SUBJECT 2594

OUTLINE OF INVESTIGATION

FOR

Electric Vehicle Supply Equipment

Issue Number: 1

November 5, 2009

SUMMARY OF TOPICS

This First Issue of Subject 2594, Outline of Investigation for Electric Vehicle Supply Equipment, covers requirements for electric vehicle (EV) supply equipment, rated a maximum of 250 V ac, with a frequency of 60 Hz, and intended to provide power to an electric vehicle with an on-board charging unit and intended for use where ventilation is not required.

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: http://ulstandardsinfonet.ul.com/ulforeword.html

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PROTECTION OF USERS AGAINST INJURY

PERFORMANCE

MARKING

INSTRUCTIONS

APPENDIX A

APPENDIX B

INTRODUCTION

1 Scope

1.1 This outline covers electric vehicle (EV) supply equipment, rated a maximum of 250 V ac, with a frequency of 60 Hz, and intended to provide power to an electric vehicle with an on-board charging unit. This outline covers electric vehicle supply equipment intended for use where ventilation is not required.

1.2 With reference to 1.1, the products covered by this outline include EV cord sets and EV charging stations. EV cord sets may be designated as portable cord sets or stationary cord sets and may be designated for indoor or outdoor use. EV charging stations may be designated as either movable or permanent charging stations and may be designated for indoor or outdoor use.

1.3 The products covered by this outline are intended for use in accordance with the National Electrical Code (NEC), ANSI/NFPA 70.

1.4 This outline does not cover cord sets or power supply cords for applications other than EV charging cord sets. Cord sets and power supply cords are covered by the Standard for Cord Sets and Power Supply Cords, UL 817. EV Cables are covered by the Standard for Flexible Cords and Cables, UL 62, and the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

1.5 With reference to 1.2, this outline does not cover electric vehicle charging units. These products provide an output that is delivered directly to charge an on-board battery pack. These products are covered by the Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202.

1.6 This outline does not cover electric vehicle connectors, which are covered by the Standard for Plugs, Receptacles, and Couplers for Electric Vehicles, UL 2251.

2 Components

2.1 Except as indicated in 2.2, a component used as a part of a unit covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the units covered by this standard.

2.2 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.

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

2.4 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.

3 Units of Measurement

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

4 Undated References

4.1 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.

5 Glossary

5.1 For the purposes of this outline, the following definitions apply. In addition, in the text of this document, the term “device” refers to the product covered by this outline.

5.2 ACCESSIBLE – Able to be contacted by an accessibility probe.

5.3 BONDED (BONDING) – The permanent joining of metallic parts to form an electrically conductive path that provides electrical continuity and the capacity to conduct any current likely to be imposed without a risk of electric shock or fire.

5.4 BONDING JUMPER – A conductor, including a strap or similar part that is used to provide the required electrical conductivity between metal parts required to be electrically connected.

5.5 BRANCH CIRCUIT – The portion of the building wiring system beyond the final overcurrent protective device on the power-distribution panel that protects the circuit to the receptacle outlet.

5.6 CHARGING CIRCUIT INTERRUPTING DEVICE (CCID) – A device that continuously monitors the differential current among all of the current-carrying line conductors in a grounded system and rapidly interrupts the circuit under conditions where the differential current exceeds the rating of the charging circuit interrupting device. The device is identified by the letters CCID followed by the differential trip current rating of either 5 or 20 mA.

5.7 CHARGING STATION, MOVABLE – A device used to provide power to an on-board charger. The device is cord connected and intended to be moved from one position to another between uses.

5.8 CHARGING STATION, PERMANENT – A device used to provide power to an on-board charger. The device is permanently wired and fixed in place to the supporting surface, a wall, a pole, or other structure.

5.9 CONTROL CIRCUIT – A circuit that carries electric signals but not main power current.

5.10 CORD SET, PORTABLE – An EV cord set that is intended for indoor or outdoor use, and is intended to be carried from charging location to charging location and is transported in the vehicle when not in use. This type of cord set will be subject to changing environmental conditions and all foreseeable abuses.

5.11 CORD SET, STATIONARY – An EV cord set that is intended for indoor or outdoor use, and is intended to be installed in a dedicated location in order to charge a vehicle. The cord set may be intended to be routinely moved after this installation, and it may have provisions for removal from its installation without the use of a tool. This type of cord set will be subject to limited environmental conditions when intended for indoor use only, and will be subject to limited abuses due to the intended installation.

5.12 DEGREE OF PROTECTION – The extent of protection provided by an enclosure against access to parts which result in a risk of injury, ingress to foreign solid objects, and/or ingress of water as verified by standardized test methods.

5.13 DIRECT PLUG-IN EQUIPMENT – Devices that are provided with the means to connect to the wall outlet built into the product. No power cord is provided.

5.14 ELECTRIC VEHICLE (EV) – An over-the-road automotive type vehicle for highway use, such as a passenger automobile, bus, truck, van, or similar vehicle, which receives primary or supplementary power from an electric motor that draws current from a rechargeable storage battery. This term is used to cover electric vehicles, hybrid electric vehicles, and plug-in hybrid electric vehicles.

5.15 ELECTRIC VEHICLE PLUG – A device intended to receive power when inserted into an electric vehicle receptacle, which establishes connection between conductors of the attached EV cable and the conductors connected to the EV receptacle.

5.16 ELECTRIC VEHICLE RECEPTACLE – A device that is intended to provide power to an inserted EV plug, and that is usually installed as a fixed outlet on electric vehicle supply equipment.

5.17 ENCLOSURE – That portion of a device that reduces the accessibility of a part that involves a risk of fire, electric shock, injury to persons, or hazardous energy levels, or reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

5.18 ENERGIZED PART – A part at some potential with respect to another part or earth.

5.19 EXPOSED – Visible but not necessarily able to be contacted by an accessibility probe.

5.20 GROUND – A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth or to some conducting body that serves in place of the earth.

5.21 GROUNDED – Connected to earth or to some conducting body that serves in place of earth.

5.22 GROUNDED CONDUCTOR – A system or circuit conductor that is intentionally grounded.

5.23 GROUNDING CONDUCTOR – The conductor used to connect the non-current-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both at the service equipment or at the source of a separately derived system.

5.24 GROUNDING MONITOR/INTERRUPTER – A device that monitors equipment grounding continuity in a charging system, and either prevents the circuitry from becoming energized under conditions where the grounding is not available or interrupts the circuit under conditions where the grounding is lost during operation.

5.25 INSULATION CLASSES – The following insulation classes are used to describe insulation between different circuits:

a) Basic Insulation – the insulation required for the proper functioning of a device, and for basic protection against electrical hazards.

b) Supplementary Insulation – An independent insulation provided in addition to the basic insulation to protect against electric shock hazards in the event the basic insulation fails.

c) Double Insulation – A system of two independent insulations, each of which is capable of acting as the sole insulation between live and accessible parts in the event of failure of the other insulation. The insulation system resulting from a combination of basic and supplementary insulation.

d) Reinforced Insulation - A single insulation system with such mechanical and electrical qualities that it, in itself, provides the same degree of protection against the risk of electric shock, as does double insulation. The term “single insulation system” does not require that the insulation must be in one homogeneous piece. The insulation system comprises two or more layers that shall not be tested as supplementary or basic insulation.

5.26 ISOLATION MONITOR/INTERRUPTER – A device that monitors the insulation resistance of an isolated circuit to ground and prevents energization of the circuit or disconnects an energized circuit when the insulation resistance drops below a predetermined value.

5.27 ISOLATION MONITOR/INTERRUPTER WITH SELF CHECK – A device similar to that described in 5.26 except that it is also equipped with an automatic supervisory circuit that periodically checks the operation of the isolation monitor and does not permit energizing the circuitry, or during operation, disconnects the energizing circuitry connected to the load terminals of the isolated circuit under conditions where the isolation monitor does not function properly.

5.28 KNOCKOUT – A portion of a wall of a sheet metal enclosure so fashioned that it may be removed readily by a hammer, screwdriver, and pliers at the time of installation in order to provide a hole for the attachment auxiliary device or raceway, cable, or fitting.

5.29 LEAKAGE CURRENT – Electric current which flows through a person upon contact between accessible parts of a device and ground or between accessible parts of a device and other accessible parts of the device.

5.30 LIMITED ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 V and the energy limited to 100 volt-amperes by a means provided as part of the design.

5.31 LIVE PART – A conductive part, such as metal, within the device that during intended use has a potential difference with respect to earth ground or any other conductive part.

5.32 LOW-VOLTAGE, LIMITED-ENERGY (LVLE) CIRCUIT – A circuit involving an alternating current voltage of not more than 30 volts, rms (42.4 volts peak) or a direct current voltage of not more than 60 volts and supplied by:

a) An inherently limited Class 2 transformer or power unit or a not inherently limited Class 2 transformer or power unit and a fuse or other circuit protective device that is:

1) Not of the automatic reclosing type;

2) Trip-free from the reclosing mechanism; and

3) Either not readily interchangeable with a device of a different rating or a marking in accordance with 76.8 is provided; or

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 25.11 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source.

5.33 MEASUREMENT INDICATION UNIT (MIU) – The output voltage across the meter, in millivolts rms, in the measurement instrument in Figure 44.3, divided by 500 ohms.

5.34 OVERVOLTAGE CATEGORY – A grouping of products based on typical installed location with respect to overvoltage protection and available energy.

5.35 POLLUTION DEGREE – The level of pollution present at the location on or in a product where the clearance and creepage distance measurement is made, and can be controlled by design of the product. For example, enclosures can be used to achieve pollution degree 3, and encapsulation can be used to achieve pollution degree 1.

5.36 PRIMARY CIRCUIT – Wiring and components that are conductively connected to the branch circuit.

5.37 PRIMARY SOURCE – The branch circuit to which the ac input of the device is connected.

5.38 SAFETY CIRCUIT – Any circuit that is used to reduce the risk of fire, electric shock, or injury to persons. For example, in some applications, an interlock circuit would be considered a safety circuit.

5.39 THREADED CONDUIT ENTRY – A conduit entry that is threaded so as to secure a rigid conduit without the use of a bushing or locknut.

5.40 TOOL – A screwdriver, coin, key or any other object that is used to operate a screw, latch, or similar fastening means.

5.41 VEHICLE CONNECTOR – A connector, which by insertion into a electric vehicle inlet, establishes an electrical connection to the electric vehicle for the purpose of providing power and information exchange, with means for attachment of an EV cable. This device is part of the Vehicle Coupler.

5.42 VEHICLE COUPLER – The means enabling the connection, at will, of an EV cable to the vehicle. It consists of a Vehicle Connector and a Vehicle Inlet.

5.43 VEHICLE INLET – The part incorporated in, or fixed to the vehicle or intended to be fixed to it, which receives power from the vehicle connector. This device is part of the Vehicle Coupler.

CONSTRUCTION

6 General

6.1 EV cord sets

6.1.1 EV cord sets shall consist of an attachment plug, flexible power cord, personnel protection system, EV cable, and a vehicle connector. For direct plug in EV cord sets, the flexible power cord is not provided.

6.1.2 An EV Cord Set shall be provided with one or more enclosures that house all hazardous live parts, and energy hazardous circuits, excluding the flexible power cord or the EV cable. The enclosure shall protect the various parts of the device against mechanical damage from forces external to the EV Cord Set. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, and access to hazardous energy, shall comply with the applicable enclosure requirements specified in this outline. See 6.1.3.

6.1.3 EV Cord Sets shall be investigated based on the intended use of the cord set. Intended use shall be classified as one of the following:

a) Indoor use only, stationary cord set;

b) Indoor/outdoor use, stationary cord set; or

c) Indoor/outdoor use, portable cord set.

See 43.3 and Appendix B for a list of applicable tests for each intended use classification. Construction requirements will specify which classification is required to comply with that specific requirement. Construction requirements with no specification apply to all classification types. All EV cord sets shall be evaluated based on an expected operating ambient of minus 22°F to 104°F (minus 30°C to 40°C).

6.1.4 The frame or chassis of the device shall not be used to carry current during intended operation.

6.2 EV charging stations

6.2.1 EV charging stations shall terminate in a grounding type, non-locking type, NEMA receptacle, an EV receptacle, or an EV connector on the vehicle side of the device.

6.2.2 An EV charging station shall be provided with enclosures that house all hazardous live parts, and energy hazardous circuits, excluding the flexible power cord and the EV cable. The enclosure shall protect the various parts of the device against mechanical damage from forces external to the EV charging station. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, and access to hazardous energy, shall comply with the applicable enclosure requirements specified in this outline. See 6.2.3.

6.2.3 EV charging stations shall be investigated based on the intended use of the charging station. Intended use shall be classified as one of the following:

a) Indoor use only, movable charging stations;

b) Indoor/outdoor use, movable charging stations;

c) Indoor use only, permanent charging stations;

d) Indoor/outdoor use, permanent charging stations.

See 43.3 and Appendix B for a list of applicable tests for each intended use classification. Construction requirements will specify which classification is required to comply with that specific requirement. Construction requirements with no specification apply to all classification types. All EV charging stations shall be evaluated based on an expected operating ambient of minus 22°F to 104°F (minus 30°C to 40°C).

6.2.4 The frame or chassis of the device shall not be used to carry current during intended operation.

7 Frame and Enclosure

7.1 General

7.1.1 An enclosure shall be formed and assembled so that it has the strength and rigidity required to resist the abuses to which it may be subjected without resulting in a risk of fire or electrical shock due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other defects.

7.1.2 The enclosure shall prevent molten metal, burning insulation, flaming particles, or similar materials from falling on combustible materials outside the enclosure.

7.1.3 A part, such as a dial, display face, or nameplate, that serves as a functional part of the enclosure shall comply with the enclosure requirements in this outline.

7.1.4 A component that produces arcing or sparking, such as a snap switch, a relay, or a receptacle, shall be inherently located at least 18 inches (457 mm) above the floor. For products where these components are not inherently located above 18 inches, the requirements in 7.1.5 – 7.1.6 apply.

Exception: Arcing and sparking components that have been evaluated and found to be suitable for use in a Class 1, Division 2 location need not comply with this requirement.

7.1.5 Products that are intended to be carried by hand and are capable of being placed on the floor and which would allow arcing and sparking components to be located less than 18 inches (457 mm) from the floor, shall be marked in accordance with 76.9.

7.1.6 Movable products that are intended to be floor supported and contain arcing and sparking components inherently located above 18 inches (457 mm) shall be marked in accordance with 76.10.

7.1.7 All enclosures shall be rated for a specific degree of environmental protection as outlined in 7.7.

7.2 Access covers

7.2.1 An access cover shall be hinged where it gives access to a fuse or other overload protective device located in a hazardous live circuit, the functioning of which requires renewal or resetting by the user, or where it is required for the user to open the cover in connection with intended operation of the device. A means shall be provided to hold the cover positively closed.

7.2.2 A door or cover giving access to a fuse shall be tight fitting.

7.3 Metallic enclosures

7.3.1 General

7.3.1.1 A metallic enclosure shall comply with the requirements for mechanical strength in 7.6.

7.3.1.2 A metallic enclosure, constructed of aluminum, steel, stainless steel, or similar metals, is considered to comply with flammability requirements without test. Magnesium shall not be used as an enclosure material.

7.3.1.3 A metallic enclosure shall comply with the applicable environmental considerations for the intended use in accordance with Section 7.7.

7.3.2 Cast metal enclosures

7.3.2.1 The thickness of cast metal for an enclosure shall be as specified in Table 7.1.

Exception:

Table 7.1
Thickness of cast-metal enclosures

Use, or dimension of area involved	Minimum thickness, inch (mm)			
	Die-cast metal		Cast metal of other than the die-cast type	
Area of 24 square inches (154.8 cm^2) or less and having no dimension greater than 6 inches (152 mm)	1/16[a]	(1.6)	1/8	(3.2)
Area greater than 24 square inches (154.8 cm^2) or having any dimension greater than 6 inches (152 mm)	3/32	(2.4)	1/8	(3.2)
At a threaded conduit hole	1/4	(6.4)	1/4	(6.4)
At an unthreaded conduit hole	1/8	(3.2)	1/8	(3.2)

[a] The area limitation for metal 1/16 inch (1.6 mm) thick is obtained by the provision of reinforcing ribs subdividing a larger area.

7.3.3 Sheet metal enclosures

7.3.3.1 Sheet metal enclosures shall comply with the requirements in the Standard for Enclosures for Electrical Equipment, UL 50, or 7.3.3.2 – 7.3.3.5.

7.3.3.2 With reference to 7.3.3.1, the thickness of a sheet metal enclosure shall not be less than that specified in Tables 7.2 and 7.3.

7.3.3.3 Tables 7.2 and 7.3 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.

7.3.3.4 With reference to Tables 7.3 and 7.4, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has the same outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that are applied via the enclosure surface. A construction has equivalent reinforcement when it produces a structure that is as rigid as one built with a frame of angles or channels.

7.3.3.5 With reference to 7.3.3.4 and Tables 7.3 and 7.4, a construction does not have a supporting frame when it is:

a) A single sheet with single formed flanges – formed edges;

b) A single sheet that is corrugated or ribbed;

c) An enclosure formed or fabricated from sheet metal; or

d) An enclosure surface loosely attached to a frame – for example, by spring clips.

Table 7.2
Thickness of carbon steel or stainless steel enclosures

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness inch (mm)			
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	Uncoated		Metal coated	
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[d]	(0.51)	0.023[d]	(0.58)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)				
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026[d]	(0.66)	0.029[d]	(0.74)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)				
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)				
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)				
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)	0.056	(1.42)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)				
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)	0.063	(1.60)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)				
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)				

Table 7.2 Continued on Next Page

Table 7.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness inch (mm)			
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	Uncoated		Metal coated	
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)	0.084	(2.13)
38.0	(103.4)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)				
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093	(2.36)	0.097	(2.46)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)				
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108	(2.74)	0.111	(2.82)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)				
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)	0.126	(3.20)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)				

[a] See 7.3.3.4 and 7.3.3.5.

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

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

[d] Sheet steel for an enclosure intended for outdoor use shall not be less than 0.034 inch (0.86 mm) thick when metal coated and not less than 0.032 inch (0.81 mm) thick when uncoated.

Table 7.3
Thickness of aluminum, copper, or brass enclosures

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

[a] See 7.3.3.4 and 7.3.3.5.

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

Table 7.3 Continued on Next Page

Table 7.3 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness inches (mm)
Maximum width[b] inches	(cm)	Maximum length[c] inches	(cm)	Maximum width[b] inches	(cm)	Maximum length inches	(cm)	

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

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use shall not be less than 0.029 inch (0.74 mm) thick.

7.4 Nonmetallic enclosures

7.4.1 General

7.4.1.1 A nonmetallic enclosure shall comply with the requirements for mechanical strength in 7.6.

7.4.1.2 Nonmetallic materials used in the construction of enclosures shall have a flammability rating in accordance with Flammability, Section 18.

7.4.1.3 A nonmetallic enclosure shall comply with the applicable environmental considerations for the intended use in accordance with 7.7. See 43.3.

7.4.1.4 Enclosures of molded or formed thermoplastic material shall be constructed so that any shrinkage or distortion of the material over time will not allow for the user to be exposed to hazardous live parts. Compliance is determined by the Mold Stress Test, Section 64.

7.4.1.5 The minimum thickness of a nonmetallic enclosure shall be such as to comply with the requirements of 7.4.1.1 – 7.4.1.4.

7.4.1.6 A polymeric material enclosure having in any single unbroken section, a projected surface area greater than 10 square feet (0.93 m^2) or a single linear dimension greater than 6 feet (1.83 m) shall have a flame-spread rating of 200 or less when tested in accordance with the:

a) Standard for Test for Surface Burning Characteristics of Building Materials, UL 723, or

b) Radiant-panel furnace method in the Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, ASTM E162.

7.4.2 Electrical properties

7.4.2.1 A polymeric material used for enclosures of live parts shall comply with the requirements in Sections 70 – 72.

Exception No. 1: A polymeric material having a maximum Comparative Tracking Index (CTI) performance level class of 3 need not comply with the Comparative Tracking Index Test, Section 70.

Exception No. 2: A polymeric material having a Hot Wire Ignition (HWI) performance level class values not greater than those shown in Table 7.4 for the applicable flammability classification need not comply with the Glow Wire Test, Section 71. For materials with other then VTM flammability classifications, the material shall be evaluated using the specimen thickness employed in the end product or minimum 0.118 inch (3.0 mm) thickness, whichever thickness is greater.

Exception No. 3: A polymeric material having High Current Arc Resistance to Ignition (HAI) performance level class values not greater than those shown in Table 7.4 for the applicable flammability classification need not comply with the High Current Arc Resistance to Ignition Test, Section 72. For materials with other than VTM flammability classifications, the material shall be evaluated using the specimen thickness employed in the end product or minimum 0.118 inch (3.0 mm) thickness, whichever thickness is greater.

Exception No. 4: A polymeric material which encloses insulated live parts where the insulation thickness is greater than 0.028 inch (0.071 mm), need not comply with the Glow Wire Test, Section 71.

Exception No. 5: A polymeric material used in an enclosure that is separated through air by more than 1/32 inch (0.8 mm) form uninsulated live parts and more than 1/2 inch (12.7 mm) from arcing parts need not comply with the requirements in Sections 70 – 72.

