



UL 2231-2

STANDARD FOR SAFETY

Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems

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UL Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems, UL 2231-2

Second Edition, Dated September 7, 2012

Summary of Topics

This new edition of the Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems, UL 2231-2, is being issued as a Trinational Standard with ANCE and CSA.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated February 17, 2012 and July 6, 2012.

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NMX-J-668/2-ANCE
First Edition



CSA Group
CSA C22.2 No. 281.2-12
First Edition



Underwriters Laboratories Inc.
UL 2231-2
Second Edition

Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems

September 7, 2012



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This Standard is subject to periodic review, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquires@csagroup.org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Second Edition.

The most recent designation of ANSI/UL 2231-2 as an American National Standard (ANSI) occurred on September 7, 2012. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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Preface

This is the harmonized ANCE, CSA Group, and UL Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems. It is the First edition of NMX-J-668/2-ANCE, the First edition of CSA C22.2 No. 281.2, and the Second edition of UL 2231-2. This edition of UL 2231-2 supersedes the previous edition published in 2002.

This harmonized standard was prepared by the Association of Standardization and Certification (ANCE), CSA Group, and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Working Group for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits are gratefully acknowledged.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

The present Mexican Standard was reviewed and approved by the Comité de Normalización de la Asociación de Normalización y Certificación, A.C., CONANCE.

This standard was reviewed by the CSA Subcommittee on Electric Vehicle – Personal Protection Systems for Supply Circuits, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

This standard has been approved by the American National Standards Institute (ANSI) as an American National Standard.

Where reference is made to a specific number of specimens to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

Level of harmonization

This standard uses the IEC format but is not based on, nor is considered equivalent to, an IEC standard.

This standard is published as an equivalent standard for ANCE, CSA Group, and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

Reasons for differences from IEC

This standard provides particular requirements for personnel protection systems for electric vehicle supply circuits for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for these products for use in accordance with these codes. Therefore, this standard does not employ any IEC standard for base requirements.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

ANCE effective date

The effective date for ANCE will be announced through the Diario Oficial de la Federación (Official Gazette) and is indicated on the cover page.

CSA Group effective date

The effective date for CSA Group will be announced through *CSA Informs* or a CSA Group certification notice.

UL effective date

As of September 7, 2012, all products Listed or Recognized by UL must comply with the requirements in this Standard.

A UL effective date is one established by Underwriters Laboratories Inc. and is not part of the ANSI approved standard.

Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems

INTRODUCTION

1 Scope

1.1 This Standard is intended to be read together with Annex A, Ref. No. 1. The requirements of Annex A, Ref. No. 1 apply unless modified by this Standard.

2 General

2.1 This Part contains the construction and performance requirements that are applied to a device that is intended to become an integral part of an overall device or charging system.

2.2 Annex A, Ref. No. 1 contains an outline of the features required to provide protection based on voltage and grounding or isolation of the system or part of the system under consideration.

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this standard shall comply with the requirements for that component.

3.2 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.

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

3.4 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.

4 Units of Measurement

4.1 The values given in SI (metric) units shall be normative. Any other values given shall be for information purposes only.

5 Normative References

5.1 Where reference is made to any Standards, such reference shall be considered to refer to the latest editions and revisions thereto available at the time of printing, unless otherwise specified.

5.2 Products covered by this standard shall comply with the referenced installation codes and standards noted in Annex A as appropriate for the country where the product is to be used. When the product is intended for use in more than one country, the product shall comply with the installation codes and standards for all countries where it is intended to be used.

CONSTRUCTION

6 General

6.1 The design, workmanship, and degree of production uniformity shall be such that the reliability of the device to perform the functions evaluated by the requirements is high.

7 Grounding

Note: In Canada, equipment grounding conductors are referred to as bonding conductors.

7.1 A grounding circuit shall comply with Annex A, Ref. No. 2 with respect to the size of the grounding conductors.

7.2 All accessible parts of a device that are likely to become energized when arc-over, insulation failure, or the similar conditions occur, shall be connected together and to the terminals intended for an equipment grounding conductor.

