open-circuit recovery voltage – that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage each of the first six, half cycles measured at the 45 degree and 135 degree points on the wave is to be not less than 85 percent of the rms value of the rated voltage of the controller. The instantaneous value of recovery voltage measured at the 45 degree and 135 degree points of each of the first six, half cycles is in no case to be less than 75 percent of the rms value of the rated voltage of the SPD.

53.3.8 If there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow in a circuit that employs secondary closing, the detailed measurement of recovery voltage characteristics as indicated in 53.3.7 is not required.

53.4 Instrumentation for test currents above 10,000 amperes

53.4.1 When used, the galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing are to be of a type having a flat (± 5 percent) frequency response from 50 – 1200 Hz. For fast acting fuses, current limiters, or motor-short-circuit protectors, a galvanometer may need to have a flat frequency response from 50 – 9000 Hz or an oscilloscope may be needed to obtain accurate values of peak current, (I_p), and energy let-through, (I^2t). Digital data acquisition equipment with comparable or better specifications may be used in lieu of galvanometer driven oscillographs.

53.4.2 Galvanometers, when used, are to be calibrated as described in [53.4.3](#) – [53.4.6](#).

53.4.3 When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage is to be applied so as to cause the galvanometer to deflect in both directions. Additional calibrations are to be made using approximately 50 percent and approximately 150 percent of the voltage used to obtain the deflection indicated above, except that if the anticipated maximum deflection is less than 150 percent, such as a symmetrically closed single-phase circuit, any other suitable calibration point is to be chosen. The sensitivity of the galvanometer circuit in volts per millimeter (or inch) is to be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per millimeter (or inch) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is to be used for the determination of the rms current as described in [53.3.2](#).

53.4.4 A 60 Hz sine-wave potential may be used for calibrating the galvanometer circuit, using the same general method described in [53.4.3](#). The resulting factor is to be multiplied by 1.414.

53.4.5 When a current transformer is used to determine the circuit characteristics, an alternating current is to be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short circuit current is flowing in the primary. Additional calibrations are to be made at approximately 50 percent and approximately 150 percent of the current used to obtain the deflection indicated above except that if the anticipated maximum deflection is less than 150 percent, such as in a symmetrically closed single-phase circuit, any other suitable calibration point is to be chosen. The sensitivity of the galvanometer circuit in rms amperes per millimeter (or inch) is to be determined in each case and the results averaged. The average sensitivity is to be multiplied by the current-transformer ratio and by 1.414 to obtain peak amperes per millimeter (or inch). This constant is to be used for the determination of the rms current as described in [53.3.2](#).

53.4.6 All the galvanometer elements employed are to line-up properly in the oscillograph, or the displacement differences are to be noted and used as needed.

53.4.7 The sensitivity of any galvanometers used and the recording speed are to be such that the values of voltage, current, and power factor can be determined accurately. The recording speed is to be at least 1.5 m (60 inches) per second.

53.4.8 With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found acceptable for use as a reference connected into the circuit, the tests described in [53.4.9](#) and [53.4.10](#) are to be conducted to verify the accuracy of the manufacturer's instrumentation.

53.4.9 With the secondary open-circuited, the transformer is to be energized and the voltage at the test terminals observed to see if rectification is occurring making the circuit unacceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings are to be made to demonstrate that residual flux in the transformer core will not cause rectification. If testing is done by closing the secondary circuit, this check can be omitted providing testing is not commenced before the transformer has been energized for approximately 2 seconds, or longer if an investigation of the test equipment shows that a longer time is necessary.

53.4.10 With the test terminals connected together by means of a copper bar, a single-phase circuit is to be closed as nearly as possible at the moment that will produce a current wave with maximum offset. The short circuit current and voltage are to be recorded. The primary voltage is to be recorded if primary closing is used. The current measured by the reference shunt is to be within 5 percent of that measured using the manufacturer's instrumentation and there is to be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

53.4.11 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt is to be removed from the circuit. The reference coaxial shunt is not to be used during the final calibration of the test circuit nor during the testing of SPD.

54 Insulation Resistance Test

54.1 As required by Capacitors, Section [26](#), a capacitor shall have an insulation resistance of not less than 2 MΩ between live parts and accessible dead metal parts.

54.2 For a capacitor whose outer enclosure consists wholly or partly of insulating material, the term accessible dead metal parts as used in [54.1](#) signified metal foil wrapped around and in intimate contact with the exterior of the enclosure so as to leave a space of 5 mm (0.2 inch) between the edge of the foil and any terminal or bare lead.

54.3 In determinations of insulation resistance, a direct potential of not less than 250 V is to be employed, and the value of insulation resistance to be determined one minute after application of the test potential. The capacitor is not to be energized during this test.