Table 7.4
Hot wire ignition (HWI) and high-current arc resistance to ignition (HAI) ratings of insulating materials

	HWI[b,d]		HAI[c,d]	
Flammability classification[a]	**Mean ignition time (sec)**	**PLC**	**Mean no. of arcs**	**PLC**
V-0, VTM-0	7 and up to 15	4	15 and up to 30	3
V-1, VTM-1	15 and up to 30	3	30 and up to 60	2
V-2, VTM-2	30 and up to 60	2	30 and up tp 60	2
HB	30 and up to 60	2	60 and up to 120	1

[a] Flammability Classification – described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

[b] Hot Wire Resistance to Ignition – described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

[c] High-Current Arc Resistance to Ignition – described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

[d] Mean ignition time and mean no. of arcs to be used to evaluate filament wound tubing, industrial laminates, vulcanized fiber, and similar polymeric materials only. All other materials are to be judged using the performance level class values.

7.4.3 Thermal properties

7.4.3.1 A polymeric material used for the enclosure of live parts shall have the relative thermal index rating shown in Table 7.5 for the specific application of the insulating material.

Table 7.5
Minimum relative thermal indices of insulating materials used in insulation and enclosure applications

Application	Minimum relative thermal index[a] – Degrees C		
	Electrical[c]	Mechanical[b] with impact	Mechanical[b] without impact
Permanently wired devices (including equipment or vehicle inlets and receptacles)	100	100	100
Cord connected devices (including attachment plugs, connectors and adapters)	100	100	100

[a] Relative Thermal Index - described in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

[b] For industrial laminates, vulcanized fiber and similar polymeric materials, the minimum RTI for Mechanical shall be the values specified for Mechanical Without Impact.

7.5 Openings in enclosures

7.5.1 General

7.5.1.1 The enclosure of a device shall be designed and constructed to reduce the risk of emission of flame, molten metal, flaming or glowing particles, or flaming drops.

7.5.1.2 Enclosures, regardless of the materials, shall not be provided with ventilation openings unless designated as Type 1 or Type 2 enclosures.

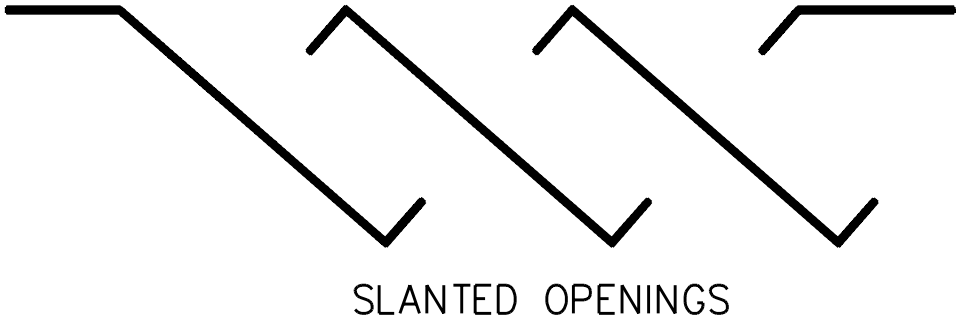
7.5.2 Enclosure top ventilation openings

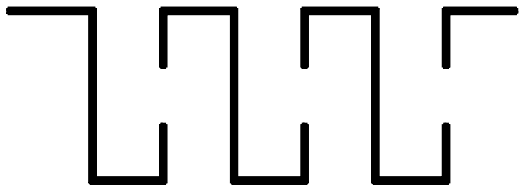
7.5.2.1 The minor dimension – see 7.5.2.2 – of any ventilation opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock shall not exceed 3/16 inch (4.8 mm) unless the configuration is such that the risk of direct vertical entry of a falling object to uninsulated live parts is reduced by means of a trap or restriction. See Figure 7.1 for examples of top surface ventilation openings that reduce the risk of direct entry.

Exception: The 3/16 inch (4.8 mm) limitation does not apply for ventilation openings located 6 feet (1.8 m) or higher from the floor, when the device is installed in accordance with the manufacturer's instructions. Such ventilation openings shall comply with the accessibility requirements in Protection of Users - Accessibility and User Servicing, Section 8.

7.5.2.2 With reference to the requirement in 7.5.2.1, the minor dimension of a ventilation opening is the diameter of the largest cylindrical probe that is capable of being inserted through the opening.

Figure 7.1
Cross section of top opening designs





EC500 VERTICAL OPENINGS

7.5.3 Enclosure side ventilation openings

7.5.3.1 The ventilation openings on the sides of an enclosure shall comply with one of the following:

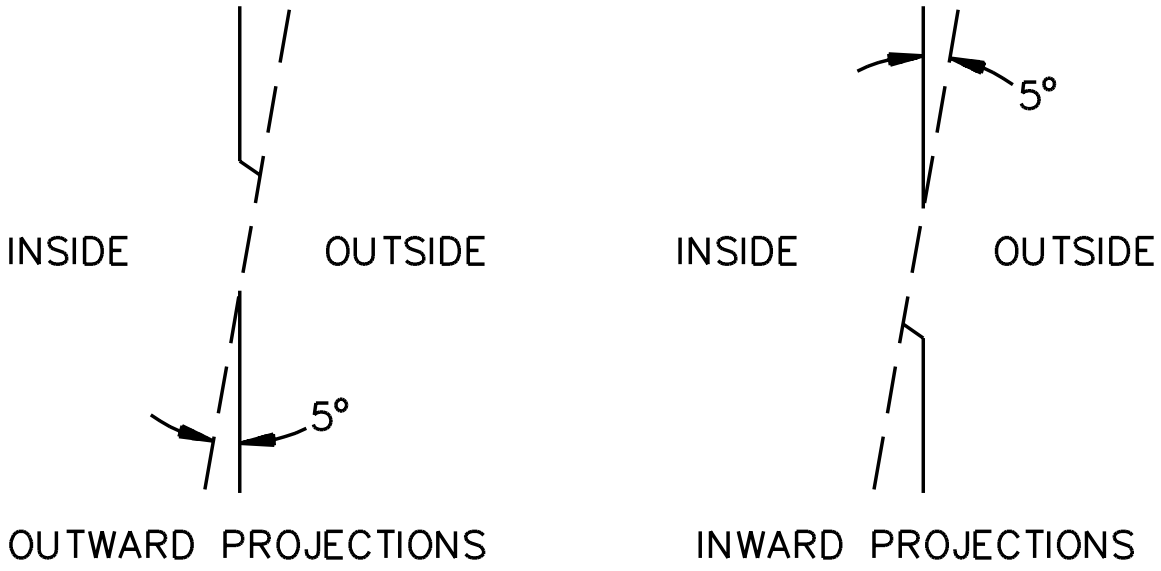
a) They shall not exceed 3/16 inch (4.8 mm) in any dimension;

b) They shall be provided with louvers that are shaped to deflect outwards an external vertically falling object – see Figure 7.2; or

c) They shall be so located that an object, upon entering the enclosure, is unlikely to fall on uninsulated live parts involving a risk of fire or electric shock – see 7.5.3.2.

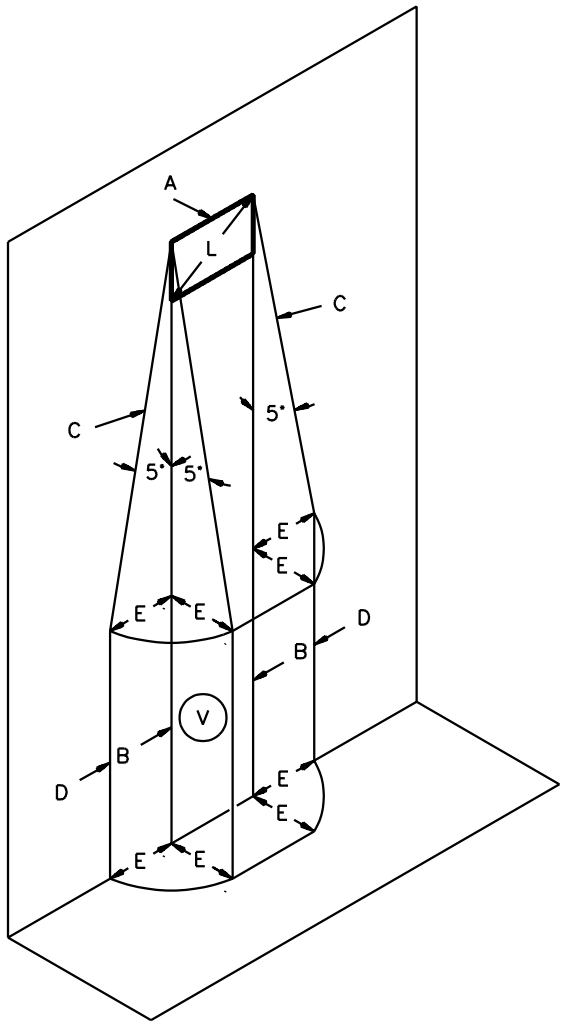
7.5.3.2 Where a portion of the side of the enclosure falls within the area as traced out by the 5 degree angle in Figure 7.3, the limitations for bottom ventilation openings shall apply to that portion of the side.

Figure 7.2
Cross section of top opening designs



EC513

Figure 7.3
Cross section of top opening designs



S3162A

A – Enclosure side opening

B – Vertical projection of the outer edges of the side opening

C – Inclined lines that project as a 5 degree angle from the edges of the side opening to points located E distance from B

D – Line which is projected straight downward in the same plane as the enclosure side wall

E – Projection of the opening (not to be greater than L)

L – Maximum dimension of the enclosure side opening

V – Volume in which bare parts at hazardous voltage are not located

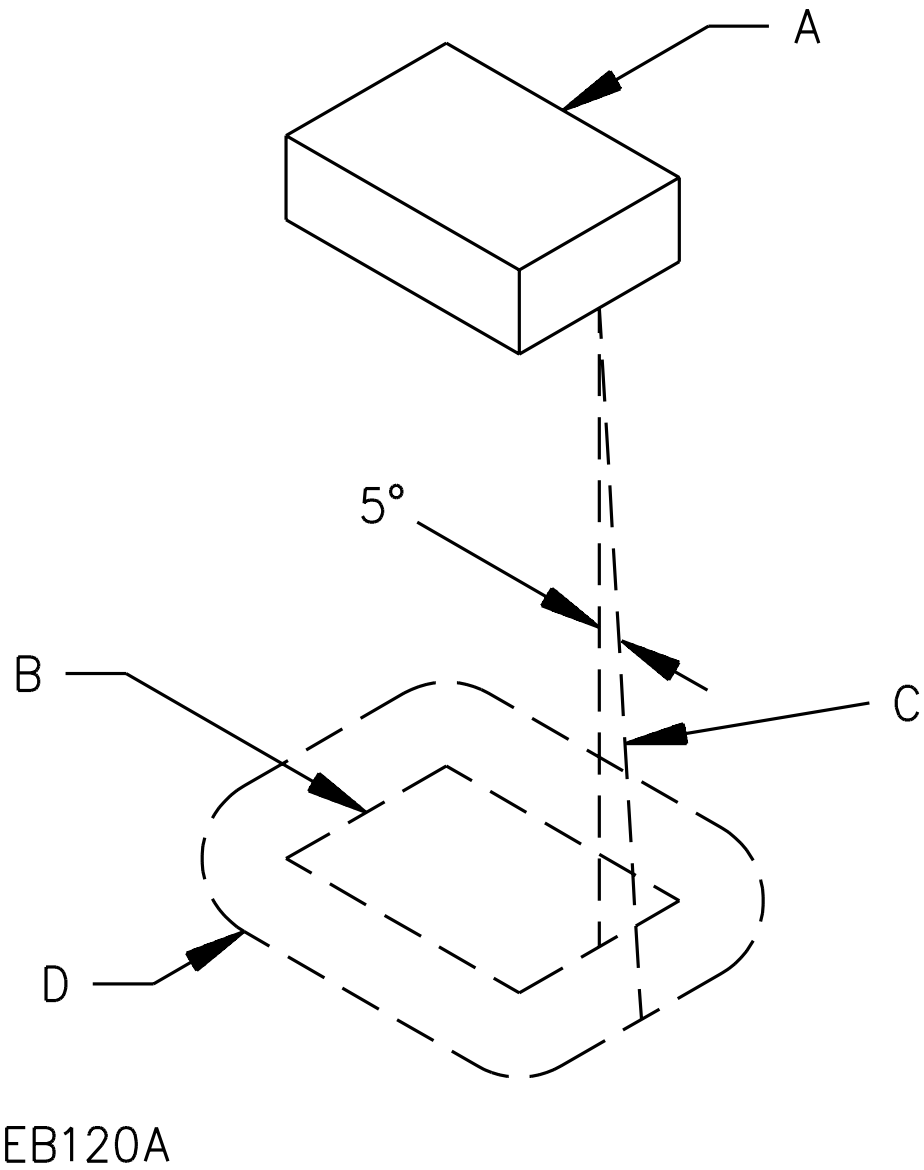
7.5.4 Enclosure bottom ventilation openings

7.5.4.1 The requirement in 7.5.1.1 requires a complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in Figure 7.4.

Exception No. 1: Ventilation openings in the bottom panel are allowed when noncombustible baffle plates are provided to reduce the risk of materials from falling directly from the interior of the device onto the supporting surface or any other location under the device. An example of such a baffle is illustrated in Figure 7.5.

Exception No. 2: Ventilation openings in the bottom of an enclosure are allowed when the openings incorporate a perforated metal plate as described in Table 7.6, or a galvanized or stainless steel screen having a 14 by 14 mesh per inch (2 by 2 mesh per millimeter) constructed of wire with a diameter of 0.018 inch (0.4 mm) minimum.

Figure 7.4
Enclosure bottom



A – Region to be shielded by barrier. This consists of the entire component when it is not otherwise shielded, and of the unshielded portion of a component which is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line which traces out minimum area of barrier. When moving, the line is always: (1) tangent to the component, (2) five degrees from the vertical, and (3) so oriented that the area traced out on a horizontal plane is maximum.

D – Location (horizontal) and minimum area for barrier. The area is that included inside the line of intersection traced out by the inclined line C and the horizontal plane of the barrier.

Figure 7.5
Example of a bottom-enclosure baffle

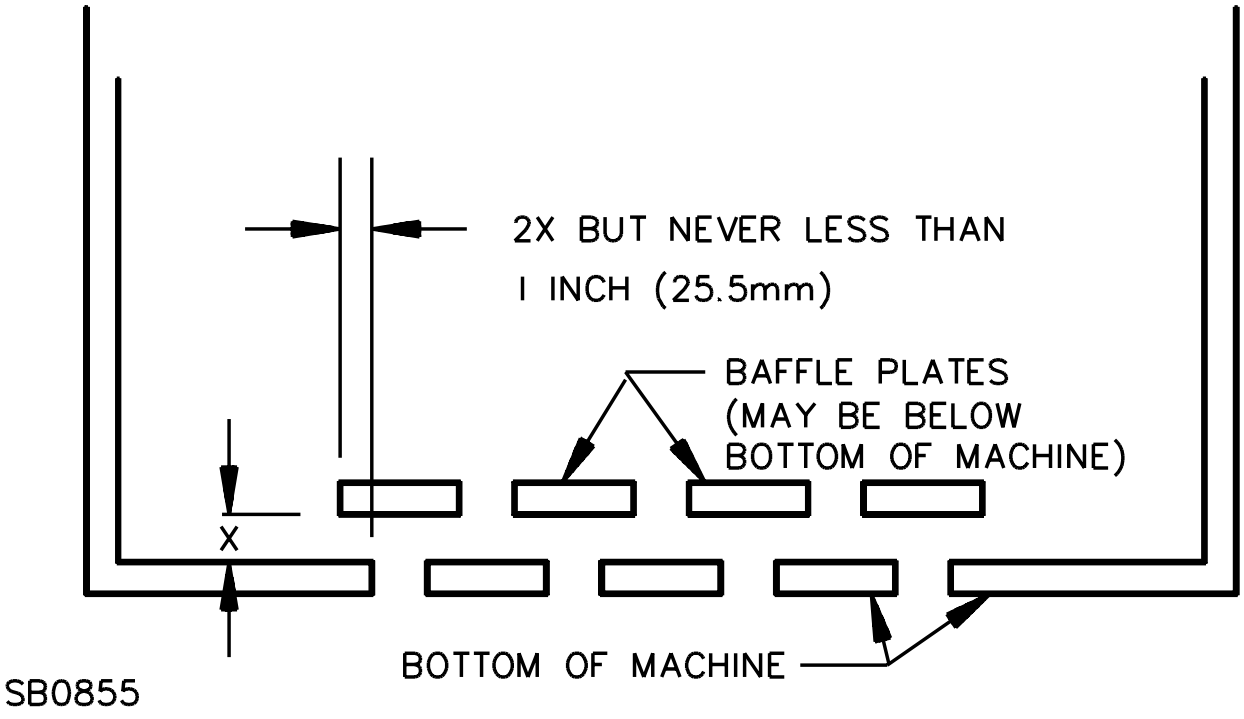


Table 7.6
Perforated metal plates for enclosure bottom

Minimum thickness, inch	(mm)	Maximum diameter of holes, inch	(mm)	Minimum spacings of holes center to center, inch	(mm)
0.026	(0.66)	0.045	(1.14)	0.067	(1.70)
				233 holes per inch^2	(645 mm^2)
0.026	(0.66)	0.047	(1.19)	0.093	(2.36)
0.030	(0.76)	0.045	(1.14)	0.067	(1.70)
0.030	(0.76)	0.047	(1.19)	0.093	(2.36)
0.032	(0.81)	0.075	(1.91)	0.125	(3.18)
				72 holes per inch^2	(645 mm^2)
0.035	(0.89)	0.075	(1.90)	0.125	(3.18)
0.036	(0.91)	0.063	(1.60)	0.109	(2.77)
0.036	(0.91)	0.078	(1.98)	0.125	(3.18)
0.039	(0.99)	0.063	(1.60)	0.109	(2.77)
0.039	(0.99)	0.079	(2.00)	0.118	(3.00)

Note – In accordance with Exception No. 2 to 7.5.4.1.

7.5.5 Openings for wiring

7.5.5.1 The requirements described in 7.5.5.2 – 7.5.5.11 apply to fixed units.

7.5.5.2 Enclosures shall be designed for use with appropriate conductor entry provisions to maintain the specified environmental capability of the particular enclosure type being evaluated.

7.5.5.3 When threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or when an equivalent construction is employed, there shall not be less than three nor more than five threads in the metal, and the construction of the enclosure shall be such that a conduit bushing is capable of being attached as intended. When threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or similar material there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors equivalent to that provided by a standard conduit bushing with an internal diameter the same as that of the corresponding trade size of rigid conduit.

7.5.5.4 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and similar material that are supplied as a part of an enclosure shall comply with the Standard for Metallic Outlet Boxes, UL 514A, and the Standard for Conduit, Tubing and Conduit Fittings, UL 514B.

7.5.5.5 A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure.

7.5.5.6 A knockout shall be provided with a flat surrounding surface so that the conduit bushing is capable of being seated as intended, and shall be located so that installation of a bushing at any knockout to be used during installation does not result in spacing between an uninsulated live part and the bushing to be less than that specified in Spacings, Section 22.

7.5.5.7 Knockouts shall not be provided in a Type 12 enclosure.

7.5.5.8 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 7.5.5.6, it is to be assumed that a bushing having the dimensions specified in Table 7.7 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

7.5.5.9 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings, Section 22, shall be provided between uninsulated live parts and a conduit bushing installed at any location that is to be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the device are ways to specify such a location. The specified location of the openings shall be such that damage to internal parts does not result when openings are made.

Table 7.7
Knockout or hole sizes and dimensions of bushings

Trade size of conduit	Knockout or hole diameter		Bushing dimensions			
			Overall diameter		Height	
inches	inches	(mm)	inches	(mm)	inches	(mm)
1/2	7/8	(22.2)	1	(25.4)	3/8	(9.5)
3/4	1-3/32	(27.8)	1-15/64	(31.4)	27/64	(10.7)
1	1-23/64	(34.5)	1-19/32	(40.5)	33/64	(13.1)
1-1/4	1-23/32	(43.7)	1-15/16	(49.2)	9/16	(14.3)
1-1/2	1-31/32	(50.0)	2-13/64	(56.0)	19/32	(15.10)
2	2-15/32	(62.7)	2-45/64	(68.7)	5/8	(15.9)
2-1/2	3	(76.2)	3-7/32	(81.8)	3/4	(19.1)
3	3-5/8	(92.1)	3-7/8	(98.4)	13/16	(20.6)

7.5.5.10 With respect to the requirement in 7.5.5.9, means shall be provided so that an opening for conduit is capable of being made without subjecting internal parts to contamination resulting from the presence of metallic particles. Compliance with this requirement is possible by the use of a removable, bolted plate.

7.5.5.11 A polymeric- or metal-closure plug for an unused conduit opening shall comply with the requirements in the Standard for Metallic Outlet Boxes, UL 514A, and shall maintain the specified environmental capability of the enclosure in accordance with 7.5.5.2.

7.5.6 Drainage openings

7.5.6.1 Type 2 and 3R enclosures shall have provisions for drainage. Drainage openings shall not be less than 3.2 mm in diameter (1/8 inch in diameter) or more than 6.4 mm in diameter (1/4 inch in diameter), unless baffled or provided with a drainage fitting.

7.5.6.2 For Type 2 and 3R enclosures that also meet the requirements of other enclosure types, the drainage openings shall be closed by a removable plug, and instructions shall be provided in accordance with 80.4.

7.5.6.3 Type 2 and 3R enclosures that also meet the requirements of other enclosure types need not have drainage holes if the enclosure is provided with instructions in accordance with 80.5.

7.5.7 Openings for mounting

7.5.7.1 Any openings provided for mounting shall be external to the enclosure cavity or shall comply with 7.5.7.2 – 7.5.7.4.