7.3 Except as described in 7.4 the equipment grounding conductor shall be sized in accordance with Annex A, Ref. No. 2.

7.4 When a charging circuit interrupting device is intended for use in a circuit where the voltage to ground is greater than 300 Vrms, the impedance of the grounding circuit shall not be higher than that value which limits the voltage to 150 Vrms on accessible parts with respect to earth at the site of the fault during a low impedance fault.

7.5 The accessible parts of a device intended for use on an isolated supply with not more than 150 Vrms between conductors are not required to be grounded.

7.6 In a portable product, accessible parts that are double insulated from energized parts shall not be grounded unless the grounding path is monitored by use of a ground/monitor interrupter.

7.7 Except as indicated in 16.3, a portable device shall be provided with an equipment grounding conductor that extends to the vehicle connector. On the supply side of the interrupting contacts of the CCID, the equipment grounding conductor shall not be connected to accessible conductive parts. On the load side of the CCID interrupting contacts, the equipment grounding conductor shall be connected to the vehicle connector and shall not be connected to accessible metal unless permitted by the construction and potentials involved. See Table 2 of Annex A, Ref. No. 1.

8 Insulation and Protective Features

8.1 An interrupting device such as a charging circuit interrupting device, a grounding monitor/interrupter or an isolation monitor/interrupter, shall have insulation and features or accessories that are required for the voltage rating and type of system where use is intended. See Protective Systems, Section 6, of Annex A, Ref. No. 1 for insulation requirements and features.

8.2 Double insulation or reinforced insulation shall be provided in that part of a grounded circuit between the connections to the supply and the interrupting contacts of the charging circuit interrupting device.

8.3 A device that is required to be double insulated and is rated 120 or 127 or 120/240 Vrms or less shall comply with Annex A, Ref. No. 3.

8.4 A device that is required to be double insulated and is rated more than 120 or 127 or 120/240 Vrms shall comply with the intent of Annex A, Ref. No. 3.

9 Double or Reinforced Insulation Bridged By Components

9.1 Any electrical component that bridges double or reinforced insulation shall comply with 9.2 through 9.4 as applicable.

9.2 Capacitors that bridge double or reinforced insulation shall consist of two capacitors in series, each complying with Subclass Y1 of Annex A, Ref. No. 4. They shall each be rated for the total working voltage across the pair and shall have the same nominal capacitance value.

9.3 Resistors that bridge double or reinforced insulation shall be comprised of two resistors in series. They shall each comply with the requirements of Spacings, Section 12, or Clearances and Creepage Distances, Section 13, between their terminations based on the total voltage across the pair and shall have the same nominal resistance value.

9.4 Where accessible conductive parts or circuits are separated from other parts by double or reinforced insulation that is bridged by components in accordance with 9.1 through 9.3, the accessible parts shall comply with the requirements in Section 38.

10 Accessibility of Energized Parts

10.1 Parts of a device that are capable of being energized during normal operation shall not be accessible.

10.2 In determining compliance with the provisions of 10.1:

- a) A part is determined to be accessible when it is capable of being touched by any part of the articulated probe, see Figure 1, under normal conditions,
- b) A permanently connected device shall be mounted as intended,
- c) A door or cover that is capable of being opened or removed without the use of a separate tool shall be open or removed,
- d) A door or cover that must be opened or removed in order to use a device shall be opened or removed, and
- e) Material that is not accepted as insulation is evaluated as conductive.

11 Internal Wiring

11.1 The gauge and insulation of wires shall withstand the mechanical and electrical stresses of service. Particular consideration should be given to the effect of vibration and user servicing where wire smaller than 0.205 mm² (24 AWG) is employed.

11.2 In a double-insulated device, there shall be at least one independent means provided at a wire termination or splice, which alone prevents the conductor from becoming free to bridge supplementary or reinforced insulation in the event that the wire breaks at the termination or splice. A wire-binding screw or nut, such as one with a spring-type lock washer or equivalent, shall be suitably prevented from loosening under conditions where such loosening allows the attached conductor to become free to bridge supplementary or reinforced insulation.

11.3 Electrical splices and terminations shall provide effective, continuous conductivity.

11.4 In determining compliance of a clamped splice or termination with the provisions of 11.3, consideration shall be given to the risk of permanent deformation under mechanical load (creep).

