

July 1, 1996

1

SUBJECT 2231-2

OUTLINE OF INVESTIGATION

FOR

**PERSONNEL PROTECTION SYSTEMS FOR
ELECTRIC VEHICLE (EV) SUPPLY CIRCUITS;
PART 2: PARTICULAR REQUIREMENTS FOR
PROTECTIVE DEVICES FOR USE IN CHARGING SYSTEMS**

Issue Number 1

JULY 1, 1996

COPYRIGHT © 1996 UNDERWRITERS LABORATORIES INC.

CONTENTS**FOREWORD****INTRODUCTION**

1 Scope	5
2 General	5
3 Components	5
4 Units of Measurement	5
5 References	5

CONSTRUCTION

6 General	6
7 Grounding	6
8 Insulation and Protective Features	6
9 Accessibility of Energized Parts	7
10 Internal Wiring	9
11 Spacings	9
12 Clearances and Creepage Distances	11
13 Operating Mechanism	13
14 Isolation Monitor/Interrupter	13
15 Grounding Monitor/Interrupter	13
16 Supervisory Circuit	14

PERFORMANCE

17 General	14
18 Humidity Conditioning	15
19 Leakage Current Test	16
20 Conditioning Tests	19
21 Voltage Surge Test	20
22 System Operational Test Requirements	21
23 Resistance to False Tripping Test (<i>Reserved for future use</i>)	36
24 Resistance to Environmental Noise Test	37
25 Normal Temperature Test	38
26 Dielectric Voltage-Withstand Test	40
27 Overload	41
28 Endurance Test	41
29 Low-Resistance Ground Fault Test	42
30 Supervisory Circuit Test	44
31 Abnormal Operations Test	44
32 Extra-Low-Resistance Ground Fault Test	45
33 Short Circuit Test	46
34 Terminal Lead Strain-Relief Test	47
35 Power Supply Cord Strain-Relief Test	47
36 Mechanical Tests	47

37 Cable Flexing Test	47
-----------------------------	----

RATINGS

38 General	48
------------------	----

MARKINGS

39 General	49
------------------	----

APPENDIX A

Standards for Components	a1
--------------------------------	----

FOREWORD

A. This Outline of Investigation contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Outline of Investigation. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of these requirements by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Outline of Investigation will not necessarily be judged to comply with the Outline of Investigation if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Outline of Investigation may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Outline of Investigation.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Outline of Investigation is processed. UL shall not be responsible to anyone for the use of or reliance upon this Outline of Investigation by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Outline of Investigation.

F. Many tests required by the Outline of Investigations of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 This Part is intended to be read together with the Outline of Investigation for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits – Part 1: General Requirements, Subject 2231-1, hereafter referred to as Part 1. The requirements of Part 1 apply unless modified by this Part.

2 General

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

2.2 Part 1 of this Outline of Investigation 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 Outline of Investigation shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this Outline of Investigation.

3.2 A component need not comply with a specific requirement that:

- a) Involves a feature or characteristic not needed in the application of the component in the product covered by this Outline of Investigation, or
- b) Is superseded by a requirement in this Outline of Investigation.

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

3.4 Specific components are recognized as being 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 for which they have been recognized.

4 Units of Measurement

4.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

5 References

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

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 will be high.

7 Grounding

7.1 A system intended to provide protection shall be grounded where required to be grounded by Article 250 of the National Electric Code (NEC).

7.2 All accessible parts of a device intended for use on a grounded supply that are likely to become energized if there should be arc-over, insulation failure, or the like, 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 by Article 250 of the NEC.

7.4 When a charging circuit interrupting device is intended for use in a circuit where the voltage to ground is greater than 300 V, the impedance of the grounding circuit shall not be higher than that value which would limit the voltage to 150 V 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 V between conductors need not be grounded.

7.6 The accessible parts of a device that is double insulated shall not be grounded.

7.7 The equipment grounding conductor of a portable or cord-connected device shall be conductively connected to the grounding contacts of the attachment plug and the accessible parts in the load circuit of the interrupting contacts, and shall not be connected to accessible conductive parts of the charger or the charging circuit interrupting device that would not be protected by the contacts of the charging circuit interrupting device.

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 suitable for the voltage rating and type of system where use is intended. See Protective Systems, Section 5, of Subject 2231-1 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 120/240 V or less shall comply with the requirements of the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

8.4 A device that is required to be double insulated and is rated more than 120 or 120/240 V shall comply with the intent of UL 1097.