7.5.7.2 In accordance with 7.5.7.1, for enclosure types 3, 3S, 4, 4X, 6, 6P, 12, 12K, and 13, the mounting means may pass through the enclosure wall into the enclosure cavity if it attaches to an intermediate bracket and is shown to comply with the Environmental Tests, Section 65. The bracket shall then rely on separate mounting hardware to attach it to the building structure. The mounting means shall not have the same mounting hardware pass through the device cavity and attach directly to the building structure.

7.5.7.3 For enclosure types 1, 2, 3R, and 5, mounting means may be provided internal to the equipment cavity if the mounting openings comply with Table 7.8.

7.5.7.4 If mounting openings other than as noted in Table 7.8 are provided for Type 1, 2, 3R, or 5 enclosures, the installation instructions provided with the device shall indicate how to maintain the environmental integrity of the enclosure when mounted. See 79.4.

Table 7.8
Knockout or hole sizes and dimensions of bushings

Trade size of conduit	Knockout or hole diameter		Bushing dimensions			
			Overall diameter		Height	
inches	inches	(mm)	inches	(mm)	inches	(mm)
1/2	7/8	(22.2)	1	(25.4)	3/8	(9.5)
3/4	1-3/32	(27.8)	1-15/64	(31.4)	27/64	(10.7)
1	1-23/64	(34.5)	1-19/32	(40.5)	33/64	(13.1)
1-1/4	1-23/32	(43.7)	1-15/16	(49.2)	9/16	(14.3)
1-1/2	1-31/32	(50.0)	2-13/64	(56.0)	19/32	(15.10)
2	2-15/32	(62.7)	2-45/64	(68.7)	5/8	(15.9)
2-1/2	3	(76.2)	3-7/32	(81.8)	3/4	(19.1)
3	3-5/8	(92.1)	3-7/8	(98.4)	13/16	(20.6)

7.5.8 Glass covered openings

7.5.8.1 Glass covering an opening shall be secured in place so that it is not readily displaced in service, and shall provide mechanical protection for the enclosed parts. Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 1/16 inch (1.6 mm) thick, and glass for an opening not more than 144 square inches (929 cm^2) in area and having no dimension greater than 12 inches (305 mm) shall not be less than 1/8 inch (3.2 mm) thick. Glass used to cover an area larger than specified above shall not be less than 1/8 inch thick and shall:

a) Be of a nonshattering or tempered type that, when broken, complies with the Safety Performance Specifications and Methods of Test for Safety Glazing Materials Used in Buildings, ANSI Z97.1; or

b) Be subjected to the test described in Section 59.

7.6 Mechanical strength of enclosures

7.6.1 An enclosure, whether metallic or nonmetallic, shall comply with the applicable strength of enclosure tests, including the Impact Test, Section 55, Vehicle Drive Over Test, Section 56, and Drop Test, Section 57. See Section 38.

7.7 Environmental considerations

7.7.1 All enclosures shall be rated for one of the enclosure types in the Standard for Electrical Equipment, Environmental Considerations, UL 50E. The enclosure rating shall be appropriate for the intended conditions of use. See 7.7.2.

7.7.2 All enclosure types provide a degree of protection to personnel against incidental contact with the enclosed equipment. Protection against specific environmental conditions for each enclosure type is defined in Table 7.9. The enclosure type rating is applicable only after proper installation of the equipment. Enclosures that are indicated as suitable for use outdoors, are inherently suitable for use indoors.

Table 7.9
Enclosure types and intended use

Enclosure type	Intended use
1	Indoor use primarily to provide a degree of protection against limited amounts of falling dirt
2	Indoor use primarily to provide a degree of protection against limited amounts of falling dirt and water
3	Outdoor use primarily to provide a degree of protection against falling dirt, rain, sleet, snow, and wind blown dust and damage form external ice formations
3R	Outdoor use primarily to provide a degree of protection against falling dirt, rain, sleet, and snow, and that will be undamaged by the external formation of ice on the enclosure
3S	Outdoor use primarily to provide a degree of protection against falling dirt, rain, sleet, snow, wind blown dust and to provide for operation of external mechanisms when ice laden
4	Outdoor use primarily to provide a degree of protection against falling dirt, wind blown dust, rain, sleet, snow, splashing water, hose directed water, and damage from external ice formation
4X	Outdoor use primarily to provide a degree of protection against falling dirt, corrosion, windblown dust, rain, sleet, and snow, splashing water, hose directed water, and damage from external ice formation
5	Indoor use primarily to provide a degree of protection against settling airborne dust, falling dirt, and dripping water
6	Outdoor use primarily to provide a degree of protection against falling dirt, hose directed water, rain, sleet, snow, and the entry of water during occasional temporary submersion at a limited depth and damage from external ice formation
6P	Outdoor use primarily to provide a degree of protection against falling dirt, hose directed water, rain, sleet, snow, corrosion, and the entry of water during prolonged submersion at a limited depth and damage from external ice formation
12, 12K	Indoor use primarily to provide a degree of protection against circulating dust, falling dirt, and dripping water
13	Indoor use primarily to provide a degree of protection against circulating dust, spraying of water

7.7.3 Enclosures intended for products that are to be used indoors only, shall be rated Type 1,2,5,12,12K, or 13 as a minimum. Products rated for these enclosure types shall be marked in accordance with 76.11.

7.7.4 Enclosures intended for outdoor use, or as portable devices for indoor and outdoor use, shall be rated Type 3, 3R, 3S, 4, 4X, 6, or 6P.

7.7.5 With reference to enclosure Type 3S, this enclosure type is provided with external operating mechanisms. Type 3S enclosures require that these operating mechanisms be operable when ice laden or after the ice has been removed in accordance with the manufacturer's instructions.

7.7.6 All enclosures shall comply with the applicable test requirements in Environmental Tests, Section 65. In addition, the requirements in 7.7.7 – 7.7.9 shall apply to nonmetallic enclosures or metallic enclosures with coatings that require test.

7.7.7 All nonmetallic enclosures, or metallic enclosures with coatings that require test, that are intended for outdoor use shall comply with the UV Exposure Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.7.8 All nonmetallic enclosures, or metallic enclosures with coatings that require test, shall be subjected to the Chemical exposure test, Section 65.16.

Exception: Wall mounted enclosures are not required to comply with this requirement.

7.7.9 All nonmetallic enclosures, or metallic enclosures with coatings that require test, that are intended for use outdoors, shall be subjected to the Water exposure test, Section 65.14.

7.7.10 All mechanical and electrical parts mounted on or through an enclosure shall comply with the applicable tests for the enclosure type.

7.7.11 A gasket that is provided on an enclosure to meet the environmental construction and performance requirements for that enclosure type shall comply with the Gaskets, Section 65.13.

8 Protection of Users – Accessibility and User Servicing

8.1 General

8.1.1 The requirements in this section apply to parts that are accessible to the user. For protection of service personnel requirements, refer to Protection of Service Personnel, Section 32.

8.2 Accessibility

8.2.1 To reduce the risk of unintentional contact that results in electric shock from an uninsulated live part or film-coated wire, an opening in an enclosure shall comply with either:

a) For an opening that has a minor dimension less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the probe illustrated in Figure 8.1, or

b) For an opening that has a minor dimension of 1 inch (25.4 mm) or more, such a part or wire shall be spaced from the opening as specified in Table 8.1.

Table 8.1
Minimum required distance from an opening to a part that involves a risk of electric shock

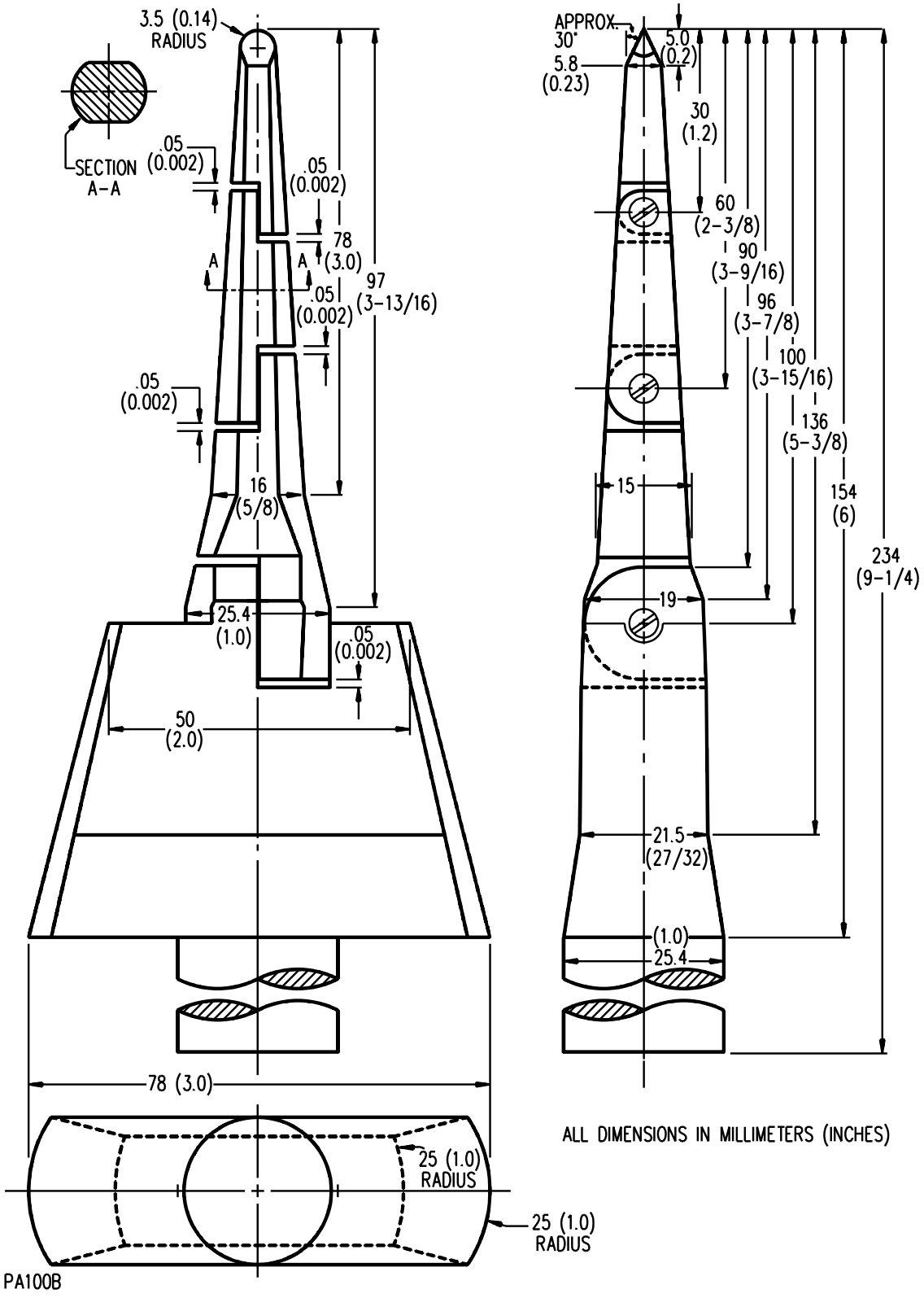
Minor dimension of opening[a,b]		Minimum distance from opening to part[b]	
Inches	(mm)	Inches	(mm)
1	(25.4)	6-1/2	(165.0)
1-1/4	(31.8)	7-1/2	(190.0)
1-1/2	(38.1)	12-1/2	(318.0)
1-7/8	(47.6)	15-1/2	(394.0)
2-1/8	(54.0)	17-1/2	(444.0)
c		30	(762.0)

[a] See 8.2.4.

[b] Between 3/4 and 2-1/8 inches (19.1 and 54 mm), interpolation is to be used to determine a value between values specified in the table.

[c] More than 2-1/8 inches (54 mm), and not more than 6 inches (152.0 mm).

Figure 8.1
Articulate probe



8.2.2 The probe specified in 8.2.1 and illustrated in Figures 8.1 shall be applied to any accessible depth of the opening and shall be rotated or angled before, during, and after insertion through the opening to any position that is required to examine the enclosure. The probe illustrated in Figure 8.1 shall be applied in any possible configuration; and, where required, the configuration shall be changed after insertion through the opening.

8.2.3 The probe mentioned in 8.2.2 shall be used as a measuring instrument to judge the accessibility provided by an opening, and not as an instrument to judge the strength of a material; it shall be applied with a maximum force of 1 pound (4.4 N).

8.2.4 With reference to the requirement in 8.2.1, the minor dimension of an opening is the diameter of the largest cylindrical probe that is capable of being inserted through the opening.

8.2.5 During the examination of a unit to determine whether it complies with the requirement in 8.2.1, a part of the enclosure that is capable of being opened or removed by the user without using a tool is to be opened or removed. A fastener, such as a slotted-head thumb screw, that is turned by hand, does not require the use of a tool.

8.3 User servicing

8.3.1 Service functions that are intended to be carried out by the user, in accordance with the User Maintenance Instructions, Section 81, shall comply with the requirements in 8.3.2 and 8.3.3.

8.3.2 The user shall not have access to any circuits or uninsulated parts that have a potential to earth in excess of 42.4 V peak or 60 V dc. If the user is intended to access circuits or parts of the device at potentials above this limit, an interlock system shall be provided that will completely remove the shock hazard prior to the user accessing the area.

8.3.3 Any user servicing that is intended to be performed shall not require the use of a tool to access the area where the servicing is to be performed, unless the tool is specified and that tool can not be used to access any other area of the device.

9 Protection Against Electric Shock

9.1 General

9.1.1 The user shall be protected against the risk of electric shock. All accessible circuits shall have a potential to earth not exceeding 42.4 V peak or 60 V dc.

9.1.2 In addition to the requirement in 9.1.1, the requirements in 9.2 and 9.3 also apply.

9.2 Personnel protection systems

9.2.1 Electric vehicle supply equipment shall be provided with a personnel protection system. The personnel protection system shall comply with the requirements in the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits, Part 1: General Requirements, UL 2231-1, and with the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits, Part 2: Particular Requirements for Protection Devices for Use In Charging Systems, UL 2231-2.

9.2.2 The personnel protection system shall be protected by enclosing the components in an enclosure in accordance with Frame and Enclosure, Section 7.

9.2.3 The interrupting device provided as part of the personnel protection system is required to be located as an integral part of the attachment plug or shall be located in the power supply cord not more than 12 inches (300 mm) from the attachment plug.

9.3 Stored energy on capacitors

9.3.1 For cord connected products that contain filtering capacitors or other primary capacitors, the stored energy on the capacitors shall not constitute a hazard to the user. When the attachment plug is removed from the receptacle, stored charge on the capacitors can be discharged through the user if the blades of the attachment plug are contacted. The stored charge shall dissipate within one second, in accordance with the Capacitor Discharge Test, Section 48.

10 Corrosion Protection Against Electric Shock

10.1 General

10.1.1 Enclosures shall not be constructed of metals in any combination such as to cause galvanic action that will adversely affect any part of the equipment exposed to moisture.

10.1.2 Enclosures made of the following materials shall be considered to comply with the indoor and outdoor corrosion requirements:

a) Copper, aluminum, or stainless steel, and

b) Bronze or brass containing at least 80 percent copper.

10.1.3 Fasteners and hinges used on an enclosure shall be resistant to corrosion and shall comply with the same requirements as the enclosure.

10.1.4 Other than as permitted by 10.1.6, both the inside and outside surfaces of an enclosure made of ferrous material, along with any external ferrous parts attached to these enclosures, shall be protected against corrosion in accordance with 10.2 or 10.3.

10.1.5 The requirements in 10.2 and 10.3 do not contemplate corrosion that might be caused by exposure to the earth or other corrosive agents.

10.1.6 The corrosion protection requirement does not apply to:

a) Bearings, sliding surfaces of a hinge or shaft, and the like, located on the exterior of the enclosure;

b) Sheared or cut edges and punched holes of galvanized steel; or

c) Parts such as a decorative grill, and the like, that are not required to from part of the enclosure.

10.2 Indoor corrosion protection

10.2.1 Type 1, 2, 5, 12, 12K, and 13 ferrous enclosures and external ferrous parts attached to the enclosure shall either be:

a) Protected against corrosion by enameling, painting, galvanizing, or other equivalent means, or

b) Tested in accordance with Indoor corrosion protection test, Section 65.8.

10.3 Outdoor corrosion protection

10.3.1 Type 3, 3R, 3S, 4, 4X, 6, and 6P ferrous enclosures and external ferrous parts attached to the enclosure shall be protected against corrosion in accordance with 10.2 or 10.3.2 – 10.3.9.

10.3.2 An enclosure of cast iron or malleable iron at least 1/8 inch (3.2 mm) thick shall be protected against corrosion by:

a) A 0.00015 inch (0.0038 mm) thick coating of zinc, cadmium, or the equivalent on the outside surface, and a visible coating of such metal on the inside surface, or

b) One coat of an organic finish of the epoxy or alkyd resin type or other outdoor paint on each surface.

10.3.3 Unless suitability of a paint can be determined by consideration of its composition, corrosion tests are required.

10.3.4 An enclosure of sheet steel less than 0.126 inch (3.20 mm) thick if zinc coated or 0.123 inch (3.12 mm) thick if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 10.3.7:

a) Hot-dipped, mill galvanized, sheet steel conforming with the coating designation G90 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron-Alloy-Coated (Galvannealed) by the Hot Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM specification. The weight of zinc coating may be determined by any acceptable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 inch (0.015 mm) on each surface with a minimum thickness of 0.00054 inch (0.014 mm). An annealed coating shall also comply with 10.3.9.

c) A zinc coating conforming with 10.3.5 (a) or 10.3.5 (b), with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface applied after forming. See 10.3.3.

d) A cadmium coating not less than 0.001 inch (0.025 mm) thick on both surfaces.

e) A cadmium coating not less than 0.00075 inch (0.019 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. Paint shall be as specified in item (c) above.

10.3.5 An enclosure of zinc-coated sheet steel 0.126 inch (3.20 mm) thick or thicker or an enclosure of uncoated sheet steel 0.123 inch (3.12 mm) thick or thicker shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to give equivalent protection as described in 10.3.7:

a) Hot-dipped, mill galvanized, sheet steel conforming with the coating designation G60 or A60 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron-Alloy-Coated (Galvannealed) by the Hot Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM specification. The weight of zinc coating may be determined by any acceptable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.010 mm) on each surface with a minimum thickness of 0.00034 inch (0.009 mm).

c) Two coats of an organic finish of the epoxy or alkyd resin type or other outdoor paint on each surface. See 10.3.3.

d) Any one of the means specified on 10.3.4.

10.3.6 The requirements in 10.3.5 also apply to an enclosure of zinc-coated sheet steel 0.056 inch (1.42 mm) thick or thicker and an enclosure of uncoated sheet steel 0.053 inch (1.35 mm) thick or thicker if the enclosure is intended to be mounted within and protected from direct exposure to weather by the enclosure of other equipment. Such an enclosure shall not be marked rainproof or raintight.

10.3.7 With reference to 10.3.4 – 10.3.6, other finishes, including paints, metallic finishes, and combinations of the two, may be accepted if comparative tests with galvanized sheet steel – without annealing, wiping, or other surface treatment – conforming with item (a) of Clause 10.3.4 or 10.3.5, as applicable, indicate that they provide equivalent protection. Among the factors that are to be taken into consideration when judging the suitability of such coating systems are exposure to salt spray and moist carbon dioxide – sulfur dioxide – air mixtures in accordance with 65.9; exposure to water in accordance with 65.14; and exposure to ultraviolet light, in accordance with 65.15.

10.3.8 If tests are required, test specimens of a finish as described in 10.3.2, 10.3.4 (c), 10.3.5 (c), or 10.3.7 are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, and the like.

10.3.9 A hot-dipped, mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted, shall be painted in the bent or formed area if the bending or forming process has damaged the zinc coating, except that such an area on the inside surface of an enclosure that is not exposed to water during the water spray test need not be painted. The zinc coating is considered to be damaged if flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25-power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

11 Mechanical Assembly

11.1 Loosening of parts as a result of handling and intended operation of the device shall not result in a risk of fire, a risk of electric shock, or a risk of injury to persons.

11.2 Screws with lock washers applied as intended, screws tightened by means of a power tool, rivets, and staked and upset screws are considered to comply without further evaluation. See 11.3.

11.3 The construction of staked and upset screws is to consist of an interference fit between the nut and bolt resulting in uneasy turning of the screw. This shall be accomplished by the use of a center punch applied to the end of a bolt after assembly, mismatching of the nut and bolt threads, or the equivalent.

11.4 A rotating part that, when loosened, results in a risk of fire, electric shock, or injury to persons, shall be assembled so that the direction of the rotation tends to tighten the means that hold the rotating part in place.

Exception: A keyed part, a press fit, a part locked in place with a pin, or equivalent means to hold a rotating part in place is considered to comply with 11.4.

11.5 A switch, fuseholder, attachment plug, or other component that is handled by the operator shall be mounted securely, and shall not turn when handled. In addition, the connection shall comply with the requirements in 11.6.

11.6 The means of securing components mentioned in 9.5 shall include more than friction between surfaces. A lock washer is an example of a means to secure a device having a single hole mounting means.

12 Supply Connections

12.1 Permanently connected devices

12.1.1 General

12.1.1.1 A permanently connected device shall have provision for connection of a wiring system. This provision shall consist of either wiring terminals as specified in 12.1.1.3 – 12.1.2.10 or wiring leads as specified in 12.1.1.3 and 12.1.3.1 – 12.1.3.6 and a means for connection of cable or conduit as specified in 12.2.1.

Exception: The requirements described in 12.1.1.3 – 12.1.3.6 do not apply to the means for connection to accessible signal circuits.