12 Spacings

12.1 Except as described in 12.2, the spacings of a device shall be evaluated in accordance with:

- a) Spacings, Section 12, and Table 1, or
- b) Clearances and Creepage Distances, Section 13.

Table 1
Through-air and over-surface spacings

Parts separated by	Operating potential between parts											
	70 V peak or less				71 – 200 V peak				201 – 400 V peak			
	Through air		Over surface		Through air		Over surface		Through air		Over surface	
	Open ^a mm (inch)	Closed- in ^b mm (inch)	Open ^a mm (inch)	Closed- in ^b mm (inch)	Open ^a mm (inch)	Closed- in ^b mm (inch)	Open ^a mm (inch)	Closed- in ^b mm (inch)	Open ^a mm (inch)	Closed- in ^b mm (inch)	Open ^a mm (inch)	Closed- in ^b mm (inch)
Functional insulation ^c	1.6 ^d (1/16)	1.6 ^d (1/16)	1.6 ^d (1/16)	1.6 ^d (1/16)	3.2 (1/8)	1.6 ^d (1/16)	6.4 (1/4)	1.6 (1/16)	6.4 (1/4)	3.2 (1/8)	9.5 (3/8)	3.2 (1/8)
Supplementary insulation	3.2 (1/8)	1.6 (1/16)	6.4 (1/4)	1.6 (1/16)	3.2 (1/8)	1.6 (1/16)	6.4 (1/4)	3.2 (1/8)	6.4 (1/4)	1.6 (1/16)	9.5 (3/8)	3.2 (1/8)
Double or reinforced insulation	6.4 (1/4)	3.2 (1/8)	12.7 (1/2)	3.2 (1/8)	6.4 (1/4)	3.2 (1/8)	12.7 (1/2)	6.4 (1/4)	12.7 (1/2)	6.4 (1/4)	19 (3/4)	6.4 (1/4)
^a A space that is not specially protected from deposition of dirt. ^b A space that is specially protected from deposition of dirt such that the construction complies with the requirements of the Dust Test of 41. ^c Smaller spacings may be acceptable where they are inherent in a suitable component. ^d Shall not be less than 0.8 mm (1/32 inch) at a printed wiring board without conformal coating.												

12.2 When a device is an integral part of a charging system, the spacings of the device shall be evaluated in accordance with Annex A, Ref. No. 5.

12.3 Except as indicated below, the through-air and over-surface spacings between conductive parts shall not be less than the values shown in Table 1.

a) At field-wiring terminals, spacings shall not be less than the values shown in Table 2.

b) For printed wiring boards with suitable conformal coating which has been determined to comply with the requirements for conformal coatings in Annex A, Ref. No. 6, spacings are able to be reduced to 0.8 mm (1/32 inch), and are able to be further reduced when the coating is determined to be suitable and a special dielectric withstand test is performed between the conductors.

Table 2
Field wiring terminals spacings

Voltage (RMS)	Spacing distance (over surface or through air)	
	Opposite polarity mm (inch)	To ground mm (inch)
0 – 150	6.4 (1/4)	12.7 (1/2)
151 – 300	9.5 (3/8)	12.7 (1/2)
301 – 600	12.7 (1/2)	12.7 (1/2)
601 – 1000	25.4 (1)	25.4 (1)

12.4 Except as permitted in note c to Table 1, when a groove or a slot in insulating material is less than 0.4 mm (1/64 inch) wide, the contour of the slot or groove shall be disregarded in measuring spacings over the surface.

12.5 Spacings measured along the boundary of insulating materials that have been joined together are regarded as over surface spacings unless it is shown that the dielectric strength of the boundary is not less than that of any of the materials joined.

12.6 In determining compliance with the provisions of Spacings, Section 12, or Clearances and Creepage Distances, Section 13, parts not locked in position, parts subject to random orientation (such as non-circular heads of screws), adjustable parts of terminal connectors, and similar parts, shall be moved to the most adverse position.

12.7 In determining spacings through openings in a housing of insulating material, the use of metal foil is permitted to bridge the opening but shall not be pressed into the opening.