55 Capacitor Endurance Test

55.1 As required by Capacitors, Section [26](#), three representative devices of a capacitor employed in SPDs connected across the line or line (or neutral) to ground prior to being subjected to the Capacitor Endurance Test specified in [55.2](#) and [55.3](#), shall complete with acceptable results the Dielectric Voltage-Withstand Test, Section [39](#) and the Insulation Resistance Test, Section [54](#).

55.2 The representative devices shall be placed in a full draft circulating air oven maintained at a uniform temperature equal to or greater than the maximum temperature measured on the capacitor during the normal temperature test, but not less than 50°C (122°F). The representative devices shall be operated for 1000 hours at the voltage specified in [55.3](#) at the rated frequency.

55.3 The test voltage for capacitors connected across the line shall be 1.5 times rated voltage and for capacitors connected from line (or neutral) to ground shall be 1.7 times rated voltage.

55.4 Following the Capacitor Endurance Test, the representative devices shall be subjected to and comply with the Dielectric Voltage-Withstand Test, Section [39](#) with test voltages of 90 percent of the specified values, and the Insulation Resistance Test, Section [54](#). The capacitor shall not show any evidence of ignition, sealant leakage, cracking, breakage, or similar physical damage.

56 Component Breakdown Test

56.1 As required by [23.1](#), an SPD shall be subjected to the Component Breakdown Test, [56.2](#) – [56.11](#).

56.2 With reference to the requirement in [56.1](#), a risk of fire or electric shock is considered to exist if any of the following occur:

- a) Glowing, charring, or flaming of the cheesecloth or tissue paper as specified in [56.6](#);
- b) Opening of the 3A fuse specified in [56.7](#);
- c) Emission of flame, sparks, or molten metal from the enclosure;
- d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#); or
- e) Loss of structural integrity to a degree that the equipment collapses or experiences such displacement of parts that may lead to short-circuiting or grounding of live parts.

56.3 The circuit between any two terminals of a device is to be opened or shorted. Only one of the simulated fault conditions is to be imposed at a time. For a multi-terminal device, only two terminals are to be short-circuited at a time. Simulated circuits may be used, but if the tests performed on simulated circuits indicate likely damage to other parts of the equipment to the extent that the safety of the equipment may be affected, the tests shall be repeated on the equipment.

56.4 Each test is to be conducted on a separate sample unless it is agreeable to those concerned that more than one test be conducted on the same sample.

56.5 A part of equipment that may be removed during routine operation or maintenance is to be omitted if it will result in a more severe test, and the part is not:

- a) Necessary for the functioning of the equipment;
- b) Exposed to view during intended operation; and
- c) Captivated.

56.6 During these tests, the sample is to be placed on a softwood surface covered with white tissue paper, and a single layer of cheesecloth is to be draped loosely over the entire enclosure.

Exception No. 1: Units not having bottom openings need not be placed on a softwood surface covered with white tissue paper.

Exception No. 2: When it is impractical to drape the entire enclosure, cheesecloth may be placed only over all ventilating openings.

56.7 During each test, exposed dead-metal parts of the sample are to be connected to earth ground through a 3A nontime-delay fuse.

56.8 The supply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20-ampere minimum), except that where this value does not correspond with the standard rating of a fuse or a circuit breaker, the next higher standard device rating shall be used. The test voltage and frequency are to be adjusted to the maximum rated voltage of the product.

Exception: If a marking on the product literature indicates the use of branch circuit protection exceeding 125 percent of the input current, such protection shall be used.

56.9 Each abnormal condition is to be conducted for 7 hours or until one or more of the following results are observed:

- a) A risk of fire or electric shock develops. See [56.2](#).
- b) The branch-circuit fuse opens.
- c) The supplementary protective device opens.
- d) Any other circuit component opens.
- e) A minimum of one hour elapses, circuit conditions stabilize, and there is no further evidence of overheating of parts.

56.10 The overheating of parts referred to in [56.9\(e\)](#) may be detected by an indicator such as an odor, smoke, discoloration, cracking of materials, charring, flaming, glowing, arcing, changes in circuit current through the applied fault, or any similar phenomenon.

56.11 If a fault condition is terminated by opening of circuit component as specified in [56.9\(d\)](#), the test is to be conducted two more times using new components for each test.

57 Strain Relief Test

57.1 The strain-relief means provided on the supply cord of a cord-connected SPD, or the specified cable installed in an SPD intended for connection using exposed wiring methods, shall withstand for one minute without displacement a direct pull of 156 N (35 lbf) applied to the cord with the connections within the SPD disconnected.