12.1.1.2 The requirement in 12.1.1.1 applies to the wiring connection means for alternating current and direct current power circuits of a device. These connections are intended to be made in the field when the device is installed.

12.1.1.3 A wiring terminal or lead shall be used for the connection of a conductor having an ampacity based on Table 310-16 of the National Electrical Code, ANSI/NFPA 70 of no less than 125 percent of the maximum current that the circuit carries during the Input Test, Section 46.

12.1.2 Wiring terminals

12.1.2.1 A wiring terminal shall comply with the requirements in 12.1.1.3 for a wire of each metal for which it is marked. See 74.12.

12.1.2.2 A wiring terminal shall be provided with a pressure terminal connector of other than the crimping type and the terminal shall be securely fastened in place – for example, firmly bolted or held by a screw.

Exception No. 1: A pressure terminal connector, including a crimping type, may be field installed in accordance with 12.1.2.4.

Exception No. 2: A wire binding screw may be employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor where upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position

12.1.2.3 A wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This shall be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method.

Exception: A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 12.1.2.4 may turn when the least spacing between adjacent terminals and also between terminals and dead metal parts, complies with Spacings, Section 23, for when connectors are oriented in such a position that results in these spacings.

12.1.2.4 In accordance with Exception No. 1 to 12.1.2.2 and the exception to 12.1.2.3, a pressure terminal connector is not required to be provided when the conditions in (a) – (e) are complied with:

a) One or more component terminal assemblies shall be available from the device manufacturer or others, and they shall be specified in the instruction manual. See 78.3 (f).

b) The fastening hardware such as a stud, nut, bolt, spring, or flat washer, or similar part as mounted on or separately packaged with the device, or specified in the instruction manual.

c) The installation of the terminal assembly shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.

d) Where the pressure terminal connector provided in a terminal assembly requires the use of other than an ordinary tool for securing the conductor, the tool and any required instructions for using the tool shall be included with the device. See 78.3 (h).

e) Installation of the pressure terminal connector in the intended manner shall result in a device complying with the requirements of this outline.

12.1.2.5 An insulating base for support of a pressure terminal connector shall be subjected to the Strength of Terminal Insulating Base and Support Test, Section 58.

12.1.2.6 A wire binding screw at a field wiring terminal shall not be smaller than No. 10 (4.8 mm diameter).

Exception: A No. 8 (4.2 mm diameter) screw being used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor, or a No. 8 or 6 (4.2 mm or 3.5 mm diameter) screw being used at a terminal intended for connection of a 16 or 18 AWG (1.3 or 0.82 mm^2) control circuit conductor, is allowed.

12.1.2.7 A wire binding screw shall thread into metal.

12.1.2.8 A terminal plate tapped for a wire binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick.

Exception: A terminal plate less than 0.050 inch (1.27 mm) thick may be used in a low voltage, limited energy circuit when the tapped threads withstand the tightening torque specified in Table 12.1 without stripping.

Table 12.1
Tightening torque for wire-binding screws

Size of terminal screw, number	Wire sizes to be tested, AWG[a]	Tightening torque	
		Pound-inches	Newton meters
6	16 – 18 (ST)	12	1.4
8	14 (S) and 16 – 18 (ST)	16	1.8
10	10 – 14 (S) and 16 – 18 (ST)	20	2.3

[a] ST – stranded wire; S – solid wire.

12.1.2.9 There shall be two or more full threads in the metal of a terminal plate. When the metal is extruded at the tapped hole, at least two full threads shall be provided.

12.1.2.10 A terminal for connection of a grounded conductor of an alternating current power circuit shall be identified as described in 74.14.

12.1.3 Field wiring leads

12.1.3.1 A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is connected, and shall not be smaller than 18 AWG (0.82 mm^2), for example, a 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a 6 AWG (13.3 mm^2) field-provided conductor. A field-wiring lead shall not be less than 6 inches (152.4 mm) long.

Exception: An 18 AWG (0.82 mm^2) size field wiring lead may be used for connection to a 12 AWG (3.3 mm^2) size branch circuit conductor.

12.1.3.2 A field wiring lead shall consist of general building wire, or other wiring where it has an insulation of:

a) At least 1/32 inch (0.8 mm) thick thermoplastic material;

b) At least 1/64 inch (0.4 mm) thick rubber plus a braid cover for applications of 300 V or less;

c) At least 1/32 inch (0.8 mm) thick rubber plus a braid cover for applications between 301 and 600 volts.

12.1.3.3 A field wiring lead shall be subjected to the test specified in 52.2.4.

12.1.3.4 A field wiring lead provided for connection to an external line voltage circuit shall not be connected to a wire binding screw or pressure terminal connector located in the same compartment as the free end of the wiring lead unless the screw or connector is rendered unusable for field wiring connection or the lead is insulated at the unconnected end, and a marking is provided on the device in accordance with 74.15.

12.1.3.5 The free end of a field wiring terminal that is not used in every installation, such as a tap for a multivoltage transformer, shall be insulated.

12.1.3.6 A field wiring lead for connection of a grounded conductor shall be identified as described in 74.14.

12.1.4 Wiring compartments

12.1.4.1 A wiring compartment on a fixed device shall be located so that wire connections therein is accessible for inspection, without disturbing either factory or field connected wiring, after the device is installed in the intended manner.

12.1.4.2 Wiring compartments, raceways, or similar devices for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that are capable of damaging conductor insulation.

12.1.5 Openings for conduit or cable connection

12.1.5.1 For a permanently connected device, openings for wiring and conduit shall comply with the requirements specified in 7.5.5.

12.1.6 Wire bending space

12.1.6.1 A permanently connected device employing pressure terminal connectors for field connection of circuits described in 12.1.1.2 shall be provided with space within the enclosure as specified in 12.1.6.3 – 12.1.6.7 for the installation of conductors including grounding conductors that are employed in the installation.

12.1.6.2 The conductor size used in judging the wiring space is to be based on the use of a conductor sized in accordance with 12.1.1.3.

12.1.6.3 Wire bending space for field installed conductors shall be provided opposite any pressure wire connector as specified in 12.1.6.4 or 12.1.6.5 and opening or knockout for a wireway or conduit in a gutter as specified in 12.1.6.9.

12.1.6.4 When a conductor is not capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 12.2. A wire is capable of entering or leaving a top, back, bottom, or side surface when there is an opening for conduit or a wireway.

12.1.6.5 Where a conductor is not capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 12.3. The wire bending space is in accordance with Table 12.3 when a barrier is provided between the connector and the opening, or drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector. See illustrations A, B, and C of Figure 12.1.

Table 12.2
Minimum wire-bending space for conductors through a wall opposite terminals in inches (mm)

Wire size,		Wires per terminal (pole)[a]											
AWG or kcmil	(mm^2)	1		2			3			4 or more			
14 –10 AWG	(2.1 – 5.3)	Not Specified		–			–			–			
8	(8.4)	1-1/2	(38.1)	–			–			–			
6	(13.3)	2	(50.8)	–			–			–			
4	(21.1)	3	(76.2)	–			–			–			
3	(26.7)	3	(76.2)	–			–			–			
2	(33.6)	3-1/2	(88.9)	–			–			–			
1	(42.4)	4-1/2	(114)	–			–			–			
0	(53.5)	5-1/2	(140)	5-1/2			7		(179)		–		
2/0	(67.4)	6	(152)	6			7-1/2		(191)		–		
3/0	(85.0)	6-1/2	(165)	6-1/2	[1/2]	(165)	8		(203)		–		
4/0	(107)	7	(179)	7-1/2	[1-1/2]	(191)	8-1/2	[1/2]	(216)		–		
250 kcmil	(127)	8-1/2	(216)	8-1/2	[2]	(216)	9	[1]	(229)	10		(254)	
300	(152)	10	(254)	10	[2]	(254)	11	[1]	(279)	12		(305)	
350	(177)	12	(305)	12	[3]	(305)	13	[3]	(330)	14	[2]	(355)	
400	(203)	13	(330)	13	[3]	(330)	14	[3]	(355)	15	[3]	(381)	
500	(253)	14	(355)	14	[3]	(355)	15	[3]	(381)	16	[3]	(406)	
600	(304)	15	(381)	16	[3]	(406)	18	[3]	(457)	19	[3]	(483)	
700	(355)	16	(406)	18	[3]	(457)	20	[3]	(508)	22	[3]	(559)	
750	(380)	17	(432)	19	[3]	(483)	22	[3]	(559)	24	[3]	(610)	
800	(405)	18	(457)	20		(508)	22		(559)	24		(610)	
900	(456)	19	(483)	22		(559)	24		(610)	24		(610)	
1000	(507)	20	(508)	–			–			–			
1250	(633)	22	(559)	–			–			–			
1500	(760)	24	(610)	–			–			–			
1750	(886)	24	(610)	–			–			–			
2000	(1013)	24	(610)	–			–			–			

Note – The table includes only those multiple-conductor combinations that are used. Combinations not specified shall be further evaluated.

[a] Wire bending space is not prohibited from being reduced by the number of inches shown in brackets under the following conditions:

1) Only removable or lay-in wire connectors receiving one wire each are used (more than one removable wire connector per terminal is possible) and

2) The removable wire connectors are removed from their intended location without disturbing structural or electrical parts other than a cover, and are installed with the conductor in place.

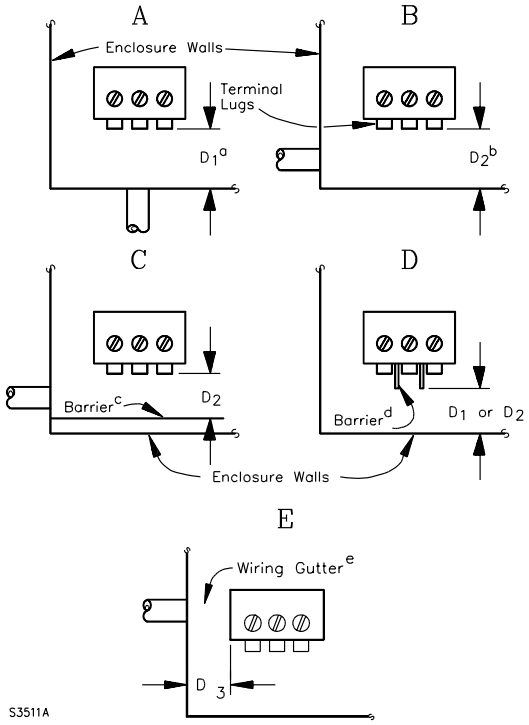
12.1.6.6 When a conductor is restricted by a barrier or other means from being bent where it leaves he connector, the distance is to be measured from the end of the barrier. See illustration D of Figure 12.1.

Table 12.3
Minimum width of gutter and wire-bending space for conductors through a wall not opposite terminals in inches (mm)

Size of wire, AWG or kcmil (mm^2)		Wires per terminal (pole)									
		1		2		3		4		5	
14 – 10 AWG	(2.1 – 5.3)	Not Specified	–	–		–		–		–	
8 – 6	(8.4 – 13.3)	1-1/2	(38.1)	–		–		–		–	
4 – 3	(21.1 – 26.7)	2	(50.8)	–		–		–		–	
2	(33.6)	2-1/2	(63.5)	–		–		–		–	
1	(42.4)	3	(76.2)	–		–		–		–	
1/0 – 2/0	(53.5 – 7.4)	3-1/2	(88.9)	5	(127)	7	(178)	–		–	
3/0 – 4/0	(85.0 – 107)	4	(102)	6	(152)	8	(203)	–		–	
250 kcmil	(127)	4-1/2	(114)	6	(152)	8	(203)	10	(254)	–	
300 – 350	(152 – 177)	5	(127)	8	(203)	10	(254)	12	(305)	–	
400 – 500	(203– 253)	6	(152)	8	(203)	10	(254)	12	(305)	14	(356)
600 – 700	(304 – 355)	8	(203)	10	(254)	12	(305)	14	(356)	16	(406)
750 – 900	(380 – 456)	8	(203)	12	(305)	14	(356)	16	(406)	18	(457)
1000 – 1250	(507 – 633)	10	(254)	–		–		–		–	
1500 – 2000	(760 – 1010)	12	(305)	–		–		–		–	

NOTE – The table includes only those multiple-conductor combinations that are frequently used. Combinations not specified shall be further evaluated.

Figure 12.1
Wire bending space



D_1 is the distance between a wire connector or an adjacent barrier and the opposite wall that conductors are intended to pass through.

D_2 is the distance between a wire connector or an adjacent barrier and the opposite wall or barrier that conductors are not intended to pass through.

D_3 is the width of a wiring gutter having a side through which conductors are intended to pass through.

[a] A conduit opening or knockout is provided in the wall opposite the terminal lugs. D_1 shall not be less than the minimum wire bending space specified in Table 12.2.

[b] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. The wall opposite the terminal lugs either is not provided with a knockout or conduit opening or a marking is provided indicating that the conduit opening or knockout is not to be used. D_2 shall not be less than the minimum wire bending space specified in Table 12.3.

[c] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. In addition, a conduit opening or knockout is provided in the wall opposite the terminal lugs, however, a barrier preventing the use of the opening is provided. D_2 shall not be less than the minimum wire bending space specified in Table 12.3.

[d] When a barrier or other means is provided restricting bending of the conductor, the distance D_1 or D_2, as applicable (see notes for D_1 and D_2 above) is to be measured from the end of the barrier.

[e] A conduit opening or knockout is provided in a wiring gutter. The width of the gutter, D_3, shall not be less than the minimum wire bending space specified in Table 12.3.

12.1.6.7 For a device not provided with a conduit opening or knockout the minimum wiring bending space mentioned in 12.1.6.4 – 12.1.6.6 shall be based on any enclosure wall capable of being used for installation of the conduit or only specific walls that are to be used as determined by a marking, drawing, or template furnished with the device.

12.1.6.8 The distance mentioned in 12.1.6.3 – 12.1.6.5 is to be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. See illustrations A – C of Figure 12.2. The wire terminal is to be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it is capable of assuming without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or similar part. A barrier, shoulder, or similar part is to be disregarded where the measurement is being made when it does not reduce the radius to which the wire must be bent. Where a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure.

Exception: See 12.1.6.6.

12.1.6.9 The width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to bending) conductors of the maximum size that are used at that knockout. The values of the minimum required width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum required bending space given in Table 12.3. See illustration E of Figure 12.1.

Exception: The wiring space is not required to be of this width when knockouts are provided elsewhere that are in compliance with these requirements, the wiring space at such other point or points is of a width that accommodates the conductors in question, and the knockout or knockouts at such other points are used in the intended wiring of the device.

12.2 Cord connected devices

12.2.1 General

12.2.1.1 For cord connected devices, flexible cords and attachment plugs shall be used for connection to the alternating current input circuit.

12.2.1.2 The cord shall be type G, SEO, SO, STO, SJEO, SJO, SJTO, W, or a cord that is equally serviceable. The flexible power cord shall terminate at the enclosure of the device. The overall length of the power cord shall comply with one of the following. The overall length of the power cord is measured from the face of the attachment plug to the point where it enters the enclosure.

a) When the interrupting device of the personnel protection system is located within the enclosure of the device, the power cord shall be no more than 12 inches (300 mm) long, and the device shall be marked in accordance with 74.17.

b) When the interrupting device of the personnel protection system is located at the attachment plug, or within the first 12 inches (300 mm) of the power cord, the overall cord length shall be a minimum of 6 feet (1.8 m) and shall be no greater than 15 feet (4.6 m).

12.2.1.3 A flexible power cord shall be rated for a voltage not less than the rated voltage of the equipment, and shall have a current rating not less than the current rating of the device.

12.2.1.4 The attachment plug of a supply cord shall have a current rating in accordance with 12.2.1.5 and have a voltage rating corresponding to the voltage rating of the device.

12.2.1.5 With reference to 12.2.1.4, the current rating of an attachment plug for the alternating current input circuit shall not be less than 125 percent of the rated input current of the device.

12.2.1.6 The attachment plug shall be a grounding type attachment plug.

12.2.2 Strain relief

12.2.2.1 Strain relief shall be provided on the flexible power cord to reduce the risk of mechanical stress being transmitted to terminals, splices, or interior wiring. See Pull strain relief test, Section 52.2. A knot in the flexible power cord is not considered an acceptable form of strain relief.

12.2.2.2 A metal strain relief clamp or band provided in accordance with 12.2.2.1 shall be provided with auxiliary insulation over the cord if damage to the cord insulation results when the strain relief tests are conducted without auxiliary insulation.

12.2.2.3 Means shall be provided to prevent a flexible power cord from being pushed into the equipment through the cord entry hole if such displacement would:

a) Result in mechanical damage to the cord;

b) Expose the cord to a temperature higher than that for which it is rated; or

c) Reduce spacings below the acceptable minimum values.

To determine compliance, the flexible power cord shall be tested in accordance with Section 52.3, Push-Back strain relief test.

12.2.3 Bushings

12.2.3.1 At the point where the flexible power cord passes through an opening in a wall, barrier, or the enclosure, there shall be a bushing or the equivalent that is secured in place, and that has a smooth, well-rounded surface against which the cord may bear. An insulating bushing shall be provided, if the wall or barrier is of metal, or if the construction is such that the cord may be subjected to strain or motion. The bushing shall comply with the requirements in the Standard for Insulating Bushings, UL 635.

12.2.3.2 A hole in porcelain, phenolic composition, or other non-conducting material, having a smooth, rounded surface, is considered to be equivalent to a bushing.

12.2.3.3 A bushing of the same material as, and molded integrally with, a flexible power cord, is acceptable if the built up section is not less than 1/16 inch (1.6 mm) thick at the point where the cord passes through the enclosure.

12.2.3.4 At a point of flexure, no additional wires or cables shall be routed through a bushing or opening with the flexible power cord.

12.3 Direct plug-in devices

12.3.1 A product that is constructed with a direct plug-in feature shall not be provided with a means for connection to the alternating current source other than the blades provided for the direct plug-in feature. In addition, the product shall comply with the requirements in 12.3.2 – 12.3.9.

12.3.2 The mechanical assembly of a direct plug-in device intended for indoor use shall be considered acceptable if the device:

a) Complies with the requirements in 12.3.3 – 12.3.9, or

b) Complies with the Standard for Class 2 Power Units, UL 1310.

12.3.3 The integral blade assembly of a direct plug-in device shall comply with the construction requirements in the Standard for Attachment Plugs and Receptacles, UL 498. See 12.3.9.

12.3.4 The mechanical assembly of a direct plug-in device intended for outdoor use shall be considered acceptable if the enclosure complies with the requirements for Environmental Considerations, Section 65, in addition to the requirements in 12.3.2.

12.3.5 The maximum acceptable moment, center of gravity, dimensions and weight of a direct plug-in device shall comply with each of the following requirements (see 12.3.6):

a) The quotient of WY/Z shall not exceed 48 ounces (1361 grams);

b) The quotient of WY/S shall not exceed 48 ounces (1361 grams);

c) The product of WX shall not exceed 80 ounce-inches (0.56 N-m); and

d) The weight of the device shall not exceed 28 ounces (794 grams).

In which:

W is the weight of the device in ounces (grams);

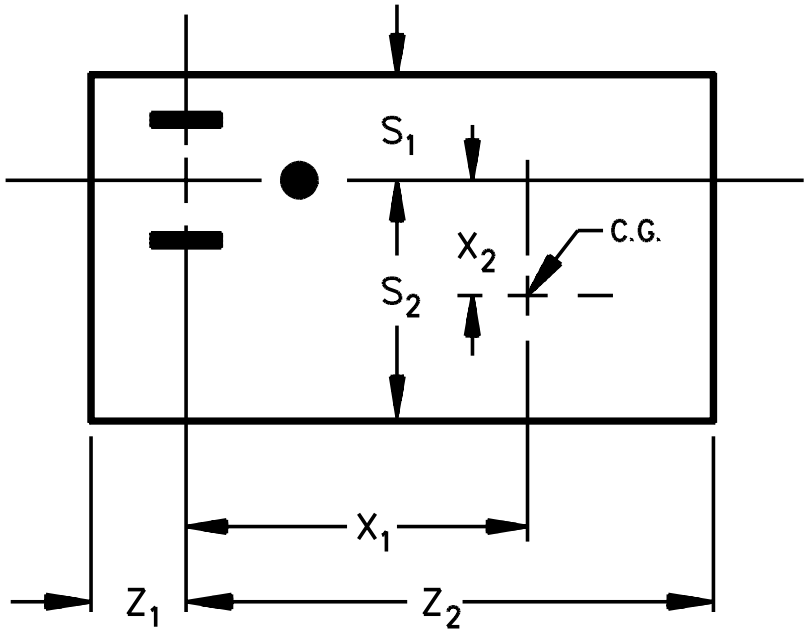
Y is the distance illustrated in Figure 12.2 in inches (mm);

Z is the lesser of Z_1 or Z_2 as illustrated in Figure 12.2 in inches (mm);

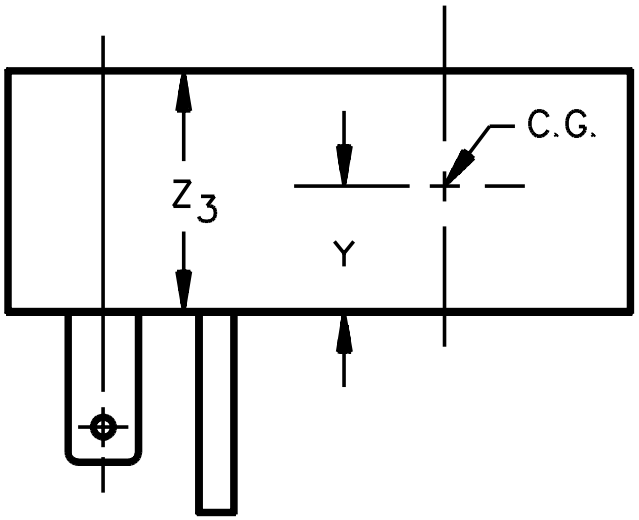
S is the lesser of S_1 or S_2 as illustrated in Figure 12.2 in inches (mm);

X is the greater of X_1 or X_2 as illustrated in Figure 12.2 in inches (mm).