12.8 Film-coated magnet wire is regarded as uninsulated in determining spacings.

13 Clearances and Creepage Distances

13.1 As an alternative to the spacings requirements specified in Spacings, Section 12, and other than as noted in 13.2 and 13.3, clearances and creepage distances may be evaluated in accordance with the requirements in Annex A, Ref. No. 7, as described in 13.4.

13.2 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 this Clause. The clearances shall be determined by physical measurement.

13.3 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in Spacings, Section 12.

13.4 In conducting evaluations in accordance with the requirements in Annex A, Ref. No. 7, the following guidelines shall be used:

- a) Unless specified elsewhere in this standard, the pollution degree shall be regarded as pollution degree 3;
- b) Equipment which operates in the direct line of the source of power to the load equipment shall be regarded as Overvoltage Category II. Other equipment covered under this Standard shall be regarded as Overvoltage Category III;
- c) Pollution degree 2 is regarded as existing on a printed wiring board between adjacent conductive material that 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 Annex A, Ref. No. 8, shall be identified as providing a Comparative Tracking Index (CTI) of 100, and if it further complies with the requirements for Direct Support in Annex A, Ref. No. 8, then it shall be identified as providing 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 Annex A, Ref. No. 7, a coating which complies with the requirements for Conformal Coatings in Annex A, Ref. No. 6, meets the intent of the requirement;
- f) Pollution degree 1 is also capable of being achieved at a specific printed-wiring board location by application of at least a 0.8-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 only clearances to determine equivalence with current through air spacings requirements is capable of being conducted in accordance with Clearance A (Equivalency), of Annex A, Ref. No. 7. An impulse test potential having a value as determined in Annex A, Ref. No. 7 shall be applied across the same points of the device as is required for the Dielectric Voltage-Withstand Test, Section 26;
- h) Evaluation of clearances and creepage distances shall be conducted in accordance with the requirements in Annex A, Ref. No. 7, for Clearance B (Controlled Overvoltage) and Creepage Distances;
- i) The voltage used in the determination of clearances shall be the equipment phase-to-ground rated supply voltage, or the voltage measured in the circuit under consideration, 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 when no isolating transformer is provided. The system voltage used in the evaluation of secondary circuitry is capable of being interpolated with interpolation continued across the table for the rated impulse voltage peak and clearance; and

- j) Determination of the dimensions of clearances and creepage distances shall be conducted in accordance with the requirements for Measurement of Clearances and Creepage Distances of Annex A, Ref. No. 7.

14 Operating Mechanism

14.1 Compliance with the provisions of System Operational Test Requirements, Section 23, shall not be prevented by manipulation or restraint of accessible control levers, knobs, and similar parts, of a device.

14.2 Except as indicated in 14.3 or 14.4, a device that has tripped in accordance with the provisions of System Operational Test Requirements, Section 23, shall not be capable of automatic reclosure.

14.3 A device with an automatic supervisory circuit shall be permitted to have an automatic reset function which permits operation following an acceptable test.

14.4 A device that has been evaluated to Annex A, Ref. No. 9, Annex A, Ref. No. 10, or both, shall be permitted to have an automatic reset function when:

- a) There is a delay of 15 minutes between the tripping function and the reset, and
- b) The device does not reset more than 4 times.

A manual intervention is able to override the delay to the automatic reset. See 43.4.

14.5 A device that trips immediately due to closing onto a fault shall not automatically reset.

14.6 Under the condition where a device opens because of a loss of power on the line side, it shall automatically continue to provide service when power is restored.

14.7 In a permanently-connected device that is not capable of tripping without power from the line, the grounded circuit conductor shall be electrically continuous during normal operation of the device.

14.8 A 120/240 Vrms or polyphase device shall function to provide protection with one or more ungrounded line terminals energized.

14.9 The requirement in 14.8 does not apply if the device is able to automatically disconnect the load when one or more ungrounded line terminals become de-energized, when that is capable of leading to a condition that results in the risk of injury to persons.