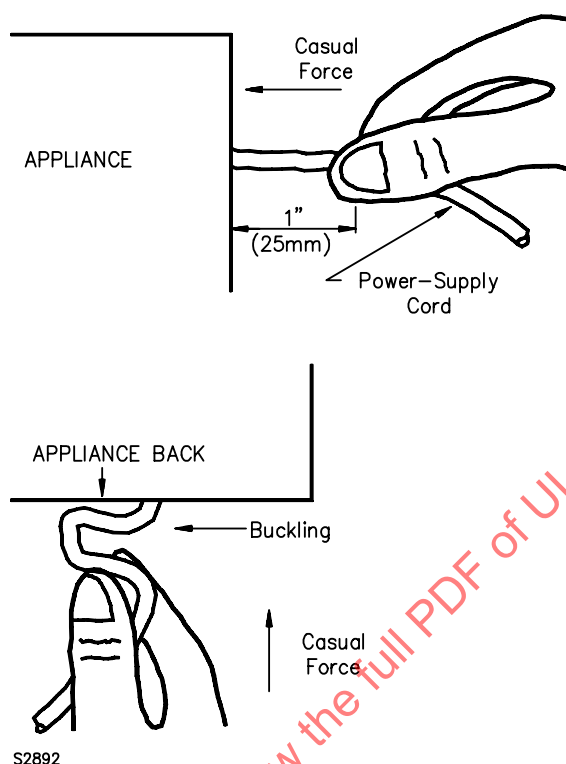
57.2 A weight exerting 156 N (35 lbf) is to be suspended on the cord and so supported by the SPD that the strain-relief means is stressed from any angle that the construction of the SPD permits. The strain relief means is not acceptable if, at the point of disconnection of the conductors, there is such movement of the cord as to indicate that stress would have been transmitted to the cord connections.

58 Push-Back Relief Test

58.1 The strain relief means provided with an SPD restrict the flexible cord from being pushed into the cord mounting opening in an appliance.

58.2 The flexible cord is to be held by the fingers 25.4 mm (1 inch) from the point where the cord emerges from the cord mounting opening. It is to be pushed back with casual force (see [Figure 58.1](#)). The force is to be applied until the cord is buckled but in no case shall the force applied exceed 26.7 N (6 lbf).

Figure 58.1
Power-Supply-Cord-Push-Back Evaluation



59 Conductor Secureness Test

59.1 A pigtail lead, specified in [14.1.2](#), shall withstand without damage or detachment, a direct pull of 89 N (20 lbf), for one minute, applied to the lead from any angle that the construction or the equipment allows.

60 Snap-On Cover Tests

60.1 A snap-on cover that gives access to uninsulated live parts and does not require a tool for removal shall be subjected to the tests in [60.2](#) – [60.4](#).

60.2 A cover that can be removed with one hand shall not be released when a squeezing force of 62 N (14 lbf) is applied to any two points, the distance between which shall not exceed 127 mm (5 inches), as measured by a tape stretched tightly over that portion of the surface of the cover that can be covered by the palm of the hand. The test shall be performed before and after ten removal and replacement operations.

60.3 A cover shall not become disengaged from the case when a direct pull of 62 N (14 lbf) is applied. For this test, the cover is to be gripped at any two convenient points. The test shall be performed before and after ten removal and replacement operations.

60.4 A cover shall withstand an impact force of 1.4 N·m (1 lbf-ft) applied to accessible faces of the cover (one blow per face) without being displaced, and there shall be no damage to internal parts or malfunction of the SPD as a result of this test. A steel ball, approximately 50.8 mm (2 inches) in diameter, and weighing approximately 535 g (1.18 lb), is to be used to apply the impact.

61 Non-Metallic Enclosure Conduit Connection Tests

61.1 General

61.1.1 A non-metallic enclosure having a threaded conduit entry for connection to a rigid conduit system shall withstand, without pulling apart or damage such as cracking and breaking, the pullout, torque, and bending requirements described in [61.2](#) – [61.4](#), each applied in turn for 5 minutes. Some distortion of the enclosure under test is acceptable. The test may be discontinued when noticeable distortion occurs.

Exception No. 1: An enclosure that is provided with a separate hub assembly, and that has instructions stating that the hub is to be connected to the conduit before being connected to the enclosure, need not be subjected to the torque test.

Exception No. 2: An SPD provided with a mounting nipple/box adapter, intended to be mounted directly to a panel, need not be subjected to these tests.

Exception No. 3: An SPD intended for use with flexible conduit and marked in accordance with [85.31](#) need not be subjected to these tests.