Figure 12.2
Wire bending space



FRONT VIEW



SIDE VIEW

C.G. = Center of Gravity

CP100

12.3.6 The values specified in 12.3.5 shall be determined as follows:

a) For devices with an output cord, the cord is to be cut off at the enclosure, or at the strain relief means if the strain relief means is outside the enclosure.

b) For devices with directly mounted accessories, the values are to be measured with he accessories in place.

c) A mounting tab is not to be included in the measurements of the linear dimensions for the purpose of determining moments unless:

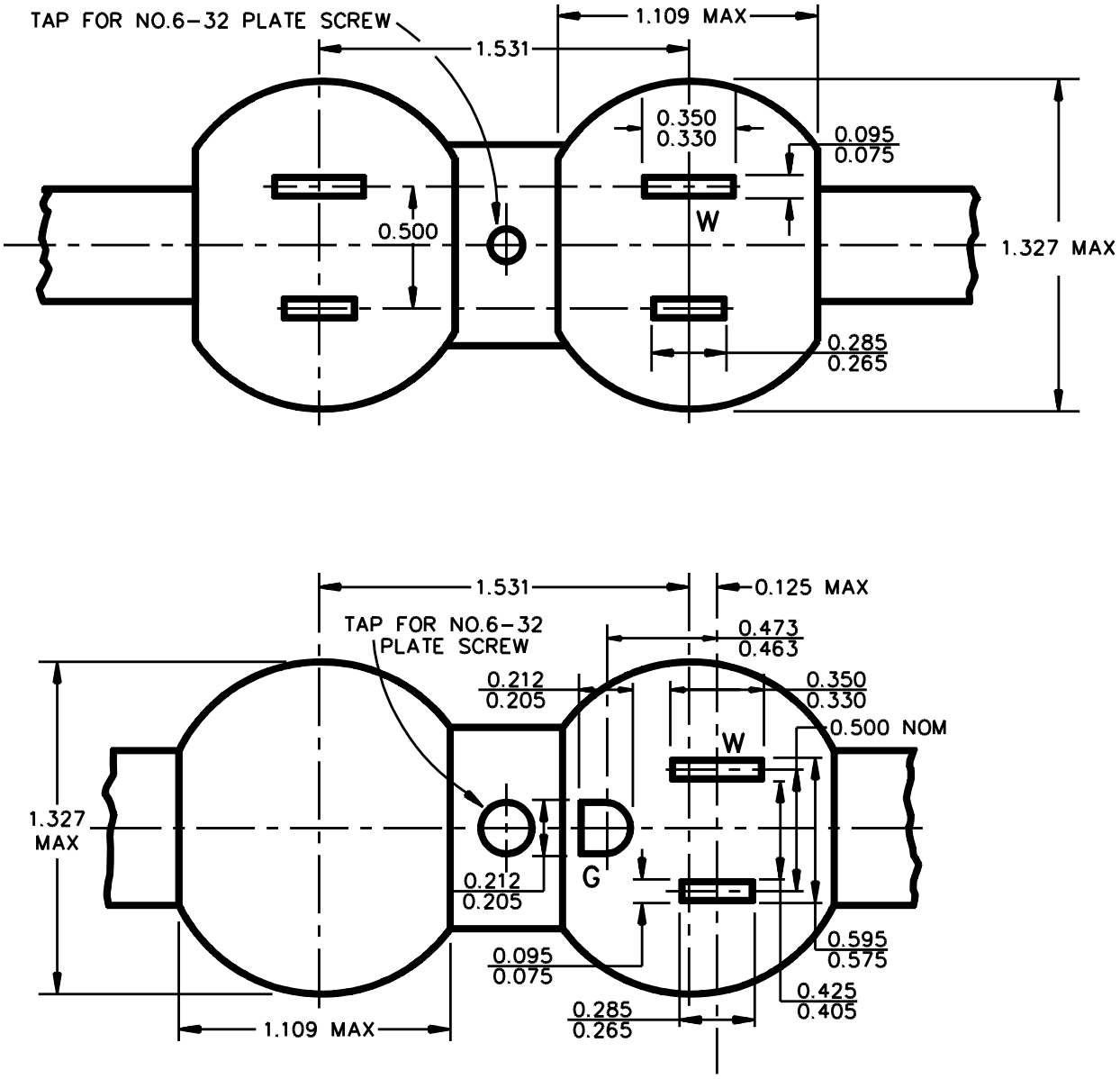
1) The tab and enclosure comply with the Drop Test, Section 57, with one impact on the tab itself, without deformation, and

2) For a polymeric enclosed device having an integral tab, the tab and enclosure do not distort at temperatures to which the material may be subjected under conditions of normal and abnormal use as determined by the Mold Stress Test, Section 64.

12.3.7 When inserted in a parallel blade duplex receptacle, no part of a device, including a mounting tab or output wiring, shall interfere with full insertion of an attachment plug or current tap into the adjacent receptacle. See Figure 12.3.

Exception: A device that renders the adjacent receptacle completely unusable in any one mounting position need not comply with this requirement.

Figure 12.3
Parallel duplex receptacle

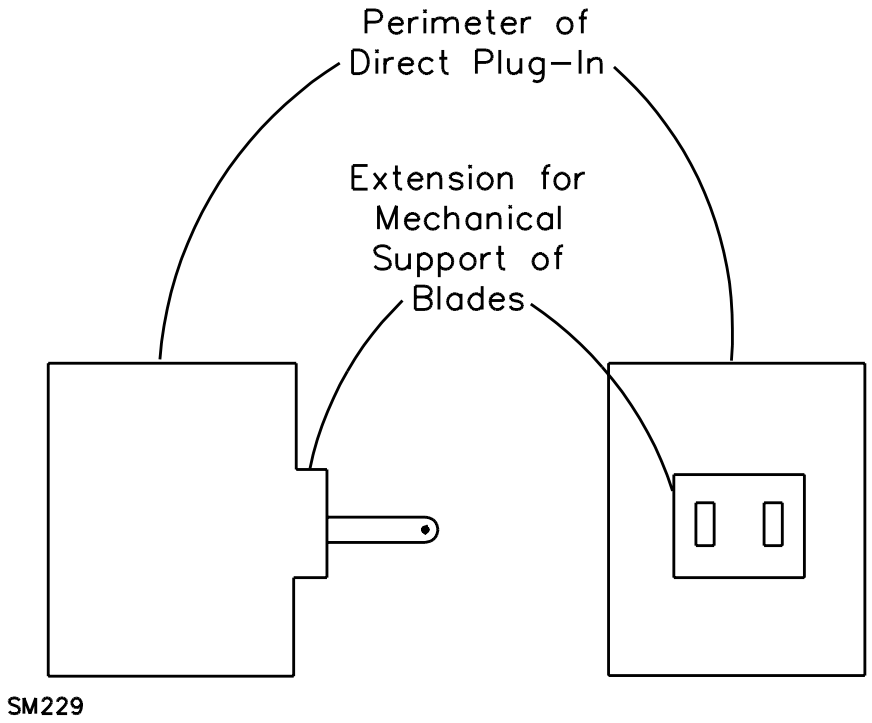


12.3.8 The enclosure of the direct plug-in device shall be capable of being gripped for removal from the receptacle to which it is connected, and the perimeter of the face section from which the blades project shall not be less than 5/16 inch (7.9 mm) from any point on either blade.

Exception: For tab mounted devices, the perimeter of the face section may not be less than 1/4 inch (6.4 mm) from any point on either blade.

12.3.9 With reference to 12.3.8, an extension from the face for mechanical support of the blades is not to be considered in the measurement provided the extension measures 0.04 inch (1 mm) or less from the face section of the direct plug-in device. See Figure 12.4.

Figure 12.4
Extension for mechanical support of blades



13 Output Connections and Wiring

13.1 General

13.1.1 The requirements in 13.1.2 – 13.1.6 apply to the output connection means at the EV supply equipment. In addition, 13.1.2 – 13.1.11 apply to the EV cable or wiring from the EV supply equipment to the EV connector if provided; and 13.1.12 – 13.1.13 apply to the EV connector if provided.

13.1.2 The EV supply equipment shall be provided with one of the following means at the output:

a) An EV receptacle in accordance with the Standard for Plugs, Receptacles, and Couplers for Electric Vehicles, UL 2251.

b) A grounding type NEMA receptacle in accordance with the Standard for Attachment Plugs and Receptacles, UL 498.

c) Wire terminals for a permanently connected EV cable. The terminals shall comply with the requirements for wiring terminals in accordance with 12.1.2.

13.1.3 With reference to 13.1.2 (c), the permanently connected EV cable shall comply with the strain relief requirements in 13.2 and the requirements for bushings in 13.3.

13.1.4 With reference to 13.1.2 (a) and 13.1.2 (b), the EV receptacle or the NEMA receptacle shall have a voltage and current rating corresponding to the rated output of the EV supply equipment.

13.1.5 With reference to 13.1.2 (a), an EV receptacle shall be designed in accordance with the standardized interface outlined in the Society of Automotive Engineers Recommended Practice for Electric Vehicle Conductive Charge Couplers, SAE J1772™, or the connection and interface shall be evaluated based on possible misconnection and shall be marked in accordance with 76.14.

13.1.6 With reference to 13.1.2 (a) and 13.1.2 (b), the output connection shall be marked with the rated voltage and current that is available at that connection. See 74.1 (c).

13.1.7 EV cables provided to complete the connection from the EV supply equipment to the vehicle shall be in accordance with the Standard for Flexible Cord and Cables, UL 62, and the Reference Standard for Electric Wires, Cables, and Flexible Cords, UL 1581.

13.1.8 The EV cables shall be type EV, EVJ, EVE, EVJE, EVT, or EVJT, and shall have a minimum voltage rating corresponding to the overall output rating of the EV supply equipment.

13.1.9 The EV cable shall contain conductors that are suitably sized for the intended output rating of the EV supply equipment.

13.1.10 The overall length of the EV cable shall not exceed 25 feet (7.5 m) in length. The length is measured from the point where the cable exits the EV supply equipment enclosure for permanently connected EV cable, or from where the cable exits the EV plug enclosure if provided as part of a cable assembly intended to connect to an EV receptacle located on the EV supply equipment, to the point where it enters the EV connector enclosure on the vehicle side of the EV cable.

Exception: EV supply equipment provided with a suitable cable management system is allowed to have a cable in excess of 25 feet (7.5 m). The cable management system shall control the cable so that it is not allowed to rest on the floor or supporting surface after use.

13.1.11 For EV cables intended to connect to an EV receptacle located on the EV supply equipment, the EV cable shall terminate in an EV plug on the EV supply equipment side. The EV plug shall comply with the applicable requirements in the Standard for Plugs, Receptacles, and Couplers for Electric Vehicles, UL 2251. The EV plug shall be designed in accordance with the standardized interface outlined in the Society of Automotive Engineers Recommended Practice for Electric Vehicle Conductive Charge Couplers, SAE J1772™, or the connection and interface shall be evaluated based on possible misconnection and shall be marked in accordance with 76.14.

13.1.12 For EV cables provided for connection of the vehicle to the EV supply equipment, the EV cable shall terminate on the vehicle side of the cable in an EV connector. The EV connector shall comply with the applicable requirements in the Standard for Plugs, Receptacles, and Couplers for Electric Vehicles, UL 2251. The EV connector shall be designed in accordance with the standardized interface outlined in the Society of Automotive Engineers Recommended Practice for Electric Vehicle Conductive Charge Couplers, SAE J1772™, or the connection and interface shall be evaluated based on possible misconnection and shall be marked in accordance with 76.14.

13.1.13 EV plugs and EV connectors provided as part of the EV supply equipment shall have a minimum voltage and current rating corresponding to the output rating of the EV supply equipment involved.

13.1.14 External connections at the output of EV supply equipment or at the vehicle connector shall be protected by a means that de-energizes the cable conductors and vehicle connector upon exposure to a strain which results in either cable rupture or separation of the cable from the EV supply equipment or the vehicle connector. In addition, there shall be no exposure to live parts after de-energization occurs.

13.2 Strain relief

13.2.1 An EV cable permanently connected to the EV supply equipment, or an EV cable connected to an EV plug on one end and an EV connector on the other, shall be provided with a means of strain relief in accordance with EV Cable Secureness Test, Section 53.

13.2.2 A metal strain relief clamp or band provided in accordance with 13.2.1 shall be provided with auxiliary insulation over the EV cable if damage to the EV cable insulation results when the strain relief tests are conducted without auxiliary insulation.

13.3 Bushings

13.3.1 Where the EV cable passes through a wall or enclosure, whether the enclosure of the EV supply equipment or the EV lug or EV connector, a bushing shall be provided to protect the EV cable. The bushing shall comply with the requirements in 12.2.3.

14 Equipment Grounding

14.1 A product shall have provisions for grounding all exposed non-current-carrying conductive parts, and all internal metal parts that are exposed to contact during servicing, that may become energized. A part shall be considered capable of becoming energized if failure of electrical spacing or insulation or both can result in conductive connection to a current carrying part.

Exception: A dead metal part as described in (a) – (e) need not comply with this requirement.

a) A small metal part (such as an adhesive attached foil marking, a screw, or a handle) that is:

1) On the exterior of the enclosure and separated from all electrical components by grounded metal, or

2) Electrically isolated from all electrical components.

b) A panel, cover, or other metal part that is isolated from all electrical components, including wiring, by a barrier of vulcanized fiber, varnished cloth, phenolic composition, or other moisture-resistant insulating material that is not less than 1/32 inch (0.8 mm) thick and is secured in place.

c) A panel, cover, or other metal part that does not enclose an uninsulated live part and that is electrically isolated from other electrical components.

d) A door or the like that can only become energized through a grounded part.

e) A small assembly screw that is positively separated from wiring and all uninsulated live part.

14.2 All non-current carrying conductive parts shall be bonded together and connected to the electrical supply equipment grounding means in accordance with Bonding, Section 15. The connection to the electrical supply equipment grounding means is considered the principal equipment ground conductor path and it shall not include a trace on a printed wiring board.

14.3 Connection to the electrical supply equipment grounding means shall be accomplished as follows:

a) In a product intended to be permanently connected, to:

1) A knockout or equivalent opening means in a metal enclosure intended to be connected to a metal enclosed wiring system suitable for grounding, or

2) The equipment grounding field wiring terminal or lead.

b) In a product provided with a flexible power supply cord and an attachment plug, to the equipment grounding conductor of the flexible power supply cord.

14.4 The equipment grounding connection shall not contain any splices.

14.5 An equipment grounding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.

14.6 An equipment grounding conductor shall be:

a) If insulated, provided with insulation having an outer surface that is green with or without one or more yellow stripes, and

b) Of a size acceptable for the application in accordance with Table 14.1, but shall not be required to be larger than the circuit conductors supplying the equipment.

Table 14.1
Minimum size of conductor

Rating of branch-circuit overcurrent-protective device to which the product is intended to be connected, amperes	Size of equipment grounding conductor			
	Copper		Aluminum	
	Wire, AWG	Equivalent cross-sectional area, cmil (mm^2)	Wire, AWG	Equivalent cross-sectional area, cmil (mm^2)
15	14	3987 (2.02)	12	6334 (3.21)
20	12	6334 (3.21)	10	10380 (5.261)
30	10	6334 (3.21)	8	16510 (8.367)
40	10	10380 (5.261)	8	16510 (8.367)
60	10	10380 (5.261)	8	16510 (8.367)
100	8	16510 (8.367)	6	26240 (13.30)
200	6	26240 (13.30)	4	41740 (21.15)
300	4	41740 (21.15)	2	66360 (33.62)
400	3	52620 (26.67)	1	83690 (42.41)
500	2	66360 (33.62)	1/0	105600 (53.49)
600	1	83690 (42.41)	2/0	133100 (67.43)

14.7 An equipment grounding conductor of a power supply cord shall be connected to the grounding blade of the attachment plug.

14.8 For a product provided with a flexible power cord, a stud and nut combination used to secure the grounding conductor to the frame shall be secured to the frame by welding the stud in place. The ground conductor shall be connected first and be in contact with the frame and secured in place by a dedicated nut and lock washer. Other bonding jumpers may be connected to the stud, but they shall be connected above the main ground connection and secured by a separate nut and lock washer.

14.9 In a product provided with a flexible power supply cord and an attachment plug, the connection between the dead metal parts required to be grounded and the equipment grounding conductor shall be made by a positive means in accordance with 15.1 and 15.3. The connection shall be made by a means not likely to be removed during ordinary servicing not involving the flexible power supply cord.

14.10 A sheet metal screw shall not be used to connect equipment grounding conductors to enclosures.

14.11 A grounding screw shall engage at least two full threads and shall be used in conjunction with upturned lugs, a cupped washer, or an equivalent method that is capable of retaining a 10 AWG conductor under the head of the screw.

14.12 A ferrous metal part is a grounding path shall be protected against corrosion by enameling, galvanizing, plating, or equivalent means.

14.13 A terminal intended for the connection of an equipment grounding conductor shall be identified by:

a) Use of a wire binding screw with a green colored head that is slotted or hexagonal, or both;

b) Use of a threaded stud with a green colored hexagonal nut;

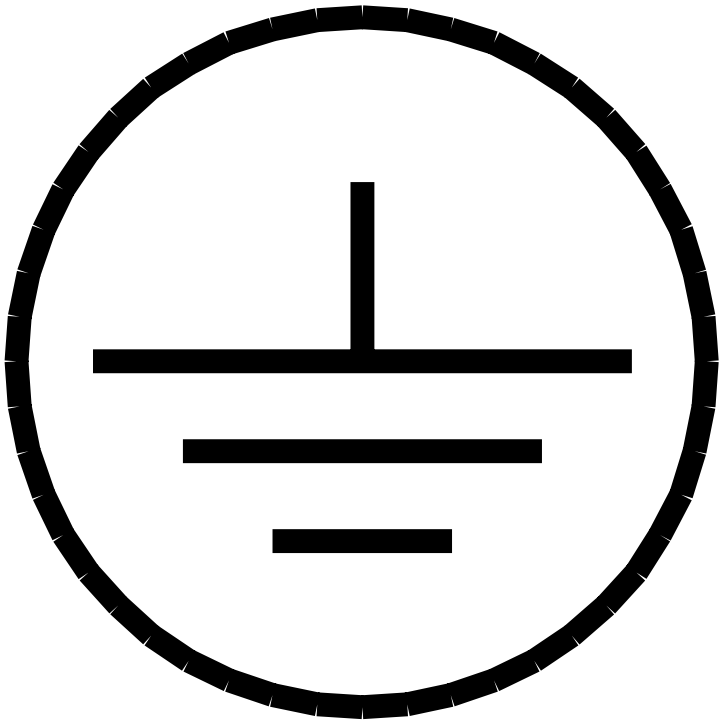
c) Use of a green colored pressure terminal connector;

d) Being marked “G”, “GR”, “GND”, “Ground”, “Grounding”, or the like;

e) A marking on a wiring diagram provided on the product; or

f) The grounding symbol illustrated in Figure 14.1 on or adjacent to the terminal or on a wiring diagram provided on the product.

Figure 14.1
Grounding symbol



15 Bonding

15.1 A conductor, including a strap, jumper, or similar part, that is used only for bonding shall:

a) Be of copper, copper alloy, aluminum or other material that has been investigated and found acceptable for use as an electrical conductor;

b) Be protected from mechanical damage;

c) Not be secured by a removable fastener used for any purpose other than bonding unless then bonding conductor is not likely to be omitted after removal and replacement of the fastener; and

d) Have the flexibility needed to withstand mechanical stress due to vibration or flexing during use.

15.2 Metal parts in a bonding path shall be galvanically compatible so as to reduce electrolytic action between dissimilar metals. The combined electrochemical potential between dissimilar metals, which are in contact, shall be less than 0.6 V as determined in accordance with Figure 15.1. Combinations of metals that fall above the line in the table shall not be used.