15 Isolation Monitor/Interrupter

15.1 An isolation monitor/interrupter shall monitor the resistance of the insulation that provides electrical isolation from ground of an isolated circuit. When the resistance from any ungrounded conductor to ground is less than 100 ohms/volt, based on nominal system voltage, the device shall not allow the load circuit to be energized.

15.2 The AC internal resistance of the monitor shall be at least 250 ohms/volt of nominal system voltage. The DC internal resistance of the measuring device shall be at least 30 ohms/volt of nominal system voltage and shall limit the measuring output current to 5mA.

15.3 An isolation monitor that has an adjustable trip setting shall also have a means to prevent tampering with the setting.

15.4 An isolation monitor shall have a built-in test circuit or means to connect circuitry to verify correct operation of the monitor.

15.5 When the circuit is intended to operate as an isolated circuit throughout the entire charging cycle, then the isolation monitor/interrupter shall continue to monitor the circuit during charging and shall open the circuit when the resistance to ground from any ungrounded conductor is less than 100 ohms/volt.

15.6 An isolation monitor intended to be used on systems where the voltage between conductors is greater than 150 Vrms and where only basic insulation is provided shall have an automatic self-test feature that:

- a) Tests the monitor to determine whether or not it is functioning within intended limits, and
- b) Does not permit energizing the circuitry connected to the load terminals under the condition that the isolation monitor is not functioning properly.

15.7 The test mentioned in 15.6 shall be performed prior to each charging cycle or at regular intervals. If testing is performed at regular intervals, the test shall be performed at least once each hour.

15.8 To demonstrate that an isolation monitor/interrupter meets the requirements of 15.1 – 15.5 tests as described in System Operational Test Requirements, Section 23, shall be performed.

16 Grounding Circuit

16.1 Grounding monitor/interrupter

16.1.1 A device intended to monitor equipment grounding continuity in a charging system shall either prevent the charger circuitry from becoming energized under conditions where the grounding is not available or shall interrupt the circuit under conditions where the grounding is lost during operation.

16.1.2 To demonstrate that a grounding monitor/interrupter meets the requirements of 16.1.1, tests as described in System Operational Test Requirements, Section 23, shall be performed.

16.2 Grounding circuit impedance

16.2.1 The impedance of the grounding circuit shall be limited to a value that does not permit a potential of more than 150 Vrms to be impressed on a person who is in a fault path. The grounding circuit is assumed to be intact and the person is in parallel with the grounding circuit. The potential available at the fault depends upon the location of the fault in the circuit.

16.2.2 In a circuit with a supply greater than 300 Vrms, the limit shall be accomplished by reducing the impedance of the grounding path to a value less than the impedance of the ungrounded conductors by an amount that limits the voltage available at a fault.

16.2.3 The impedance shall be verified by measurement.

16.3 Grounding circuit employing a switched equipment grounding conductor

16.3.1 In Mexico and the US, it shall be permissible for a CCID to employ a switching device in the equipment grounding conductor that extends to the vehicle connector provided the construction complies with the following:

- a) The device is intended for use on a supply circuit not exceeding 150 V to ground,
- b) A grounding monitor interrupter (GM/I) is provided integrally with the CCID,
- c) The switching device in the equipment grounding conductor shall close before the line switching contacts when the output is energized,
- d) The switching device in the equipment grounding conductor shall open after the line switching contacts when the output is deenergized, and
- e) The construction shall comply with Section 39.

In Canada, this requirement does not apply.

17 Supervisory Circuit

17.1 A device intended to be used on a grounded system shall be provided with a supervisory circuit that:

- a) Allows for periodic manual, convenient testing of the ability of the device to trip by way of a simulated ground-fault, or
- b) Automatically tests the system prior to each operation.

17.2 The tests shall include the entire device including the interrupting contacts.

17.3 When it is necessary to employ a separate tool in order to manually operate the supervisory circuit, operation is regarded as inconvenient within the intent of these requirements.

17.4 The simulated fault current shall be of the same polarity as an anticipated actual fault.

17.5 The results of the test shall be made known by means of an evident indication.

17.6 The current employed by the supervisory circuit shall cause tripping at 85 percent of rated voltage. At rated voltage the current shall not exceed 150 percent of the nominal rated tripping current.