61.2 Pullout

61.2.1 The equipment is to be supported by rigid conduit in the intended manner and is to support a weight of 90 kg (200 lb).

61.3 Bending

61.3.1 The equipment is to be rigidly supported by means other than the conduit fittings. A length of conduit – at least 305 mm (1 ft) long – of the proper size is to be installed:

- a) In the center of the largest unreinforced surface; or
- b) In a hub or opening if provided as part of the enclosure.

The bending moment shall be applied as specified in [Table 61.1](#).

Table 61.1
Bending Moment

Normal mounting plane of enclosure surface ^a	Conduit size, inches	Bending moment for conduit N·m (pound-inches) ^b
Horizontal	All	33.9 (300)
Vertical	1/2 – 3/4	33.9 (300)
	1 – up	67.8 ^c (600)
^a If the enclosure surface may be installed in either a horizontal or a vertical plane, the vertical bending moment value is to be used. ^b For an end-of-line enclosure and has only one 3/4 inch maximum trade size opening, the bending moment is to be 17.0 N·m (150 pound-inches). ^c For non-metallic conduit, bending moment of 33.9 N·m (300 pound-inches) is to be used.		

61.3.2 The magnitude of the weight for the bending moment is to be determined from the equation:

$$W = \frac{M - 0.5CL}{L}$$

in which:

W is weight to be hung at the end of the conduit, in pounds;

L is length of the conduit, in inches, from the wall of the enclosure to the point at which the weight is suspended;

C is weight of the conduit, in pounds; and

M is bending moment required, in pound-inches.

For the SI system of units, the equation is:

$$W = \frac{0.1M - 0.5CL}{L}$$

in which:

W , C is kilograms;

M is newton-meters; and

L is meters.

61.4 Torque

61.4.1 The equipment is to be rigidly supported by means other than the conduit fitting. A torque is to be applied to a length of installed conduit in a direction tending to tighten the connection. The lever arm is to be measured from the center of the conduit. The applied torque shall be as specified in [Table 61.2](#).

Exception: An end-of-line enclosure – an enclosure that is intended to be connected at the end of a run of conduit and has only one 3/4-inch maximum trade size opening for the connection of conduit – need only be subjected to a tightening torque of 22.6 N·m (200 pound-inches).

Table 61.2
Tightening Torque

Trade size of conduit hub, inches	Tightening torque, N·m (pound-inches)
3/4 or smaller	90.4 (800)
1, 1-1/4 and 1-1/2	113 (1000)
2 and larger	181 (1600)

62 Enclosure Impact Tests

62.1 General

62.1.1 A Type 3 SPD employing a metallic or non-metallic enclosure and a Type 1 or Type 2 SPD employing a non-metallic enclosure is to be subjected to the impact tests described in [62.2.1](#) – [62.4.2](#) without any occurrence of the following:

- a) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section 13.
- b) Any condition that might affect the safe mechanical performance of the SPD.
- c) Any other condition that increases the risk of electric shock.

Exception: Impact Testing is not required for the housing of open-type SPDs not intended to function as enclosures.

62.1.2 With reference to 62.1.1(b), cracking or denting of the enclosure that affects the function of any features such as overcurrent protective devices or strain relief is not acceptable. Cracking or denting of the enclosure is not to result in exposure of moving parts capable of causing injury to persons.

62.1.3 With reference to 62.1.1(c), the SPD is to comply with the Dielectric Voltage-Withstand Test, Section 39 after being subjected to the impact tests described in this section.

62.2 Drop impact test

62.2.1 Each of three samples of the Type 3 SPD, is to be subjected to the impact that results from its being dropped three times (a series) through a distance of 0.91 m (3 feet) from the bottom of the SPD to strike a concrete surface in the positions most likely to produce adverse results. In each drop, the sample is to strike in a position on the enclosure different from those of each of the other two drops in the series.

Exception: If agreeable to those concerned, fewer samples may be used in accordance with Figure 62.1 wherein each series consists of three drops of the sample. The overall performance is acceptable upon completion of any one of the sequences represented in the figure.