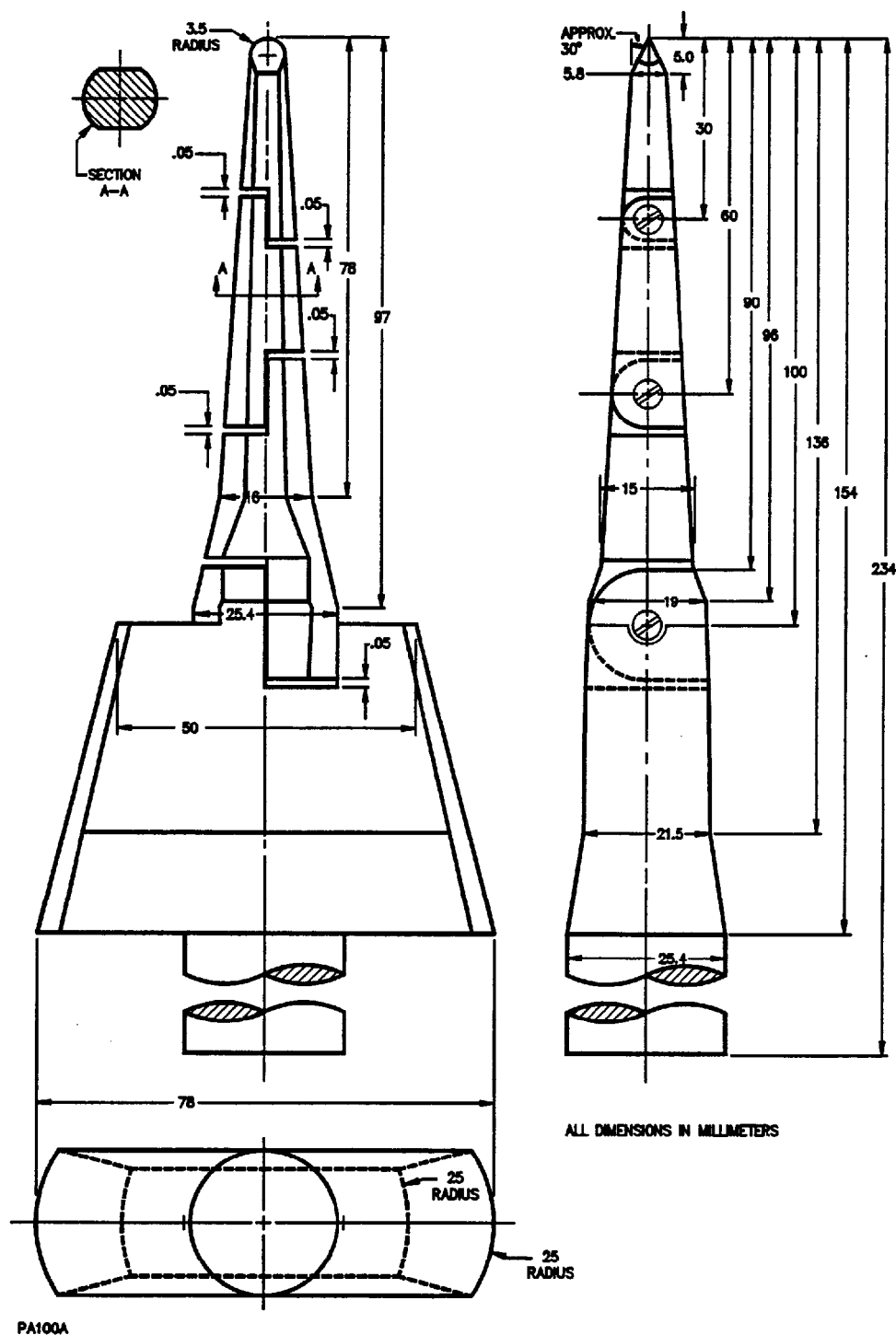
9 Accessibility of Energized Parts

9.1 Parts of a device that may become energized shall not be accessible.

9.2 In determining compliance with the provisions of 9.1:

- a) A part is considered to be accessible if it can be touched by any part of the articulated probe, see Figure 9.1, when the device is functioning,
- b) A permanently connected device is to be mounted as intended,
- c) A door or cover that can be opened or removed without the use of a separate tool is to be open or removed,
- d) A door or cover that must be opened or removed in order to use a device is to be opened or removed, and
- e) Material that is not acceptable as insulation is considered to be conductive.