Figure 15.1
Electrochemical potential

Magnesium, magnesium alloys	Zinc, zinc alloys	80 tin/20 Zn on steel, Zn on iron or steel	Aluminium	Cd on steel	Al/Mg alloy	Mild steel	Duralumin	Lead	Cr on steel, soft solder	Cr on Ni on steel, tin on steel, 12% Cr stainless steel	High Cr stainless steel	Copper, copper alloys	Silver solder, austenitic stainless steel	Ni on steel	Silver	Rh on Ag on Cu, silver/gold alloy	Carbon	Gold, platinum	
0	0.05	0.55	0.7	0.8	0.85	0.9	1.0	1.05	1.1	1.15	1.25	1.35	1.4	1.45	1.6	1.65	1.7	1.75	Magnesium, magnesium alloys
	0	0.05	0.2	0.3	0.35	0.4	0.5	0.55	0.6	0.65	0.75	0.85	0.9	0.95	1.1	1.15	1.2	1.25	Zinc, zinc alloys
		0	0.15	0.25	0.3	0.35	0.45	0.5	0.55	0.6	0.7	0.8	0.85	0.9	1.05	1.1	1.15	1.2	80 tin/20 Zn on steel, Zn on iron or steel
			0	0.1	0.15	0.2	0.3	0.35	0.4	0.45	0.55	0.65	0.7	0.75	0.9	0.95	1.0	1.05	Aluminium
				0	0.05	0.1	0.2	0.25	0.3	0.35	0.45	0.55	0.6	0.65	0.8	0.85	0.9	0.95	Cd on steel
					0	0.05	0.15	0.2	0.25	0.3	0.4	0.5	0.55	0.6	0.75	0.8	0.85	0.9	Al/Mg alloy
						0	0.1	0.15	0.2	0.25	0.35	0.45	0.5	0.55	0.7	0.75	0.8	0.85	Mild steel
							0	0.05	0.1	0.15	0.25	0.35	0.4	0.45	0.6	0.65	0.7	0.75	Duralumin
								0	0.05	0.1	0.2	0.3	0.35	0.4	0.55	0.6	0.66	0.7	Lead
									0	0.05	0.15	0.25	0.3	0.35	0.5	0.55	0.6	0.65	Cr on steel, soft solder
										0	0.1	0.2	0.25	0.3	0.45	0.5	0.55	0.6	Cr on Ni on steel, tin on steel, 12% Cr stainless steel
											0	0.1	0.15	0.2	0.35	0.4	0.45	0.5	High Cr stainless steel
												0	0.05	0.1	0.25	0.3	0.35	0.4	Copper, copper alloys
													0	0.05	0.2	0.25	0.3	0.35	Silver solder, austenitic stainless steel
														0	0.15	0.2	0.25	0.3	Ni on steel
															0	0.05	0.1	0.15	Silver
																0	0.05	0.1	Rh on Ag on Cu, silver/gold alloy
																	0	0.05	Carbon
																		0	Gold, platinum

Ag = Silver
Al = Aluminium
Cr = Chromium
Cd = Cadmium
Cu = Copper
Mg = Magnesium
Ni = Nickel
Rh = Rhodium
Zn = Zinc

NOTE. – Corrosion due to electrochemical action between dissimilar metals which are in contact is minimized if the combined electrochemical potential is below about 0.6V. In the following table the combined electrochemical potentials are listed for a number of pairs of metals in common use; combinations above the dividing line should be avoided.

S3426

15.3 Bonding shall be by a positive means, such as by a clamp, rivet, bolt, screw, welded joint, or a soldered or brazed joint using materials having a softening or melting point higher than 454°C (850°F). Terminals complying with the applicable requirements in the Standard for Electrical Quick Connect Terminals, UL 310, are acceptable to connect bonding conductors in sizes 18 – 14 AWG under the following conditions:

a) For conductor sizes 18 – 16 AWG, the minimum connector and tab width shall be 0.110 in (2.8 mm).

b) For conductor size 14 AWG, the minimum connector and tab width shall be 0.250 in (6.4 mm).

c) Quick connect tabs shall not be less than 0.032 in (0.8 mm) thick.

15.4 A bonding screw shall engage at least two full threads and shall be used in conjunction with upturned lugs, a cupped washer, or an equivalent method that is capable of retaining a 10 AWG conductor under the head of the screw.

15.5 A bonding connection means shall penetrate nonconductive coatings, such as paint or vitreous enamel.

15.6 A metal-to-metal hinge-bearing member of a door or cover used as a means for bonding the door or cover shall be of the multiple bearing pin (piano) type.

15.7 In a product provided with a power supply cord and an attachment plug:

a) A copper bonding jumper, including a clamp or strap, shall have a cross-sectional area not less than that of the equipment-grounding conductor of the power supply cord.

b) An aluminum bonding jumper, including a clamp or strap, shall have a cross-sectional area not less than that of a conductor two AWG sizes larger than the circuit equipment grounding conductor of the power supply cord.

Exception No. 1: A conductor, including a strap, jumper, or similar part, having a smaller cross-sectional area is acceptable if it complies with the requirements in the Bonding Conductor Test, Section 60.

Exception No. 2: A conductor, including a strap, jumper, or similar part, for a component or electrical enclosure need not be larger than the largest conductors supplying power to the component or components adjacent to the dead metal parts.

15.8 In a product intended to be permanently connected to the electrical supply, a copper or aluminum bonding jumper, including clamp or strap, shall not be smaller than, or have an equivalent cross-sectional area less than, the size specified in Table 14.1.

Exception No. 1: A smaller bonding jumper may be used as provided in Exception Nos. 1 and 2 to 15.7.

Exception No. 2: A bonding jumper need not be larger than the circuit conductors supplying the equipment.

15.9 If the continuity of a bonding system relies on the integrity of a nonmetallic material, the dimensional stability of the material shall be considered in addition to any other material characteristics that could affect the bond. These material characteristics include the material's mechanical strength, thermal aging characteristics, moisture absorption properties, combustibility, and resistance to impact, distortion, creep, arcing, and ignition. The bonding system, together with the nonmetallic material, shall comply with the Bonding Conductor Test, Section 60.

16 EV Bonding

16.1 14.1 If the EV cable and associated connections are provided with the EV supply equipment, means shall be provided for incorporating the bonding means for the vehicle or the vehicle shall be isolated from the source in accordance with the applicable requirements for personnel protection systems in Section 9.2.

17 Internal Wiring

17.1 Wires

17.1.1 The internal wiring of a device shall be rated for the particular application with respect to the temperature and voltage, exposure to oil or grease, and other conditions of service to which the wiring is subjected.

17.1.2 With respect to 17.1.1, the effects of vibration, if installed on-board an EV, impact, and exposure are to be evaluated for wires smaller than 24 AWG (0.21 mm^2).

17.1.3 All wiring shall be polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), or neoprene insulated, or shall comply with the vertical wire flame test requirements in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, as evidenced by a surface marking "VW-1".

17.1.4 The length of a power supply cord inside a device shall be limited to that needed for electrical connections.

17.2 Protection of wires

17.2.1 Internal wiring shall not be accessible when judged in accordance with Protection of Users – Accessibility and User Servicing, Section 8, unless it is located and secured within the enclosure such that the risk of it being subjected to stress or mechanical damage is reduced.

17.2.2 Wires within an enclosure, compartment, raceway or similar part shall be located or protected to reduce the risk of unintentional contact with any sharp edge, burr, fin, or similar part that damages the conductor insulation.

17.2.3 Internal wiring shall be so routed and secured that neither it nor related electrical connections are to be subjected to stress or mechanical damage.

17.2.4 A hole in a sheet metal wall through which insulated wires pass and on which they bear shall be provided with a smoothly rounded bushing or shall have smooth, rounded surfaces upon which the wires bear, to avoid abrasion of insulation.

17.2.5 A bushing provided in accordance with 17.2.4, shall comply with 12.2.3.

17.2.6 Metal clamps and guides used for routing stationary internal wiring shall be provided wit smooth well rounded edges.

17.2.7 Auxiliary mechanical protection that is not electrically conductive shall be provided under a metal clamp at which pressure is exerted on a conductor having thermoplastic insulation less than 0.030 inch (0.76 mm) thick and no overall braid, and on any wire or wires that are subject to motion.

18 Flammability

18.1 Nonmetallic materials used for insulation, barriers, internal parts, enclosures, decorative parts, and so on, shall comply with the following requirements. Metallic enclosures are considered to comply with flammability requirements without further evaluation, except magnesium shall not be used as a material for enclosures.

18.2 Nonmetallic materials used to form enclosures shall have a minimum flammability rating in accordance with Table 18.1.

Table 18.1
Flammability ratings of enclosures

Product type	Flammability rating
Portable equipment	V-1
Stationary equipment	V-1
Movable equipment	5V
Permanent equipment	5V

18.3 Nonmetallic materials internal to the enclosure, but not intended for direct support of live parts, shall be rated V-2 minimum.

Exception No. 1: The internal insulating system of components where component requirements exist need not have a flame class rating.

Exception No. 2: A small part, gasket, or other nonmetallic part that is located such that it cannot propagate flame from one area to another within the equipment, and is not located in close proximity to uninsulated live parts, is a not required to have a flame class rating.

18.4 Nonmetallic materials located outside of the enclosure, and not used to complete the enclosure, are considered decorative parts. These parts shall be rated HB minimum, except as indicated in 18.5.

18.5 Cables entering and exiting the enclosure shall be rated VW-1 minimum. Strain relief bushings for these cables will complete enclosures when installed as intended, and shall have a flammability rating equivalent to the applicable enclosure type rating in Table 18.1. Other components such as electric vehicle couplers and attachment plugs, shall comply with the flammability requirements in the applicable component standard for that component.

18.6 Printed wiring board materials shall be rated V-1 minimum.

18.7 For the requirements outlined in 18.2 – 18.6, the flammability rating of the material shall be provided as part of the material rating or the flammability rating may be determined by the applicable tests in Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

19 Current Carrying Parts

19.1 A current carrying part shall be of silver, copper, a copper-based alloy, stainless steel, aluminum, or other material determined to be acceptable for the application. Plated iron or steel shall not be used for parts that are depended upon to carry current. Wire binding screws shall not be of iron or steel.

19.2 Iron or steel, if protected against corrosion by zinc, tin, or equivalent plating, can be used for screws, plates, yokes, or other parts that are employed as a means of clamping the conductor providing such parts are not the primary current carrying members.

19.3 Suitable means shall be provided for retaining live parts, within such limits of alignment as to ensure that plugs will enter receptacles, connectors, and the like, in the intended manner.

19.4 Uninsulated live parts shall be secured in place so that they do not turn or shift, when turning or shifting results in a reduction in the clearance and creepage distances below those required in Spacings, Section 22.

19.5 A current carrying part shall be prevented from turning relative to the surface on which it is mounted if such turning would adversely affect the performance of the device.

20 Electrical Connections

20.1 The requirements described in 20.2 – 20.7 apply to connections of internal wiring that are factory installed in the device.

20.2 A splice or connection shall be mechanically secure and shall make electrical contact.

20.3 A soldered connection is determined to be mechanically secure when the lead is:

a) Wrapped one full turn around a terminal;

b) Bent at a right angle after being passed through an eyelet or opening, except on printed wiring boards where components are inserted or secured (as in a surface mounted component) and wave- or lap-soldered; or

c) Twisted with other conductors.

20.4 When stranded internal wiring is connected to a wire binding screw, the construction shall be such that loose strands of wire do not contact other uninsulated conductive parts. This is to be accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, soldering of all strands together, or by any other equivalent means.

20.5 A nominal 0.110, 0.125, 0.187, 0.205, or 0.250 inch wide quick connect terminal shall comply with the Standard for Electrical Quick Connect Terminals, UL 310. Other sizes of quick connect terminals shall be investigated with respect to crisp pullout, engagement-disengagement forces of the connector and tab, and temperature rise; all tests shall be conducted in accordance with UL 310.

20.6 An open end spade lug is not to be used unless an additional means, such as upturned ends on the lug or bosses or shoulders on the terminal, is provided to hold the lug in place when the binding screw or nut loosens.

20.7 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings are maintained between the splice and other metal parts. Insulation over the splice is allowed to have one or more of the following:

a) A splicing device such as a pressure wire connector, employed when insulated for the voltage and temperature the device is to be subjected.

b) Insulating tubing or sleeving used to cover a splice shall be used in accordance with 22.2.2.

c) Two layers of thermoplastic tape, or two layers of friction tape, or one layer of friction tape and one layer of rubber tape, where the voltage involved is less than 250 volts. Thermoplastic tape wrapped over a sharp edge shall not be used.

21 Gaskets

21.1 A gasket of elastomeric or thermoplastic material or a composition gasket utilizing an elastomeric material that is provided on an enclosure to meet the environmental construction and performance requirements of this outline shall be in accordance with the Standard for Gaskets and Seals, UL 157, and considered suitable for this use or it shall comply with the Gasket test, Section 65.13.

21.2 A gasket shall be secured with adhesive or by mechanical means. The gasket and its securing means shall not be damaged when the joint is opened.

22 Spacings

22.1 General

22.1.1 The spacings for a device shall not be less than the applicable values specified in Table 22.1 or as provided in Alternate Spacings – Clearances and Creepage Distances, Section 23.

Exception No. 1: As provided in 22.2.1 where liners and barriers are used.

Exception No. 2: The spacings requirements in Table 22.1 do not apply to inherent spacings of a component such as a switch, power switching semiconductor, or similar component. See 22.1.6.

22.1.2 Where an uninsulated live part is not rigidly secured in position by means other than friction between surfaces or where a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that, for any position resulting from turning or other movement of the parts in question, at least the minimum required spacings shall be maintained.

22.1.3 With reference to 22.1.2, a lock washer applied as intended is a method of rigidly securing a part.

Table 22.1
Spacings

Potential involved, volts rms (Peak)		Minimum spacings, inch (mm)					
		Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part				Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[a]	
		Through air		Over surface		Shortest distance	
0 – 50	(0 – 70.7)	1/16	(1.6)[b,c]	1/16	(1.6)[b,c]	1/16	(1.6)[b]
Greater than 50 to 150	(70.7 to 212.1)	1/8	(3.2)[b,c]	1/4	(6.4)[c]	1/4	(6.4)
Greater than 150 to 300	(212.1 to 424.2)	1/4	(6.4)	3/8	(9.5)	1/2	(12.7)
Greater than 300 to 600	(424.2 to 848.4)	3/8	(9.5)	1/2	(12.7)	1/2	(12.7)
Greater than 600 to 1000	(848.4 to 1414)	3/4	(19.1)[d]	3/4	(19.1)[d]	3/4	(19.1)

[a] For the purpose of this requirement, a metal piece attached to the enclosure is a part of the enclosure when deformation of the enclosure reduces spacings between the metal piece and uninsulated live parts.

[b] The spacing between field-wiring terminals of opposite polarity and the spacing between a field-wiring terminal and a grounded dead metal part shall not be less than 1/4 inch (6.4 mm).

[c] At closed-in points only, such as a screw and washer construction of an insulated stud mounted in metal, a spacing of 3/64 inch (1.2 mm) meets the intent of the requirement.

[d] Between uninsulated high-voltage parts and (1) uninsulated high-voltage parts of opposite polarity or different potentials, (2) earth-grounded metal parts, (3) uninsulated primary-circuit parts, (4) insulated primary-circuit parts, (5) insulated high-voltage parts of opposite polarity, or of different potentials.

22.1.4 Inherent spacings of the components mentioned in Exception No. 2 of 22.1.1 shall comply with the requirements for the component in question where the spacings are less than the values specified in this outline. Spacings from such components to another component and to the enclosure shall comply with the applicable spacings specified in this outline.

22.1.5 With respect to judging spacings, an uninsulated live part is at opposite polarity to uninsulated live parts in another circuit. Spacings are to be based on the highest of the circuit voltages.

22.1.6 Film coated wire is an uninsulated live part when judging spacings.

22.1.7 Spacings at filed wiring terminals are to be measured with conductors installed in the terminals. The gauge of these conductors is to be based on the rating of the circuit containing the terminals.

22.1.8 Spacings between uninsulated live parts of different potential and between such parts and dead metal that are capable of being grounded in service are not specified for parts of limited energy circuits in accordance with 5.30.

22.2 Insulation barriers

22.2.1 An insulating liner or barrier of material such as vulcanized fiber may be employed in lieu of required spacings mentioned in Exception No. 1 to 22.1.1 but not as the sole support of uninsulated live parts involving a risk of fire or electric shock when it is not less than 0.028 inch (0.71 mm) thick and it is so located that it is not adversely affected by arcing. Other insulating materials used as a barrier or as either direct or indirect support of uninsulated live parts involving a risk of fire or electric shock shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 1: Vulcanized fiber not less than 0.013 inch (0.33 mm) thick is used only when:

a) In conjunction with an air spacing of not less than 50 percent of the minimum through air spacing; and

b) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 volts rms or less.

Exception No. 2: Mica not less than 0.006 inch (0.165 mm) may be used as insulation between a heat sink and a live case of a semiconductor device.

22.2.2 Insulating tubing complying with the requirements in the Standard for Extruded Insulating Tubing, UL 224, is used as insulation of a conductor in lieu of the minimum spacings and for capacitor cases in lieu of bonding the case for grounding, only when the following conditions are met:

a) The conductor is not subjected to compression, repeated flexure, or sharp bends;

b) The conductor or case covered with the tubing is well rounded and free from sharp edges;

c) The tubing is used in accordance with the manufacturer's instructions; and

d) The conductor or case is not subjected to a temperature or voltage higher than that for which the tubing is rated.

22.2.3 A wrap of thermoplastic tape, complying with the requirements in the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510 is allowable when all of the following conditions are met:

a) The wrap is no less than 0.013 inch (0.33 mm) thick, is applied in two or more layers, and is used in conjunction with no less than one-half the required through air spacing.

b) The wrap is no less than 0.028 inch (0.72 mm) thick when used in conjunction with less than one-half the required through air spacing.

c) Its temperature rating is no less than the maximum temperature observed during the temperature test.

d) The tape is not subject to compression.

e) The tape is not wrapped over a sharp edge.

23 Alternate Spacings – Clearances and Creepage Distances

23.1 As an alternative to the spacing requirements of Section 22, as applicable, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, is used. The spacing requirements of UL 840 shall not be used for field wiring terminals and spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end use application is to be taken into account and is capable of modifying those characteristics given in 23.2 and 23.3.

23.2 The level of pollution for indoor use equipment shall be pollution degree 2. For outdoor use equipment, the level of pollution shall be pollution degree 3. Hermetically sealed or encapsulated enclosures, or coated printed wiring boards in compliance with the Printed Wiring Board Coating Performance Test of the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are pollution degree 1.

23.3 The equipment shall be rated overvoltage category II as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

23.4 In order to apply Clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

23.5 All printed wiring boards are considered to have a minimum comparative tracking index of 100 without further investigation.

24 Separation of Circuits

24.1 Factory wiring

24.1.1 Insulated conductors of different circuits within a device, including wires in a terminal box or compartment, shall be either separated by barriers or segregated and shall be so separated or segregated from uninsulated live parts connected to different circuits.

Exception: For insulated conductors of different circuits, when each conductor is provided with insulation intended for the highest of the circuit voltages, no barriers or segregation are required.

24.1.2 For the purpose of the requirement in 24.1.1, different circuits include:

a) Circuits connected to the primary and secondary windings of an isolation transformer,

b) Circuits connected to different isolated secondary windings of a multi-secondary transformer,

c) Circuits connected to secondary windings of different transformers,

d) Input and output circuits of an optical isolator,

e) AC power input and AC power output circuits,

Exception: The power circuit outlined in (e) that is not provided with an isolation component – such as a transformer – between the input and output, are not considered different circuits.

24.1.3 Segregation of insulated conductors is to be accomplished by clamping, routing, or an equivalent means that maintains permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

24.2 Separation barriers

24.2.1 A barrier used to provide separation between the wiring of different circuits shall be grounded metal or insulating material complying with the requirements for flammability classification in Flammability, Section 18, and with the requirements for Insulating Materials, Section 31. The barriers shall be no less than 0.028 inch (0.71 mm) thick, and supported so that it is not capable of being readily deformed so as to defeat its purpose.

24.2.2 A barrier used to provide separation between field wiring of one circuit and field or factory wiring or uninsulated live parts of another circuit shall be spaced no more than 1/16 inch (1.6 mm) from the enclosure walls and interior mechanisms, component-mounted panels, and other parts that serve to provide separated compartments.

24.3 Field wiring

24.3.1 The equipment shall be constructed so that a field-installed conductor of a circuit shall be separated as specified in 24.3.2 or separated by barriers as specified in 24.2.1 and 24.2.2 from:

a) Factory-installed conductors connected to any other circuit, unless the conductors of both circuits are insulated for the maximum voltage of either circuit.

b) An uninsulated live part of another circuit and from an uninsulated live part where short circuit with it results in a risk of fire, electric shock, electrical energy involving high current levels, or injury to persons.

24.3.2 Separation of a field-installed conductor from another field-installed conductor and from an uninsulated live part connected to another circuit is accomplished by locating an opening in the enclosure for the conductor opposite to the conductor terminal so that, when the installation is complete, the conductors and parts of different circuits are separated by a minimum of 1/4 inch (6.4 mm). In determining whether a device having such openings complies with this requirement, it is to be wired as in service including 6 inches (152.4 mm) of slack in each conductor within the enclosure. No more than average care is to be exercised in routing the wiring and stowing the conductor slack into the wiring compartment.

24.3.3 With reference to 24.3.2, where the number of openings in the enclosure does not exceed the minimum required for the intended wiring of the device, and where each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening is to be connected to the terminal opposite that opening. Where more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the risk of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated.

25 Control Circuits

25.1 An LVLE circuit as described in 5.32 or a limited energy circuit as described in 5.30 may be connected to a single point reference ground.

25.2 Except as indicated in 25.3, an LVLE circuit is not required to be investigated. Printed wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 17.1.1 and 30.1.

25.3 Safety circuits shall be judged by the requirements for primary circuits.

25.4 A control circuit, including associated electronic components on printed wiring boards, is not required to be investigated when the maximum voltage and current are limited as specified in Table 25.1. Printed wiring boards and insulated wires used in such circuits shall be types that are required for the application. See 17.1.1, 17.1.3, and 30.1.

Exception: The current values specified in Table 25.1 do not apply when the circuit includes an overcurrent protection device as described in 25.8 and 25.9.

Table 25.1
Limit for control circuits

Maximum voltage	Maximum current
0 – 42.4 V peak	8A
0 – 30 V dc	8A
30 – 60 V dc	$150/V_{max}$

25.5 With reference to the current specified in Table 25.1, the maximum current is to be measured under any condition of loading including short circuit using a resistor that is to be continuously readjusted during the 1-minute period to maintain maximum load current, without exceeding the value indicated in Table 25.1.