Figure 62.1

Procedures for Impact Tests

PROCEDURE FOR IMPACT TEST ON HAND-SUPPORTED APPLIANCES

Series Number	Sample Number								
	1	2	3	1	2	3	1	2	3
1	↓ A	N	N	↓ A	N	N	↓ A	N	N
2	↓ A	N	N	↓ A	N	N	↓ U	↓ A	N
3	↓ A	N	N	↓ U	↓ A	N	↓ A	N	↓ U

Arrows indicate sequence of test procedure

A – Acceptable results from drop
U – Unacceptable results from drop
N – No test necessary

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Each series consists of three drops or one ball impact as applicable

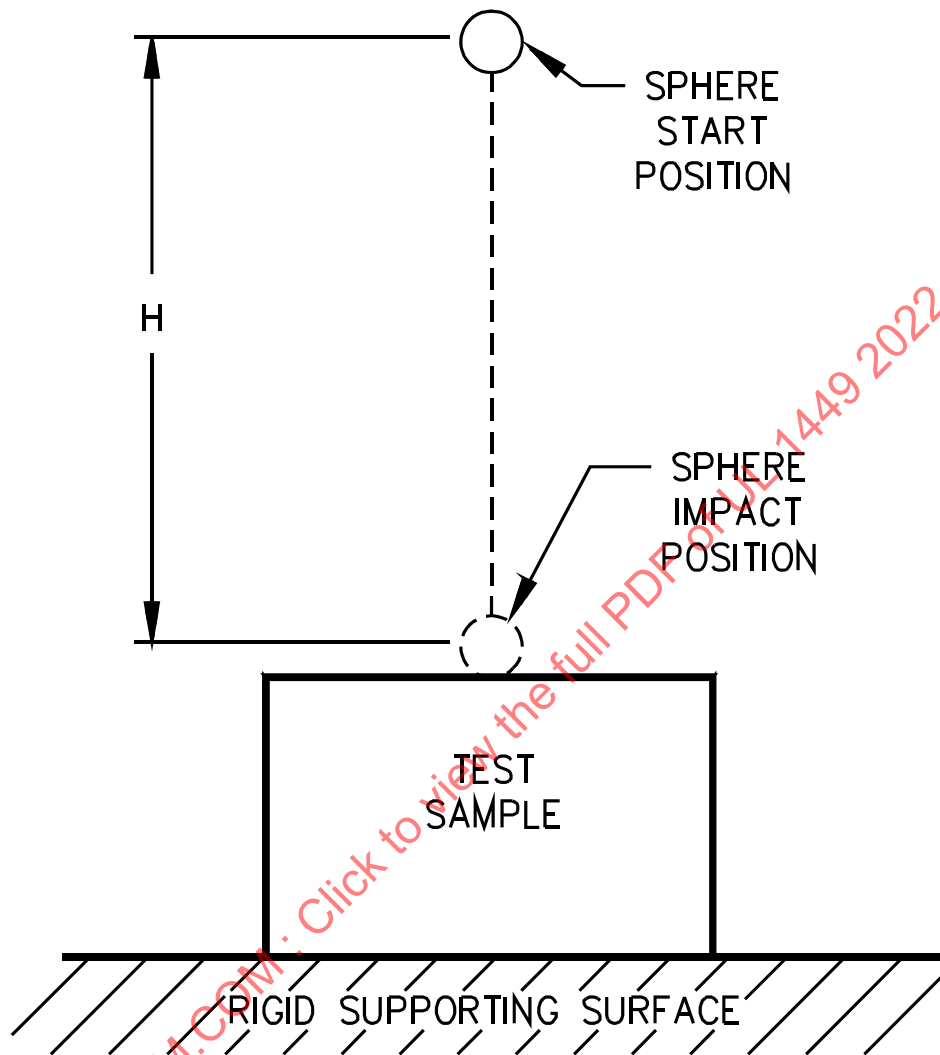
62.3 Steel sphere impact test

62.3.1 Each of three samples of the SPD shall be subjected to a single impact of 6.8 J (5 ft-lbf). Each impact shall be applied to an enclosure surface not impacted previously in the test sequence. Each impact is to be imparted by dropping a steel sphere 50.8 mm (2 inches) in diameter, and weighing 0.535 kg (1.18 lb) from a height that will produce the specified impact as shown in [Figure 62.2](#). The ball shall not impact on a receptacle face, overcurrent protective device, switch, pilot light or similar component. For surfaces other than the top on an enclosure, either the sample could be supported on the side and subjected to the ball impact mentioned above, or the steel sphere is to be suspended by a cord and swung as a pendulum, dropping through the vertical distance necessary to cause it to strike the surface with the specified impact as shown in [Figure 62.2](#). Three samples are to be employed for the tests in the equipment restrained mode.