Figure 9.1
Articulated probe



^a The probe is to be used only as a gauge and inserted with minimal force. The probe shall be rotated with the moveable sections straight or in any possible position resulting from bending one or more sections in the same direction.

10 Internal Wiring

10.1 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 No. 24 AWG (0.21 mm²) is employed.

10.2 In a double-insulated device, there shall be at least one independent means provided at a wire termination or splice, which alone could prevent the conductor from becoming free to bridge supplementary or reinforced insulation in the event that the wire should break at the termination or splice. A wire-binding screw or nut, such as one with a spring-type lockwasher or equivalent, shall be suitably prevented from loosening if such loosening could allow the attached conductor to become free to bridge supplementary or reinforced insulation.

10.3 Electrical splices, terminations, and the like shall provide effective, continuous conductivity.

10.4 In determining compliance of a clamped splice or termination with the provisions of 10.3, consideration is to be given to the likelihood of permanent deformation under mechanical load (creep).

11 Spacings

11.1 The spacings of a device are to be evaluated in accordance with:

- a) Spacings, Section 11, and Table 11.1, or
- b) Clearances and Creepage Distances, Section 12.

Exception: If a device is an integral part of a charging system, then the spacings of the device are to be evaluated in accordance with the requirements in Spacings, Section 22, of the Outline of Investigation for Electric Vehicle (EV) Charging System Equipment, Subject 2202.

11.2 Except at field-wiring terminals, the through-air and over-surface spacings between conductive parts shall not be less than the values shown in Table 11.1.

11.3 Spacings at field wiring terminals shall not be less than the values shown in Table 11.2.

Table 11.1
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	Through air	Over surface
	Open ^a inch (mm)	Closed-in ^b inch (mm)	Open ^a inch (mm)	Closed-in ^b inch (mm)	Open ^a inch (mm)	Closed-in ^b inch (mm)	Open ^a inch (mm)	Closed-in ^b inch (mm)
Functional insulation	1.16 ^d (1.6)	1/16 ^d (1.6)	1/16 ^d (1.6)	1/16 ^d (1.6)	1/8 (3.2)	1/16 ^d (1.6)	1/4 (6.4)	1/8 (3.2)
Supplementary insulation	1/8 (3.2)	1/16 (1.6)	1/8 (3.2)	1/16 (1.6)	1/8 (3.2)	1/8 (3.2)	1/4 (6.4)	1/8 (3.2)
Double or reinforced insulation	1/4 (6.4)	1/8 (3.2)	1/2 (12.7)	1/8 (3.2)	1/4 (6.4)	1/8 (3.2)	1/2 (12.7)	1/4 (6.4)

^a A space that is not specially protected from deposition of dirt.
^b A space that is specially protected from deposition of dirt.
^c Smaller spacings may be acceptable where they are inherent in a suitable component.
^d May be less than 1/16 inch (1.6 mm), but not less than 1/32 inch (0.8 mm) at a printed wiring board without conformal coating.
^e For printed wiring boards with suitable conformal coating which has been determined to comply with the requirements for conformal coatings in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, spacings may be reduced to 1/32 inch (0.8 mm), and may be further reduced if the coating is determined to be suitable and a special dielectric withstand test is performed between the conductors.

Table 11.2
Field wiring terminals spacings

Voltage (RMS)	Spacing distance (over surface or through air)	
	Opposite polarity inch (mm)	To ground inch (mm)
0 – 150	1/4 (6.4)	1/2 (12.6)
151 – 300	3/8 (9.5)	1/2 (12.6)
301 – 600	1/2 (12.6)	1/2 (12.6)
601 – 1000	1 (25.4)	1 (25.4)

11.4 Except as permitted in note c to Table 11.1, if a groove or a slot in insulating material is less than 1/64 inch (0.4 mm) wide, the contour of the slot or groove is to be disregarded in measuring spacings over the surface.

11.5 Spacings measured along the boundary of insulating materials that have been joined together are considered to be spacings over surface unless it can be shown that the dielectric strength of the boundary is not less than that of any of the materials joined.

11.6 In determining compliance with the provisions of Spacings, Section 11, or Clearances and Creepage Distances, Section 12, parts not locked in position, parts subject to random orientation (such as noncircular heads of screws), adjustable parts of terminal connectors, and the like, are to be moved to the most adverse position.