17.7 An automatic test system shall be subjected to analysis in accordance with:

- a) Annex A, Ref. No. 9,
- b) Annex A, Ref. No. 10, or
- c) Both (a) and (b), as appropriate.

18 Leakage Cancellation

18.1 It is expected that some electric vehicle supply equipment will be used in locations where a Class A GFCI is required to be installed in accordance with Annex A, Ref. No. 11. In order to prevent unwanted tripping of a Class A GFCI due to leakage currents that exceed the Class A GFCI trip threshold, it shall be permissible for a cord connected CCID20 to employ leakage cancellation provided the construction complies with the following:

- a) The device is intended for use on a supply circuit not exceeding 150 V to ground,
- b) The device is provided with an attachment plug rated 15 or 20 amperes,
- c) A grounding monitor interrupter (GM/I) is provided integrally with the CCID, and
- d) The construction shall comply with Section 40.

PERFORMANCE

19 General

19.1 The representative device or devices being evaluated shall be subjected to the tests shown in Table 3 in the order shown. At the manufacturer's discretion, a representative device can be subjected to more than one test sequence.

Table 3
Test sequence for representative devices

Test	Reference	Test sequence													
		A	B	C	D	E	F	G	H	I	J	K	L	M	N
Humidity Conditioning	Section 20	X	X	X											
Leakage Current Test	Section 21	X	X	X											
Conditioning Tests	Section 22	X	X	X	X										
Ground-Fault Trip Threshold	Subsection 23.2	X													
Interrupting Time	Subsection 23.3	X													
High-Resistance Ground Fault Test	Subsection 23.4	X													
Second Neutral Ground	Subsection 23.5	X													
Test for Isolation Monitor/ Interrupters	Subsection 23.6		X												
Tests for Ground Monitor/ Interrupters	Subsection 23.7			X											
Normal Temperature Test	Section 25				X										
Overload Test	Section 27					X									
Endurance Test	Section 28					X									
Low-Resistance Ground Fault Test	Section 29						X								
Abnormal Operations Test	Section 31							X							
Extra-Low-Resistance Ground Fault Test	Section 32								X						
Short Circuit Test	Section 33									X					
Dielectric Voltage-Withstand Test	Section 26	X	X	X	X	X	X	X	X	X					
Terminal Lead Strain-Relief Test	Section 34										X				
Power Supply Cord Strain-Relief Test	Section 35										X				
Mechanical Tests	Section 36										X				

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Table 3 Continued

Test	Reference	Test sequence													
		A	B	C	D	E	F	G	H	I	J	K	L	M	N
Cable Flexing Test	Section 37										X				
Accessible Conductive Parts With Double Or Reinforced Insulation Bridged By Components	Section 38											X			
Switched Equipment Grounding Conductor Tests – Contact Switching Sequence	Subsection 39.1												X		
Switched Equipment Grounding Conductor Tests – Mechanical Endurance Test	Subsection 39.2												X		
Switched Equipment Grounding Conductor Tests – Ground Fault Test	Subsection 39.3													X	
Leakage Cancellation Tests	Section 40														X

19.2 The tests in Sequences A, B, and C shall be performed in the sequence shown, except that the Conditioning Tests is permitted to precede Humidity Conditioning.

19.3 A device that is double insulated shall also comply with the performance requirements of Annex A, Ref. No. 12.

20 Humidity Conditioning

20.1 A representative device that is to be subjected to Test Sequence A, B, or C from Table 3 shall be conditioned in an atmosphere as described in 20.2.

20.2 The conditioning mentioned in 20.1 and 21.9 is exposure to air at a relative humidity of 93 ± 2 percent at a temperature of $32.0 \pm 2.0^\circ\text{C}$ ($89.6 \pm 3.6^\circ\text{F}$). The device shall be exposed to ambient air at a temperature of at least 30°C (86°F) until thermal equilibrium is attained before placed in the test chamber. A device shall be kept in the chamber for 168 hours.

21 Leakage Current Test

21.1 Except as described in 21.2, the leakage current of a device, when tested in accordance with 21.4 – 21.10, shall not be more than 0.5 MIU-RR.