25.6 With reference to the voltage limit specified in Table 25.1, measurement is to be made with the device connected to the rated voltage of the device and with all loading circuits disconnected. Where a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

25.7 When the control circuit mentioned in 25.4 is not limited as to available short-circuit current by the construction of a transformer and the circuit includes either one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network – see 25.11 – the circuits in which the current is limited in accordance with 25.8, 25.9, or 25.10 are not required to be investigated.

25.8 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 25.7 shall be rated or set at not more than the values specified in Table 25.2.

Table 25.2
Rating for secondary fuse or circuit protector

Circuit voltage (volts, rms)	Maximum overcurrent protection (amperes)
20 or less	5
More than 20 but not greater than 60	100/V[a]
[a] V is the maximum output voltage, regardless of load, with the primary energized.	

25.9 A fuse or circuit protective device may be connected in the primary of a transformer to limit the current in accordance with 25.7 when the protection is equivalent to that specified in 25.8 as determined by conducting the Overcurrent Protection Calibration Test, Section 73.

25.10 One or more resistors or a regulating network used to limit the current in accordance with 25.9 shall be such that the current under any condition of load including short circuit does not exceed the values indicated in Table 25.1.

25.11 Where a regulating network is used to limit the voltage or current in accordance with 25.4 – 25.10, and the performance is affected by malfunction, either short circuit or open circuit, of any single component - excluding a resistor - the network shall comply with the environmental tests specified in the Standard for Test for Safety-Related Controls Employing Solid-State Devices, UL 991.

25.12 In a circuit of the type described in 25.7, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be investigated in accordance with the applicable requirements in this outline.

26 Switches and controls

26.1 A switch or other control device shall have current and voltage ratings not less than those of the circuit that it controls when the device is operated in its intended manner.

26.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 percent, such as a transformer, shall be either rated not less than twice the maximum load current under normal operating conditions, or be investigated for the application.

26.3 A switch used to connect a load to various sources or potentials shall be a type that has been investigated and rated for such use.

26.4 A switch or other device controlling a relay, solenoid coil, or similar device shall have a pilot duty rating intended for the application.

26.5 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multicircuit switch may control a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240-volt, 2-pole switch may control a separate 120-volt load, and both may control both legs of a single 240-volt load. Each pole of a snap switch rated as a 240-volt, 3-pole switch may control a separate load not exceeding 139 volts and the three poles may control the three legs of a 3-phase, 240-volt load.

26.6 A 240-volt or 250-volt snap switch used in a circuit involving more than 120 volts to ground shall be rated for such use as indicated by a double underlining under the voltage rating.

26.7 A switch shall not disconnect the grounded conductor of a circuit unless:

a) The switch simultaneously disconnects all conductors of the circuit, or

b) The switch is so arranged that the grounded conductor is not disconnected until the ungrounded conductors of the circuit have been disconnected.

26.8 Solid state switches shall comply with the requirements in this outline. Mechanical and electromechanical switches shall comply with the applicable requirements for switches such as in the Standard for General-Use Snap Switches, UL 20, the Standard for Industrial Control Equipment, UL 508, or other applicable standards.

26.9 Where a device switch or circuit breaker is mounted such that movement of the operating handle between the on position and off position results in one position being above the other position, the upper position shall be the on position. This requirement does not apply to a switching device having more than one on position, a double throw switch, a rotationally-operated switch, or a rocker switch.

27 Capacitors and Resistors

27.1 Capacitors

27.1.1 The materials and construction of a capacitor, its case, or both shall be such that emission of flame from the enclosure of the device during malfunction of the capacitor does not occur. See 27.1.3.

27.1.2 The materials and construction of a capacitor or its case within a device shall be such that pressures capable of causing injury to persons do not develop in the capacitor in the event of malfunction of the capacitor or the circuit in which it is connected. See 27.1.3.

27.1.3 Compliance with the requirements described in 27.1.1 and 27.1.2 shall be determined by the Abnormal Tests specified in Section 50.

27.1.4 Under both normal and abnormal conditions of use, including internal shorting of the capacitor, a capacitor containing oil that is more combustible than askarel shall not result in a risk of fire or electric shock and shall be constructed to reduce the risk of expelling dielectric medium from the enclosure of the device. See 27.1.5 and 27.1.6.

27.1.5 With reference to the requirement in 27.1.4, a capacitor complying with the requirements for protected oil-filled capacitors in the Standard for Capacitors, UL 810, is to be constructed to reduce the risk of expelling the dielectric medium.

27.1.6 With reference to 27.1.4, a device having a capacitor other than that described in 27.1.5 shall be provided with a complete noncombustible bottom panel below the capacitor.

Exception No. 1: A ventilated, bottom-panel construction complying with either Exception No. 2 to 7.5.4.1.

Exception No. 2: A ventilated, bottom-panel construction complying with the capacitor fault test described in 50.5.

27.1.7 A means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor so that it does not provide a risk of electric shock. See 9.3.1.

27.1.8 Capacitors connected across an input ac circuit shall comply with the requirements for across-the-line capacitors in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414, or Standard for Electromagnetic-Interference Filters, UL 1283.

27.2 Resistors

27.2.1 The assembly of a power resistor, such as a wire wound type requiring a separate support, shall be reliable. The resistor shall be prevented from loosening or rotating by a means other than friction between surfaces.

27.2.2 An assembly employing lock washers complies with the requirement in 27.2.1.

28 Fuses and Other Circuit Protective Devices

28.1 General

28.1.1 A fuse or other circuit protective device, the intended functioning of which requires renewal, replacement, or resetting by the user, shall be accessible from outside of the enclosure or behind a hinged cover- see 7.2.1.

28.1.2 With reference to the requirement in 28.1.1, a control-circuit fuse does not require renewal as an intended function when the fuse and the load are contained within the same enclosure.

28.1.3 The screw shell of a plug-type fuseholder and the contacts including associated live parts that are capable of being contacted by the probe illustrated in Figure 8.1 of an extractor-type fuseholder shall be connected toward the load.

Exception: In accordance with the Exception to 28.1.8.

28.1.4 A fuse and a fuseholder shall have voltage and current ratings not less than those for the circuit in which they are connected. A fuseholder shall be of the cartridge, plug, or extractor type. Plug fuses are not to be used in a circuit rated more than 125 volts or 125/250 volts, 3-wire.

Exception: Fuses intended to be replaced by only service personnel- see Protection of Service Personnel, Section 32 – may be bolted in place.

28.1.5 A plug-type fuseholder shall be of the Type S construction.

28.1.6 A circuit breaker connected in the input or the output circuit shall open all ungrounded conductors.

Exception: Where the device has provision for connection of a grounded neutral conductor, individual single-pole circuit breakers may be used as the protection for each ungrounded conductor of 3-wire single phase circuits or for each ungrounded conductor of a 4-wire, 3-phase circuit, when no conductor involves a potential to ground in excess of 150 volts. See 76.15.

28.1.7 A device shall be marked in accordance with 76.8 when it is provided with overcurrent protection consisting of an interchangeable fuse and when the fuse is accessible to the user, or used to comply with the requirements in this outline.

28.1.8 An fuse or other circuit protective device shall not be connected in the grounded (neutral) side of the line.

Exception: Additional overcurrent protection provided in the grounded side of the supply circuit is allowed when the protective device simultaneously disconnects the grounded and ungrounded conductors of the supply circuit.

28.1.9 Temperature or current-sensitive devices such as temperature limiting thermostats, thermal cutoffs, appliance protectors, fuses, circuit breakers, or similar devices that are relied upon to comply with the Abnormal Tests, Section 50, shall comply with the requirements for such devices.

28.1.10 Fuses or other circuit protective devices employing solid state component circuitry used for protection of control circuits described in 28.2.1 – 28.2.7 shall comply with the requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489.

Exception No. 1: Fuses or other circuit protective devices whose performance is not affected by malfunction, either by short circuit or open circuit, of any single component is not required to comply with these requirements.

Exception No. 2: A solid state circuit protective device provided in addition to other circuit protective devices such as a fuse or circuit breaker that is intended for the application is not required to comply with these requirements.

28.2 General

28.2.1 A control circuit that extends from the device to a remote control panel, status panel, or similar device shall be protected in accordance with 28.2.2 – 28.2.7 to reduce the risk of fire and electric shock that is capable of resulting from overload and short circuit conditions.

28.2.2 The overcurrent protective device specified in 28.2.1 shall be a circuit breaker or fuse that is either intended for branch circuit use or a supplementary type. Where the protective device consists of a fuse, the device shall be marked in accordance with 76.8.

28.2.3 Class 1 power-limited circuit, in accordance with the National Electrical Code, ANSI/NFPA 70, used to supply an external control circuit shall be supplied from a source having a rated output of no more than 30 volts and 1000 volt-amperes. When the source is other than a transformer, the circuit shall be protected by an overcurrent protection device rated no more than 167 percent of the volt-ampere rating divided by the rated voltage. The overcurrent device shall not be interchangeable with overcurrent devices of higher ratings.

28.2.4 An external control circuit derived from a Class 2 transformer is not required to be provided with overcurrent protection specified in 28.2.1.

28.2.5 An external control circuit derived from the secondary of a transformer other than that described in 28.2.3 and 28.2.4 shall be provided with overcurrent protection in accordance with 28.2.6 and 28.2.7. For transformers not having a rating, the rated primary or secondary current mentioned in 28.2.6 and 28.2.7 is to consist of the maximum current during normal operation of the device.

28.2.6 Except as described in 28.2.7, a transformer used to supply a control circuit shall be provided with overcurrent protection in the primary circuit rated as indicated in Table 28.1.

Exception: Where the rated primary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device may be used. Standard ratings of protective devices are specified in Article 240-6 of the National Electrical Code, ANSI/NFPA 70.

Table 28.1
Primary overcurrent protection for control circuit transformers

Rated primary current, amperes	Maximum rating of overcurrent device, percent of transformer primary current rating
Less than 2	300
2 or more, less than 9	167
9 or more	125

28.2.7 When a control circuit is derived from the secondary of a transformer that is provided with primary circuit overcurrent protection rated at no more than 250 percent of the rated primary current of the transformer, additional overcurrent protection is not required in the primary circuit when the secondary circuit is protected at no more than 125 percent of the rated secondary current of the transformer.

Exception No. 1: Where the rated secondary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device may be used in the secondary circuit. Standard ratings of protective devices are specified in Article 240-6 of the National Electrical Code, ANSI/NFPA 70.

Exception No. 2: Where the rated secondary current of the transformer is less than 9 amperes, the overcurrent protection in the secondary circuit is to be rated or set at no more than 167 percent of the rated secondary current.

29 Transformers

29.1 General

29.1.1 A transformer coil, unless inherently moisture resistant, shall be treated with an insulating varnish and baked, or otherwise impregnated to exclude moisture or acid vapor. Film coated magnet wire is moisture resistant for this case.

29.1.2 A thermal cutoff or other device employed to reduce the risk of fire or electric shock due to overheating of a transformer during abnormal operation shall comply with the requirements applicable to such a device in addition to the applicable requirements in this outline. For example, a thermal cutoff shall comply with the applicable requirements in this outline and those in the Standard for Thermal-Links - Requirements and Application Guide, UL 60691.

29.1.3 A transformer used to supply a signal circuit where the outlet is accessible to the user shall have its primary winding electrically isolated from its secondary winding and shall be constructed as specified in 29.2.1 – 29.2.4 so that there is no electrical connection - under normal and overload conditions - between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, where such connection results in a risk of fire or electric shock.

29.1.4 With reference to the requirement in 29.1.3, a transformer complying with the requirements in any of the following standards complies with this requirement:

a) 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;

b) Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411; or

c) Standard for Class 2 Power Units, UL 1310.

29.2 Coil insulation

29.2.1 A transformer winding including the start, all taps, finish, and crossover leads up to the point where insulated leads are provided shall be constructed, when used, as specified in Table 29.1.

Table 29.1
Transformer insulation

	Insulation required	Type of insulation
1.	Insulation between the primary wires of opposite polarity and between secondary wires of opposite polarity having a potential greater than 30 volts, rms (42.4 volts peak)	a, b, c, or d
2.	Insulation between the primary and any secondary winding	a, b, c, or d
3.	Insulation between any winding or lead connections and dead metal parts	b, c, d, e, f, or g
4.	Insulation between the crossover leads and (1) the turns of a different winding, (2) the metal enclosure of a unit, or (3) the core	a, d, e, g, or h

a. Electrical grade paper that is waxed or otherwise treated to retard the absorption of moisture and that has a total thickness of not less than 0.028 inch (0.71 mm); polyethylene terephthalate film, not less than 0.007 inch (0.178 mm) thick; or aramid paper, not less than 0.0085 inch (0.203 mm) thick.

b. A thermoplastic or thermoset coil form not less than 0.028 inch thick.

c. A material having a thickness less than 0.028 inch (0.71 mm) is used only when it is equivalent to note a or b and the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used as determined by the test described in Tests on Transformer Insulating Materials, Section 67.

d. Using spacings specified in Table 29.2 in place of the specified insulation, is not prohibited.

e. Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.013 inch (0.33 mm) when used in conjunction with an air spacing of one-half that specified in note d.

f. Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.028 inch where the insulation is in contact with the enclosure.

g. A material having a thickness less than that specified in notes e and f is not prohibited where it is equivalent to notes e and f and the material has a minimum dielectric breakdown strength of 2500 volts for the thickness used for note e and 5000 volts for the thickness used for note f as determined by the test described in Section 49.

h. Any type and thickness of insulation in addition to the magnet wire coating, or a through air spacing less than that specified in Table 29.2 is not prohibited from being used between a crossover lead and the winding to which it is connected when the construction complies with either of the following:

1. The coil withstands the applicable dielectric withstand potential described in 49.3.1 and 49.3.2. The potential is to be applied between the coil leads with the crossover lead cut at the point where it enters the inner layer.

2. The coil withstands the induced potential described in 49.5.2 and 49.5.5.

Table 29.2
Spacings within a transformer

Minimum spacing through air and over surface, inch (mm)	
Potential involved, volts	**Between any uninsulated live part and an uninsulated live part of opposite polarity, or the core[a]**
0 – 50	3/64 (1.2)
Greater than 50 to 125	1/16 (1.6)
Greater than 125 to 250	3/32 (2.4)
Greater than 250 to 600	1/4 (6.4)

NOTE – This table applies only to transformers that are treated with an insulating varnish and baked or otherwise impregnated.

[a] Includes turns of a coil having a magnet wire coating.

29.2.2 Insulating material, such as outer-wrap and crossover-lead insulation, employed to reduce the risk of live parts from becoming accessible through openings in the outer enclosure in accordance with Protection of Users - Accessibility and User Servicing, Section 8, shall comply with note (a) or (c) of Table 29.1.

29.2.3 A flanged bobbin-wound transformer shall be constructed so as to maintain physical separation between the primary and secondary windings. Physical separation accomplished by employing a 3-flange bobbin for winding the primary and secondary windings adjacent to each other is allowed. As an alternative, a telescoping bobbin construction, with each section containing an individual winding, is to be used where the primary winding is wound over the secondary winding or the secondary winding over the primary winding. The bobbin insulation shall comply with note (a), (b), (c), or (d) of Table 29.1.

Exception No. 1: A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of the requirement when:

a) The tape insulation complies with note (a) or (c) of Table 29.1;

b) The tape insulation provides a continuous overlap on the bobbin flange;

c) The transformer complies with the tests described in the Flanged Bobbin Transformer Abnormal Test, Section 51; and

d) The transformer complies with the induced potential tests described in Section 49.5.

Exception No. 2: A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of the requirement when

a) The tape insulation complies with note (a) or (c) of Table 29.1,

b) The coils are layer wound, and

c) All windings have end turns that are retained by a positive means and the spacing between end margins of the primary and secondary windings comply with item (d) of Table 29.1.

Exception No. 3: A transformer complying with the requirements in either 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, the Standard for Class 2 Power Units, UL 1310, or the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television Type Appliances, UL 1411 complies with this requirement.

29.2.4 With reference to note (c) in Exception No. 1 to 29.2.3, the Flanged Bobbin Transformer Abnormal Test, Section 51, is not required when the transformer is supplied from an LVLE circuit, or a limited energy circuit, or complies with the requirements in 28.2.

30 Printed Wiring Boards

30.1 A printed-circuit board shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796, and shall be classed V-0, V-1, or V-2 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A printed wiring board located outside an enclosure, such as in an external control circuit, and located in a LVLE circuit or a limited-energy circuit shall be classed as either minimum V-2, or HB.

30.2 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 does not become displaced and cause a risk of electric shock or fire by a force that is capable of being exerted on it during assembly, intended operation, or servicing of the power supply.

30.3 Further evaluation is to be conducted for a barrier or a partition that is part of the device assembly and that provides mechanical protection and electrical insulation of a component connected to the printed-circuit board.

31 Insulating Materials

31.1 An insulating material used for supporting live parts and a barrier material shall be moisture-resistant and not be adversely affected by the temperature and stresses to which it is subjected under conditions of use.

31.2 Insulating material is to be judged with respect to the application for which it is to be used. Materials such as mica, some molded compounds, and certain refractory materials are usually used for the sole support of live parts. When an investigation is required to determine whether a material is capable of being used, such investigation is to be conducted in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Consideration is to be given to the material's mechanical strength, resistance to hot wire ignition, resistance to high-current-arc ignition, resistance to high-voltage-arc ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions; the degree to which the material is enclosed; and any other feature affecting the risk of fire, electric shock, hazardous energy levels, or injury to persons. All factors are to be taken into account with respect to conditions of actual service.

31.3 Ordinary vulcanized fibers used for insulating bushings, washers, spearators, and barriers, shall not be the sole support for uninsulated live parts.

31.4 A sensor such as a current transformer, transducer, or similar device, shall be provided with insulation that has been evaluated for the maximum voltage and temperature involved in its application, while taking into account the presence of other circuits.

32 Protection of Service Personnel

32.1 The requirements in this section apply only to service personnel who find they must reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the device is energized.

32.2 Live parts shall be so arranged and covers so located as to reduce the risk of electric shock or exposure to energy hazardous parts while covers are being removed and replaced.

32.3 An uninsulated live part involving a risk of electric shock or exposure to hazardous energy shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by service personnel adjusting or resetting controls, or similar action or performing mechanical service functions with the equipment energized, such as adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

32.4 Live parts involving a risk of electric shock, or exposure to hazardous energy, located on the back side of a door or cover shall be either guarded or insulated to reduce the risk of unintentional contact of the live parts by service personnel.

32.5 A component that requires examination, resetting adjustment, servicing, or maintenance while energized shall be so located and mounted with respect to other components and with respect to grounded metal parts that it is accessible for electrical service functions without subjecting the service person to the risk of electric shock or exposure to hazardous energy levels. Access to a component shall not be impeded by other components or by wiring.

32.6 For an adjustment that is to be made with a screwdriver or similar tool when the device is energized, 32.5 requires that protection be provided so that the risk of inadvertent contact with adjacent uninsulated live parts involving a risk of electric shock is reduced, taking into account that misalignment of the tool with the adjustment means is capable of resulting where an adjustment is attempted. This protection is to be provided by locating the adjustment means away from uninsulated live parts or by a guard that reduces the risk of the tool contacting uninsulated live parts.

32.7 A live relay frame or similar device, involving a risk of electric shock or exposure to hazardous energy levels, which are capable of being mistaken for dead metal, shall be guarded to reduce the risk of unintentional contact by the serviceperson or be marked in accordance with 76.16.

33 Electronic Protection Circuits

33.1 When circuit analysis or test results indicate that single component failure affects the ability of an electronic or solid-state circuit to perform its back-up, limiting, or other function intended to reduce the risk of fire, electric shock, or injury to persons the circuit shall comply with the requirements in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, including environmental and stress tests applicable to the intended usage of the end-product. When such circuits employ a microprocessor executing software to perform the safety-related function, the software shall comply with the requirements in the Standard for Software for Programmable Components, UL 1998.

33.2 When it is determined that environmental tests are required, the protection control is to be subjected to the following tests in accordance with the method described in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991:

a) Transient Overvoltage Test;

b) Ramp Voltage Test;

c) Electromagnetic Susceptibility Tests;

d) Electrostatic Discharge Test;

e) Thermal Cycling Test;

f) Humidity Test; and

g) Effects of Shipping and Storage Test.

Before and after each test, the control is to be checked for normal operation.

33.3 The following test parameters are to be used in the investigation of the control covered by 33.1 for compliance with the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991:

a) Electrical supervision of critical components;

b) Audibility as a trouble indicator for an electrical supervision circuit;

c) A field strength of 3 volts per meter (0.91 volts per foot) is to be used for the Radiated EMI Test; and

d) Exposure Class H5 is to be used for the Humidity Test.

33.4 The following test parameters are to be used in the investigation of the circuit employing software covered by 33.1 for compliance with the Standard for Software in Programmable Components, UL 1998:

a) The requirements for Software Class 1 are to be applied, and

b) A failure in the software during its intended operation does not affect compliance under the following conditions:

1) There is no loss of protective function as specified by the manufacturer, or

2) The EV supply equipment is de-energized such that there is no longer a risk.

34 Cord Reels

34.1 For EV supply equipment provided with a cord reel, the cord reel shall comply with the applicable requirements in the Standard for Cord Reels, UL 355.

34.2 If the EV supply equipment is provided with hooks, or similar means, for manually winding a cord for storage, whether it is the flexible power cord or the EV cable, the requirement in 34.1 does not apply. The wound cord shall be subjected to temperature rating verification by temperature measurements on the cord during the Temperature Test, Section 47, with 2/3 of the cord length wound as intended.