11.7 In determining spacings through openings in a housing of insulating material, metal foil may be used to bridge the opening but is not to be pressed into the opening.

11.8 Film-coated magnet wire is considered to be uninsulated in determining spacings.

12 Clearances and Creepage Distances

12.1 As an alternative to the spacings requirements specified in Spacings, Section 11, and other than as noted in 12.2 and 12.3, clearances and creepage distances may be evaluated in accordance with the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, as described in 12.4.

12.2 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 Section. The clearances shall be determined by physical measurement.

12.3 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in Spacings, Section 11.

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

- a) Unless specified elsewhere in this Outline of Investigation, the pollution degree shall be considered to be pollution degree 3;
- b) Equipment which operates in the direct line of the source of power to the load equipment shall be considered to be Overvoltage Category II. Other equipment covered under this Outline of Investigation shall be considered to be Overvoltage Category III;
- c) Pollution degree 2 may be considered to exist 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, Section 22, in UL 796 then it shall be considered to provide 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, Section 44, in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, is considered to be acceptable;
- f) Pollution degree 1 may also be achieved at a specific printed-wiring board location by application of at least a 1/32-inch (0.79-mm) 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 may be conducted in accordance with Clearance A (Equivalency), Section 4, 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 26;
- h) Evaluation of clearances and creepage distances shall be conducted in accordance with the requirements in UL 840 for Clearance B (Controlled Overvoltage), Section 5, and Creepage Distances, Section 6;
- 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 may be 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, Section 7, of UL 840.

13 Operating Mechanism

13.1 Compliance with the provisions of System Operational Test Requirements, Section 22, shall not be prevented by manipulation or restraint of accessible control levers, knobs, and the like, of a device.

13.2 A device that has tripped in accordance with the provisions of System Operational Test Requirements, Section 22, shall not be capable of automatic reclosure, except as permitted for automatic supervisory circuits. See Supervisory Circuit, Section 16.

13.3 If a device opens because of a loss of power on the line side, it shall automatically continue to provide service when power is restored.

13.4 In a permanently-connected device that cannot trip without power from the line, the grounded circuit conductor shall be electrically continuous during normal operation of the device.

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

Exception: The device may automatically disconnect the load when one or more ungrounded line terminals become de-energized, if that can lead to a condition that may result in the risk of injury to persons.

14 Isolation Monitor/Interrupter

14.1 An isolation monitor/interrupter shall monitor the impedance of the insulation that provides electrical isolation from the ground of an isolated circuit. If it is possible to draw more than 5 MIU to ground from any point on the isolated circuit when it is energized at full operating voltage, the device shall not energize the circuitry connected to its load terminals.

14.2 If 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 if it becomes possible to draw more than 5 MIU to ground from any point on the isolated circuit.

14.3 A isolation monitor intended to be used on systems where the voltage between conductors is greater than 150 V shall have an automatic self-test feature that:

- a) Will test the monitor to determine whether or not it is functioning within acceptable limits, and
- b) Will not permit energizing the circuitry connected to the load terminals if the isolation monitor is not functioning properly.

14.4 To demonstrate that an isolation monitor/interrupter meets the requirements of 14.1 – 14.2 tests as described in System Operational Test Requirements, Section 22, shall be performed.

15 Grounding Monitor/Interrupter

15.1 A device intended to monitor grounding continuity shall prevent the circuit from closing if a suitable grounding path is not present and shall open the circuit to the load if the grounding path is lost during operation.

15.2 When rated for use on a circuit where no conductor is more than 150 V above ground or where a centrally-located ground with impedance limitation is not required, a suitable grounding path is one that has an impedance no greater than 1.5 times the impedance of an ungrounded conductor.

15.3 When rated for use on a circuit where a conductor may be more than 150 V above ground or where a centrally-located ground with impedance limitation is not required, a suitable grounding path is one that has an impedance no greater than the impedance of an ungrounded conductor.

15.4 When rated for use on a circuit where a centrally-located ground with impedance limitation is required, a suitable grounding path is one that has an impedance that will limit the voltage to 150 V on accessible parts with respect to earth at the site of a fault during a low-impedance ground-fault.

15.5 To demonstrate that a grounding monitor/interrupter meets the requirements of 15.1 tests as described in System Operational Test Requirements, Section 22, shall be performed.