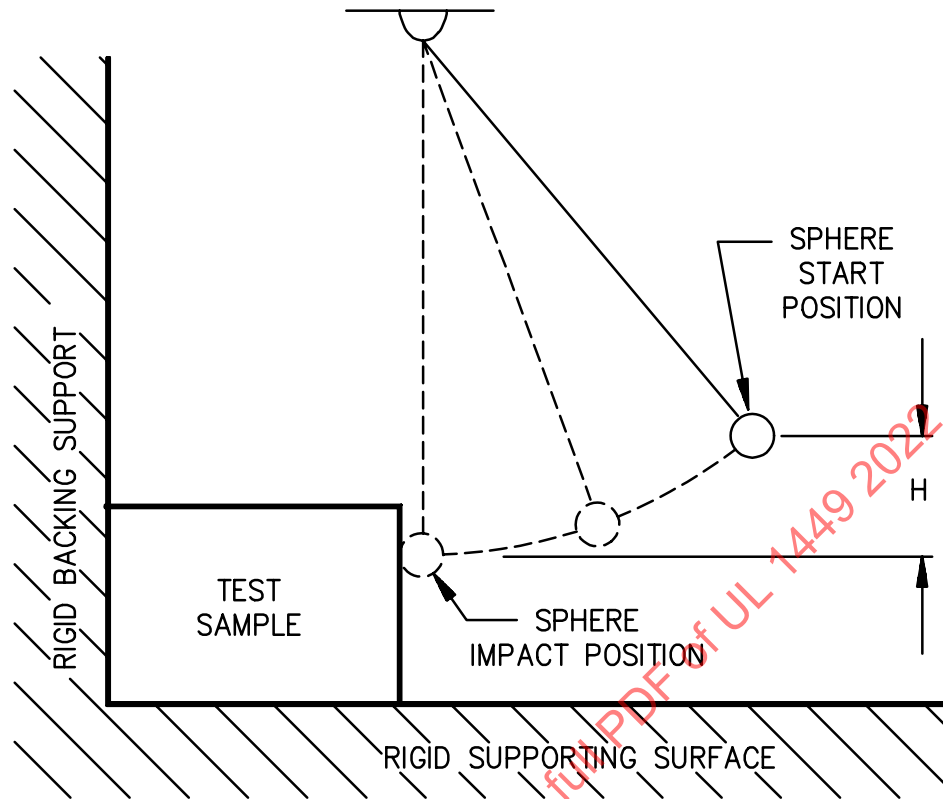
Exception: If agreeable to those concerned, fewer than three samples may be used for the tests in accordance with [Figure 62.1](#) in which each series of impacts is to consist of one impact. The overall performance is acceptable upon completion of any one of the sequences represented in the figure.

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Figure 62.2
Ball Impact Test



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NOTES –

- 1) H in [Figure 62.2](#) indicates the vertical distance the sphere must travel to produce the desired impact.
- 2) For the ball pendulum impact test the sphere is to contact the test sample when the string is in the vertical position as shown.
- 3) The supporting surface is to consist of a layer of tongue-and-groove oak flooring mounted on two layers of 19 mm (3/4 inch) plywood. The oak flooring is nominally 3/4 inch thick (actual size 3/4 by 2-1/4 inches or 19 by 57 mm). The assembly is to rest on a concrete floor. An equivalent nonresilient supporting surface may be used.
- 4) The backing surface is to consist of 3/4 inch (19 mm) plywood over a rigid surface of concrete. An equivalent nonresilient backing surface may be used.

62.4 Low-temperature steel sphere impact test

62.4.1 For an SPD with a nonmetallic enclosure, three representative devices shall be cooled to the temperature specified in [Table 62.1](#) and maintained at this temperature for 24 hours. While the unit is still cold, within one minute after removal from the temperature chamber, the samples are to be subjected to the impact described in [62.3.1](#).

Table 62.1
Low-Temperature Steel Sphere Impact Test – Temperature Conditioning Requirements

SPD Type	Use location	Temperature conditioning requirements
1, 2 or 3	Indoor-Use	0.0 ±2.0°C (32.0 ±3.6°F) ^a
1, 2 or 3	Outdoor-Use	-35.0 ±2.0°C (-31.0 ±3.6°F) ^b
^a Or the minimum ambient temperature rating of the SPD (minimum of -5°C (23°F)) whichever is lower.		
^b Or the minimum ambient temperature rating of the SPD (minimum of -40°C (-40°F)) whichever is lower.		

62.4.2 At the end of the tests described in [62.1](#) – [62.4](#), spacings shall not be less than those described in Spacings, Section [18](#).

63 Crushing Test

63.1 A Type 3 SPD employing a metallic or polymeric enclosure is to be subjected to the crush test described in [63.4](#) without any occurrence of the following:

- a) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#).
- b) Any condition that might affect the safe mechanical performance of the SPD.
- c) Any other condition that increases the risk of electric shock.

63.2 With reference to [63.1\(b\)](#), cracking or denting of the enclosure that affects the function of any features such as overcurrent protective devices or strain relief is not acceptable. Cracking or denting of the enclosure is not to result in exposure of moving parts capable of causing injury to persons.