16 Supervisory Circuit

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

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

16.2 The test shall include the entire device including the interrupting contacts.

16.3 If it is necessary to employ a separate tool in order to manually operate the supervisory circuit, operation is considered not to be convenient within the intent of these requirements.

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

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

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

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

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991,
- b) The Standard for Safety-Related Software, UL 1998, or
- c) Both (a) and (b),

as appropriate.

PERFORMANCE

17 General

17.1 A representative device(s) being evaluated shall be subjected to the tests shown in Table 17.1 in the order shown. At the manufacturers discretion, a representative device may be subjected to more than one test sequence.

Table 17.1
Test sequences for representative devices

Test name	Test sequence									
	A	B	C	D	E	F	G	H	I	J
Humidity Conditioning (Section 18)	x	x	x							
Leakage Current Test (Section 19)	x	x	x							
Conditioning Tests (Section 20)	x	x	x							
Voltage Surge Test (Section 21)	x	x	x							
Ground-Fault Trip Threshold (Section 22.2)	x									
Interrupting Time (Section 22.3)	x									
High-Resistance Ground Fault Test (Section 22.4)	x									
Tests for Isolation Monitor/Interrupters (Section 22.6)		x								
Tests for Ground Monitor/Interrupters (Section 22.7)			x							
Normal Temperature Test (Section 25)				x						
Overload (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
Cable Flexing Test (Section 37)										x

17.2 The tests in Sequences A, B, and C are to be performed in the sequence shown, except that the Impact Test may precede Humidity Conditioning.

17.3 A device that is double insulated shall also comply with the performance requirements of the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

18 Humidity Conditioning

18.1 A representative device that is to be subjected to Test Sequence A, B, or C from Table 17.1 shall be conditioned in an atmosphere as described in 18.2.

18.2 The conditioning mentioned in 18.1 and 19.8 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 is to 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 is to be kept in the chamber for 168 hours.

19 Leakage Current Test

19.1 The leakage current of a device, when tested in accordance with 19.2 – 19.8, shall be no more than 0.5 MIU-RR.

Exception: The leakage current from any part to ground may exceed 0.5 MIU if components of the device are permitted to have leakage greater than 0.5 MIU. In no case shall the leakage current to ground exceed 3.5 MIU. See 19.10. The leakage current from one accessible part to another accessible part shall not exceed 0.5 MIU.

19.2 All accessible conductive surfaces are to be tested for leakage currents to determine compliance with 19.1. Where surfaces are simultaneously accessible, they are to be tested:

- a) Individually,
- b) Collectively (connected together) with the combined current measured to ground, and
- c) Point-to-point on the device for leakage current between the simultaneously accessible surfaces.

Surfaces are considered to be simultaneously accessible when they can be touched by one or both hands of a person at the same time. Accessible parts within a 100 mm by 200 mm (4 inch by 8 inch) rectangle are considered simultaneously accessible to one hand. The rectangle may be flexed or bent to closely conform to the surface of the device. Accessible parts that can be touched at the same time by the ends of a string 1.8 m (6 ft) in length are considered to be simultaneously accessible to both hands. The grounding pin, blade, or contact of an attachment plug is considered an accessible part.

19.3 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 with an area of 100 mm by 200 mm in contact with the surface. Where the surface is less than 100 mm by 200 mm, the metal foil is to be the same size as the surface. The metal foil is not to be pressed into openings and is not to remain in place long enough to affect the temperature of the representative device.

19.4 Typical measurement circuits for leakage current with the ground connection open are illustrated in Figures 19.1 and 19.2. The measurement instrument is defined in Figure 19.3. Over the frequency range of 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:

- a) The measured ratio $V1/I1$ with sinusoidal voltages is to be as close as feasible to the ratio $V1/I1$ calculated with the resistance and capacitance values of the measurement instrument shown in Figure 19.3.
- b) The measured ratio $V3/I1$ with sinusoidal voltages is to be as close as feasible to the ratio $V3/I1$ calculated with the resistance and capacitance values of the measurement instrument shown in Figure 19.3. $V3$ is to be measured by the meter M in the measuring circuit. The reading of meter M in RMS volts can be converted to MIU by dividing the reading by 500 ohms and then multiplying the quotient by 1000. The mathematic equivalent is to multiply the RMS voltage reading by 2.