63.3 With reference to [63.1\(c\)](#), the SPD is to comply with the Dielectric Voltage-Withstand Test, Section [39](#) after being subjected to the crush tests described in this section.

63.4 A previously untested sample of an SPD shall be placed on a 12.7 mm (1/2 inch) thick horizontal maple board and a crushing force of 667.2 N (150 lbf) is to be applied to three different locations of the SPD by means of a horizontal 19.1 mm (3/4 inch) diameter steel rod. The rod is to be placed across the center of the smaller dimension of the test surface of the SPD, perpendicular to the long axis of the SPD. The length of the rod is to be sufficient to span the smaller dimension of the surface being tested. Force is to be gradually applied and maintained for a period of one minute. The crushing force is not to be applied to protruding members of receptacles, switch toggles/triggers, indicator lamps and OCP reset members.

63.5 At the end of the tests described in [63.1](#) – [63.4](#), spacings shall not be less than those described in Spacings, Section [18](#).

64 Mold Stress-Relief Distortion Test

64.1 For an SPD with a polymeric enclosure, conditioning of the equipment as described in [64.2](#) shall not cause softening of the material as determined by handling immediately after the conditioning, nor shall there be shrinkage, warpage, or other distortion as judged after cooling to room temperature, that results in any of the following:

- a) Reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal, uninsulated live parts and the enclosure below the minimum acceptable values.
- b) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#).
- c) Causing a condition that results in the SPD not complying with the Strain Relief Tests, Section [57](#), if applicable.
- d) Causing interference with the intended operation or servicing of the equipment.

Exception: The conditioning described in [64.2](#) is not required for rigid thermosetting materials or for low-pressure foamed molded parts.

64.2 For equipment that has a polymeric enclosure, one sample of the equipment shall be conditioned in accordance with either (a) or (b) below:

- a) One sample of the complete equipment (in the case of an enclosure) or the part under consideration, is to be placed in a full draft circulating air oven maintained at a uniform temperature at least 10°C (18°F) higher than the maximum temperature of the material measured under actual operating conditions, but not less than 70°C (158°F) in any case. The sample is to remain in the oven for 7 hours. After its careful removal from the oven and return to room temperature, the sample is to be investigated for compliance with [64.1](#).
- b) One sample of the complete equipment is to be placed in a test cell. The circulation of air within the cell is to simulate actual room conditions. The air temperature within the cell, as measured at the supporting surface of the equipment, is to be maintained at 60°C (140°F). The equipment is to be operated in the same way as for the temperature test except for equipment that is not loaded or is not continuously loaded during the normal temperature test. Such equipment, although unloaded, shall be connected to 106 percent or 94 percent of normal rated voltage, whichever results in higher temperatures. In any case, the equipment is to be operated for 7 hours. After its careful removal from the test cell, the sample is to be investigated for compliance with [65.1](#).

65 Mounting Hole Barrier Tests

65.1 General

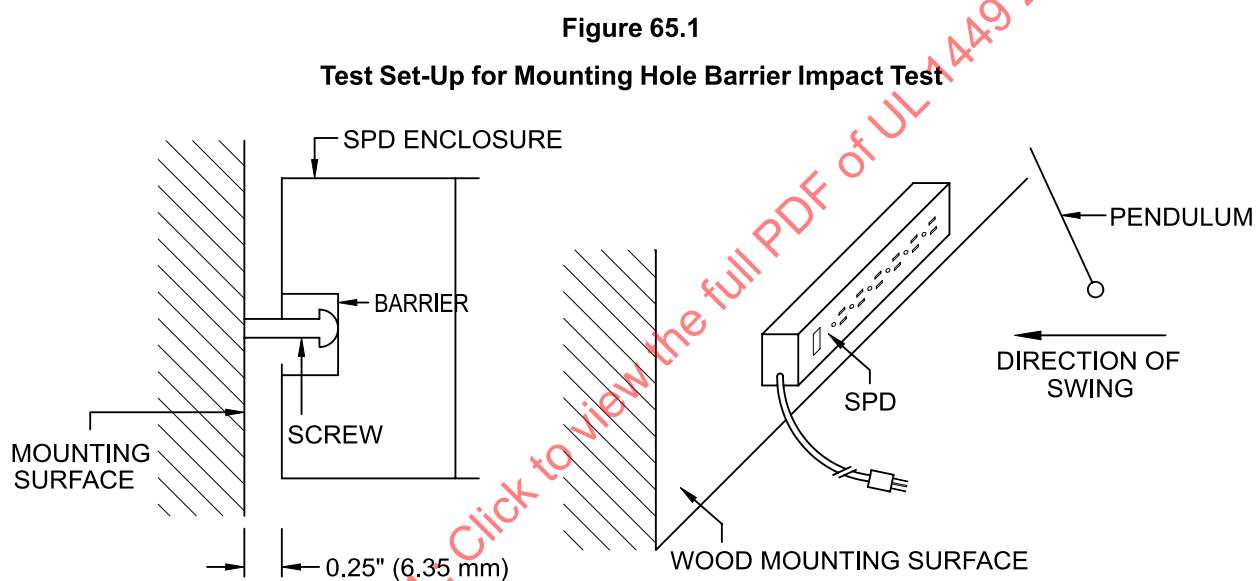
65.1.1 If penetration or deflection of a barrier behind a mounting hole of the SPD could increase the risk of fire, electric shock, or injury to persons, the SPD is to be subjected to the Mounting Hole Barrier Tests as described in [65.2.1](#) – [65.3.1](#) without any occurrence of the following due to the penetration or deflection of the barrier:

- a) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Live Parts, Section [13](#).
- b) A reduction of spacings below the values specified in Spacings, Section [18](#).

- c) Transient distortion that results in contact with live parts causing energization of a metallic enclosure.
- d) Any condition that might affect the safe mechanical performance of the SPD.
- e) Any other condition that increases the risk of electric shock.

65.2 Mounting hole barrier impact test

65.2.1 The SPD is to be mounted on a vertical surface using the hardware supplied or the hardware recommended by the manufacturer. If no hardware is supplied or recommended, the SPD is to be mounted using a No. 8 \times 3/4 inch wood screw. When the screws are resting against the barrier there is to be 6.4 mm (1/4 inch) clearance between the back of the enclosure and the mounting surface. See [Figure 65.1](#).

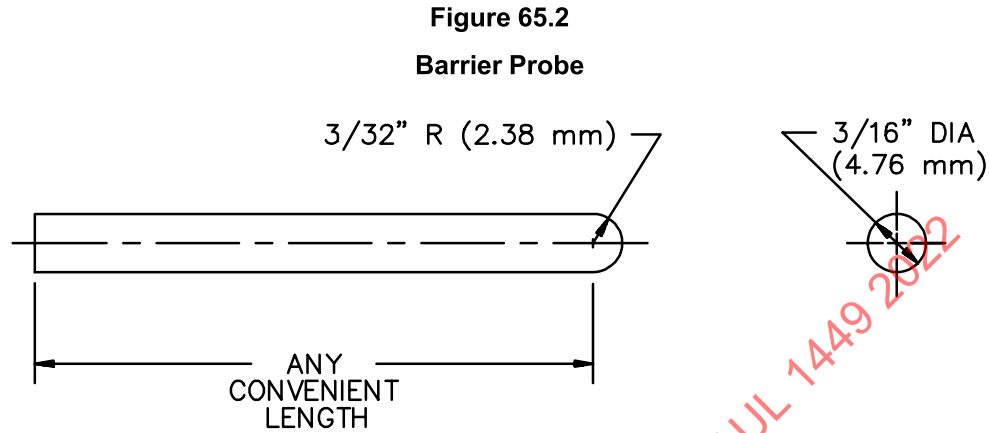


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65.2.2 Each mounting hole configuration of the SPD shall be subjected to a single impact of 6.8 J (5 ft-lbf) to the SPD mounted as specified in [65.2.1](#). This impact is to be produced by a steel sphere, 50.8 mm (2 inches) in diameter and weighing 0.535 kg (1.18 lb), suspended by a cord and swung as a pendulum, dropping through a vertical distance of 1.29 m (51 inches) to cause it to strike the representative device with the specified impact as shown in [Figure 62.2](#). Each impact shall be applied to a point on the surface that is judged to be most severe for the mounting hole configuration under test.

65.3 Mounting hole barrier probe test

65.3.1 Each barrier of an untested sample of an SPD shall withstand a force of 89 N (20 lb). The force is to be applied by means of the barrier probe shown in [Figure 65.2](#).



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66 Adequacy of Mounting Test

66.1 To determine compliance with [66.2](#) and [66.3](#), a cord-connected Type 3 SPD provided with a means for temporary mounting is to be mounted in accordance with manufacturer's installation instructions on any secure wall.

Exception: If the SPD is not provided with installation instructions, the representative device shall be tested in the most severe mounting configuration.

66.2 After the SPD has been installed according to manufacturer's instructions, a weight of four times the weight of the representative device or 2.27 kg (5 lb), whichever is greater, is to be hung from the center of the representative device as shown in [Figure 66.1](#) for each mounting configuration.