PROTECTION OF USERS AGAINST INJURY

35 General

35.1 Where the operation or user maintenance of a device involves a risk of injury to persons, means shall be provided to reduce the risk.

35.2 For the purpose of the requirements described in 35.3 – 35.6, the words “injury to persons” are in reference to physical harm to persons other than the physiological effects of electric shock.

35.3 When judging a product with respect to the requirement in 35.1, reasonably foreseeable misuse of the device shall be a factor.

35.4 A functional attachment that is made available or specified by the manufacturer for use with the basic device shall be included in the evaluation of the device. Unless the manufacturer specifies the use of two or more attachments at the same time, only one attachment at a time is to be evaluated with the device.

35.5 Whether a guard, a release, an interlock, or similar device is required and whether such a device is to be used shall be determined from an investigation of the complete device, its operating characteristics, and the risk of injury to persons resulting from a cause other than gross negligence. The investigation shall include evaluating the results of breakdown or malfunction of any component; not more than one component at a time, unless one event contributes to another. Where the investigation shows that breakdown or malfunction of a particular component results in a risk of injury to persons, that component shall be investigated for reliability.

35.6 Specific constructions, tests, markings, guards, and similar specifications, are detailed for some common constructions. Specific features and products not covered herein are to be examined and tested to determine whether they are to be used for the purpose.

36 Sharp Edges

36.1 An enclosure, a frame, a guard, a handle, or similar device shall not have sharp edges that constitute a risk of injury to persons in normal maintenance and use.

36.2 Where reference measurements are required to determine that a part as mentioned in 36.1 is not sharp enough to constitute a risk of injury to persons, the method described in the Standard for Determination for Sharpness of Edges on Equipment, UL 1439, is to be employed.

37 Enclosures and Guards

37.1 A fan blade or other moving part that is capable of causing injury to persons shall be enclosed or provided with other means to reduce the risk of unintentional contact therewith.

37.2 The degree of protection required by 37.1 depends upon the general construction and intended use of a device.

37.3 Some guards are required to be self-restoring. Other features of guards that are to be evaluated include:

a) Removability without the use of a tool;

b) Removability for servicing

c) Strength and rigidity;

d) Completeness; and

e) Creation of a risk of injury to persons, such as a pinch point, and the requirement for additional handling because of the increased need for servicing, such as for cleaning, unjamming, or similar service.

38 Strength of Enclosures

38.1 An enclosure provided to reduce the risk of fire, electric shock, injury to persons, or exposure to hazardous energy levels, shall be resistant to damage or deformation from drop impact, ball impact, and vehicle drive over in accordance with 38.2 – 38.4, as applicable for the type of device involved.

38.2 An enclosure shall not be adversely affected by dropping the product in accordance with the Drop Test, Section 57. This test is required for all products that are intended to be carried by hand from location to location, or for any products that are considered to be portable.

38.3 An enclosure shall not be adversely affected by impact of a steel sphere in accordance with the Impact Test, Section 55. This test is required for all products.

38.4 An enclosure shall not be adversely affected after being driven over by a vehicle in accordance with the Vehicle Drive Over Test, Section 56. This test is required for any product that is carried by hand or is considered portable and may be placed on the floor or ground during operation or in between operations.

39 Surface Temperatures

39.1 During the temperature test, the temperature of a surface that is capable of being contacted by the user shall not be more than the value specified in Table 39.1. When the test is conducted at a room temperature of other than 77°F (25°C), the results are to be corrected to that temperature. For devices intended for installation outdoors or on-board an EV, the results are to be corrected to 104°F (40°C).

Table 39.1
Maximum surface temperatures

Location	Composition of surface[a]			
	Metal		Nonmetallic	
Handles or knobs that are grasped for lifting, carrying, or holding	122°F	(50°C)	140°F	(60°C)
Handles or knobs that are contacted but do not involve lifting, carrying, or holding; and other surfaces subject to contact and user maintenance	140°F	(60°C)	185°F	(85°C)
Surfaces subject to casual contact but not required to be contacted to operate the device	158°F	(70°C)	203°F	(95°C)

[a] A handle, knob, or similar device made of a material other than metal that is plated or clad with metal having a thickness of 0.005 inch (0.127 mm) or less is judged as a nonmetallic part.

40 Stability

40.1 Under all conditions of servicing and intended use after installation, a fully assembled device shall not become physically unstable to the degree that an injury to operators or service personnel results. A device intended to be secured in place is considered to comply with this requirement.

40.2 A device is not to be energized during the stability test. The test is to be conducted under conditions favorable to causing the product to overturn. The following conditions are to be such as to result in the least stability:

a) Position of all doors, drawers, casters, and other movable or adjustable parts, including that of the supply cord resting on the surface supporting the device;

b) Connection of or omission of any attachment made available by or specified by the manufacturer;

c) Provision of or omission of any normal load where the product is intended to contain a mechanical load; and

d) Direction in which the device is tipped or the supporting surface is inclined.

40.3 With reference to 40.2 (a), where casters are used only to transport the device and jacks are lowered after installation, then the jacks – not the casters – are to be used in the most unfavorable position for the test, consistent with reasonable leveling of the device.

40.4 In conducting the stability test, the device is to be:

a) Placed on a plane inclined at an angle of 10 degrees from the horizontal; or

b) Tipped through an angle of 10 degrees from an at rest position on a horizontal plane.

40.5 With reference to the requirement in 40.4 (b), for a device that is constructed so that while being tipped through an angle of 10 degrees a part or surface of the device not normally in contact with the horizontal supporting surface touches the supporting surface before the device has been tipped through an angle of 10 degrees, the tipping is to be continued until the surface or plane of the surface of the device originally in contact with the horizontal supporting surface is at an angle of 10 degrees from the horizontal supporting surface.

41 Mounting Means

41.1 A mounting means for a fixed device shall withstand the load test without permanent deformation, breakage, or cracking of the mounting supports.

41.2 When mounted as specified by the manufacturer, a device shall comply with the Mounting Means Test, Section 62.

42 Strength of Handles

42.1 A handle used to support or carry a device shall withstand a load of four times the weight of the device without damage to the handle, its securing means, or that portion of the enclosure to which the handle is attached. See Strength of Handles Test, Section 63.

PERFORMANCE

43 General

43.1 A representative sample of a device is to be subjected to the applicable tests described in Sections 44 – 73. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 43.1.

Table 43.1
Values of test voltages

Rated voltage	Test voltage
Less than 110	Rated voltage[a]
110 – 120	120
121 – 219	Rated voltage[a]
220 – 240	240
241 – 250	Rated voltage[a]

[a] A unit marked with an operating voltage range shall comply with the requirements in Sections 44 – 73 while connected to a source of voltage adjusted to any value within the specified range.

43.2 A device covered by these requirements is only allowed to be rated for a frequency of 60 Hz. All tests will be performed with a source at this frequency.

43.3 For each type of product or intended use as described in 6.1.3 and 6.2.3, specific tests shall be included as applicable. See Appendix B for a list of applicable tests and sample requirements.

44 Leakage Current Test

44.1 A cord-connected device rated for a nominal 250-volt or less supply shall be tested in accordance with 44.2 – 44.8. Leakage current shall not be more than 0.75 MIU:

Exception No. 1: Conductive parts of a unit that complies with the following conditions and that have a leakage current greater than 0.75 MIU shall have a leakage current from simultaneously accessible parts to the grounded supply conductor no greater than 3.5 MIU. The leakage current between simultaneously accessible parts shall not exceed 0.5 MIU.

a) The device requires electromagnetic interference (EMI) suppression filtering for compliance with other requirements, such as Federal Communications Commission (FCC) Regulations;

b) The device is equipped with a grounding type supply cord and plug;

c) There is a low probability that a path for available current through the body exists in the expected environment. When the available current flows to ground, this involves the probability that the user is grounded during the use of the unit;

d) There is a low probability that high leakage conductive parts are contacted during normal use of the unit;

e) The probability of injury resulting from an involuntary reaction is small.

Exception No. 2: For a device that upon loss-of grounding, dependably disconnects all sources that produce leakage current, the leakage current to ground shall not exceed 5 MIU with the grounding conductor open and with the loss-of-grounding circuit disabled. The leakage current between simultaneously accessible parts on the unit shall not be more than 5 MIU.

44.2 All accessible conductive surfaces are to be tested for leakage currents to determine compliance with 44.1. 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 simultaneously accessible when they are capable of being touched by one or both hands of a person at the same time. Accessible parts within a 4 by 8 inches (100 by 200 mm) rectangle are simultaneously accessible to one hand. The rectangle shall be flexed or bent to closely conform to the surface of the device. Accessible parts that are capable of being touched at the same time by the ends of a string 6 ft (1.8 m) in length are simultaneously accessible to both hands. The grounding pin, blade, or contact of an attachment plug is an accessible part.

44.3 When a conductive part other than metal is used for an enclosure or part of an enclosure, leakage current is to be measured using a metal foil with an area of 4 by 8 inches (100 by 200 mm) in contact with the surface. Where the conductive surface has an area less than 4 by 8 inches (100 by 200 mm) the metal foil is to be the same size as the surface. The metal foil is to conform to the shape of the surface and is not to remain in place long enough to affect the temperature of the unit.

44.4 Typical measurement circuits for leakage current with the ground connection open are illustrated in Figures 44.1 and 44.2. The measurement instrument is defined in Figure 44.3. The meter that is used for a measurement need only indicate the same numerical value for a particular measurement as does the defined instrument; it need not have all the attributes of the defined instrument. Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:

a) The measured ratio V_1/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_1/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 44.3.

b) The measured ratio V_3/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_3/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 44.3. V_3 is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts is converted to MIU by dividing the reading by 500 ohms and then multiplying the quotient by 1,000. The mathematic equivalent is to multiply the RMS voltage reading by 2.

Figure 44.1
Leakage current measurement circuit used for devices intended for connection to 120 V circuits

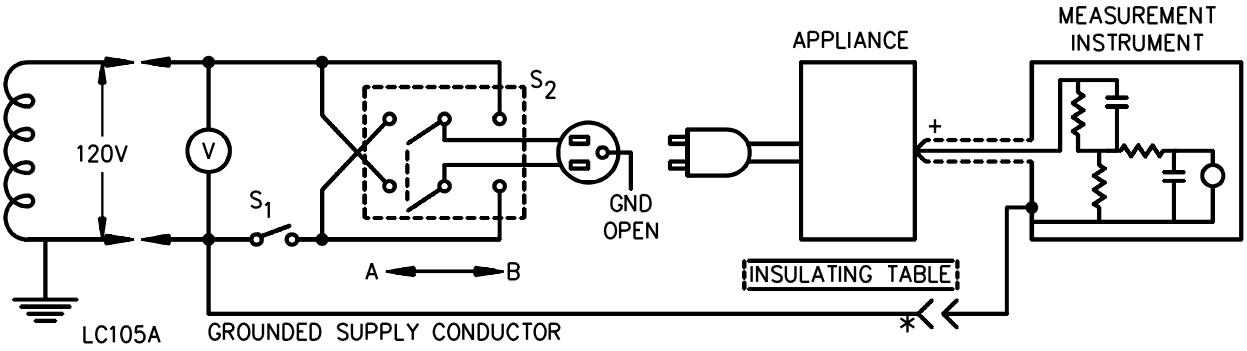
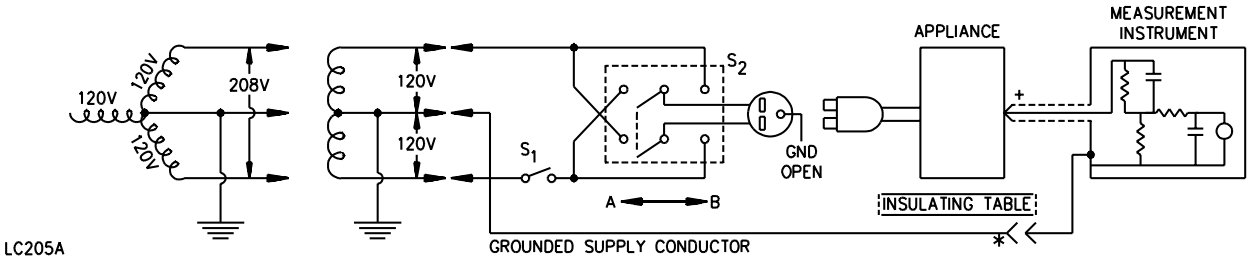


Figure 44.2
Leakage current measurement circuit used for devices intended for connection to 208 V or 240 V circuits



* Separated and used as clip when measuring currents from one part of the device to another.

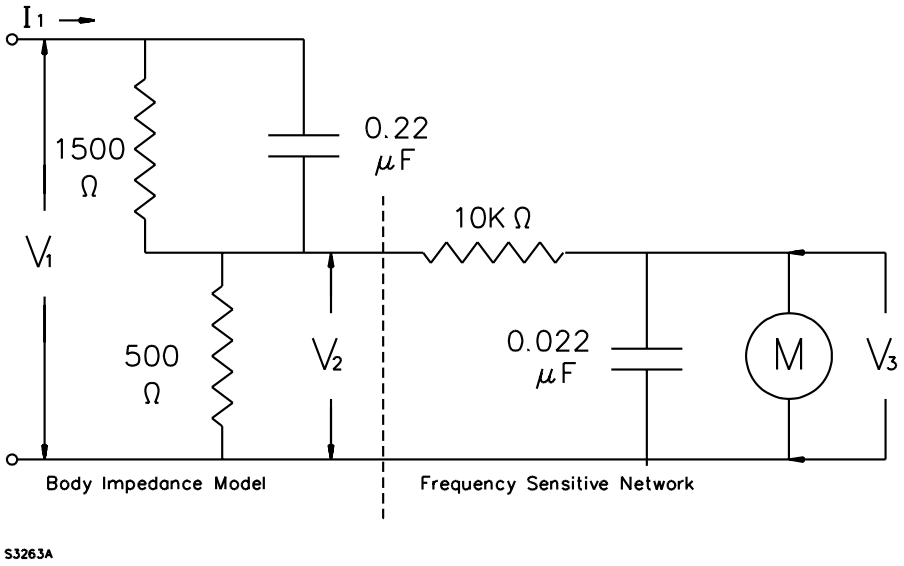
+ Probe with shielded lead

NOTES –

1) All voltages shown in Figures 44.1 and 44.2 are nominal.

2) When it is not feasible to isolate the device from ground, the supply circuit shall be isolated from ground. It is then also sometimes required to reverse the leads of the measurement instrument.

Figure 44.3
Measurement instrument for reaction (leakage) current



Note – Detailed specifications and guidance for the calibration of this instrument are given in the Standard for Leakage Current for Appliances, UL 101.

44.5 Unless the measurement instrument is being used to measure leakage current from one part of a device to another, it is to be connected between accessible parts and the supply conductor connected to ground (the grounded or grounding conductor) that has the least extraneous voltages introduced from other equipment operated on the same supply. For products rated 120 volts or 240 volts, with one supply conductor grounded, this is likely to be the grounded supply conductor.

44.6 When there is no grounded conductor connected to the device under test (for example, a 240-volt, 2-conductor product supplied by a 120/240 volt source), then the instrument return lead may be connected to either the grounded or grounding conductor of the supply depending on the other electrical loads connected to the branch circuit and operating at the time the test is conducted. Use the conductor introducing the least extraneous voltage, as indicated by the lowest leakage current reading. In environments having significant extraneous voltage introduced, an isolating transformer reduces the effects of extraneous voltages.

44.7 A sample of a device is to be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except that which occur as part of the production-line testing. The supply voltage is to be adjusted to rated voltage.

The test sequence is to be as follows, with reference to Figures 44.1 and 44.2

a) With switch S1 open, the device is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S2, and with the device switches in all their normal operating positions.

b) Switch S1 is then to be closed, energizing the product. Within 5 seconds, the leakage current is to be measured using both positions of switch S2 and with the product switch in all their normal operating positions.

c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the normal temperature test.

d) The leakage current is also to be monitored with switch S1 open while the device is at operating temperature and while cooling.

44.8 A sample is to be subjected to the entire leakage current test, as specified in 44.7, without interruption for other tests unless with the concurrence of those concerned, the tests are nondestructive tests.

45 Leakage Current Test Following Humidity Conditioning

45.1 A cord connected device rated 250 volts or less shall comply with the requirements for leakage current in 44.1, following exposure to air having a relative humidity of 88 ±2 percent at a temperature of 90 ±4°F (32 ±2°C).

45.2 To determine whether a unit complies with the requirement in 45.1, a sample of the unit is to be heated to a temperature just above 93°F (34°C) to reduce the risk of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 45.1. Immediately following the conditioning, the sample is to be removed from the humidity chamber and tested unenergized as described in 44.7 (a). The sample is then to be energized and tested as described in 44.7 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

46 Input Test

46.1 The input current to a device is to be measured with the device operating under conditions of maximum rated load as described in 46.2. The current input shall not be more than 110 percent of the rated value.

46.2 Maximum rated load refers to the rated output of the device. During this test, the EV supply equipment shall be connected to a variable resistive load set to draw the maximum rated output from the device.

47 Temperature Test

47.1 Under the conditions specified in 47.2, the device shall not reach a temperature at any point high enough to cause a risk of fire, damage any material used, cause a protective device to operate, or exceed the temperature limits specified in Table 47.1. During this test, the ambient temperature is to be as specified in 47.11.

47.2 The device shall be loaded as indicated in 46.2, and additionally simulated ground fault currents shall be applied. The simulated ground fault current shall be equal to 90 percent of the trip setting employed with the device.

47.3 For a fixed device, the ampacity of the conductors connected to the field wiring terminals or leads shall be in accordance with the smallest conductor allowed by the National Electrical Code, ANSI/NFPA 70.

47.4 A device intended for mounting or support in more than one position, or in a confined location, is to be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface is to consist of 1-inch thick trade size soft pine boards.

Table 47.1
Temperature limits

Materials and Components				Degrees C	Degrees F
B.	COMPONENTS				
	1.	Capacitors:			
		a.	Electrolytic types	65[b]	149[b]
		b.	Other than electrolytic	90[b]	194[b]
	2.	Field wiring Terminals		75[c]	167[c]
	3.	Vulcanized fiber employed as electric insulation		90	194
	4.	Relays, solenoids, and similar devices			
		a.	Class 105 coil insulation systems:		
			Thermocouple method	90[a]	194[a]
			Resistance method	110	203
		b.	Class 130 coil insulation systems:		
			Thermocouple method	110[a]	230[a]
			Resistance method	120	248
	5.	Transformer insulation systems:			
		a.	Class 105:		
			Thermocouple method	90[a]	194[a]
			Resistance method	95	203
		b.	Class 130:		
			Thermocouple method	110[a]	230[a]
			Resistance method	120	248
		c.	Class 155:		
			Thermocouple method	135[a]	275[a]
			Resistance method	140	284
		d.	Class 180:		
			Thermocouple method	150[a]	302[a]
			Resistance method	160	320
		e:	Class 200:		
			Thermocouple method	165[a]	329[a]

Table 47.1 Continued on Next Page

Table 47.1 Continued

Materials and Components			Degrees C	Degrees F
		Resistance method	175	347
	f.	Class 220:		
		Thermocouple method	180[a]	356[a]
		Resistance method	190	374
6.	Phenolic composition employed as electrical insulation or as a part the deterioration of which results in a risk of fire or electric shock		150[d]	302[d]
7.	Rubber- or thermoplastic-insulated wire and cord		60[d,e]	140[d,e]
8.	Other types of insulated wires		f	f
9.	A surface upon which a portable unit is mounted in service, and surfaces that are adjacent to the unit when so mounted		90	194
10.	Any point on or within a terminal box or compartment of a fixed unit on which field-installed conductors rests		60[c]	140[c]
11.	Thermoplastic sealing compound		g	g
12.	Selenium rectifier		75[d,g]	167
13.	Power semiconductor		h	h
14.	Printed-wiring board		i	i

[a] At a 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 is not prohibited from being 9°F (5°C) higher than that specified when the temperature of the coil as measured by the resistance method is not more than that specified.

[b] A capacitor that operates at a temperature of more than 149°F (65°C) for electrolytic and more than 194°F (90°C) for other types is not prohibited from being judged on the basis of its marked temperature limit.

[c] The temperature observed on the terminals and at points within a terminal box of a unit shall not attain a temperature higher than the temperature marking required in items p and o of 78.3.

[d] The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has heat-resistant properties in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

[e] A short length of rubber- or thermoplastic-insulated cord inside the unit is exposed to a temperature of more than 140°F (60°C) when supplementary insulation on each individual conductor is rated for the measured temperature and has dielectric properties in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, and the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

[f] The temperature is not to exceed the temperature limit of the wire except as noted in note f.

[g] A temperature limit of 185°F (85°C) meets the intent of the requirement when the stack assembly is insulated with phenolic composition or other insulating material rated for a temperature of 302°F (150°C).

[h] For a power-switching semiconductor and similar components the temperature limit on the case is the maximum case temperature specified by the semiconductor manufacturer.

[i] For a printed wiring board, the temperature limit is the specified limit of the board.

47.5 Unless investigated and found to meet the intent of the requirement, a supporting means formed of rubber or neoprene material is to be removed prior to the test. Where the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the device supported by the metal insert. At the request of the manufacturer, it is allowable to conduct the test without any means of support.

47.6 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in good thermal contact with the surface of which the temperature is being measured. Usually, good thermal contact results from securely taping or cementing the thermocouple in place. Where a metal surface is involved, brazing or soldering the thermocouple to the metal is to be done when required for good thermal contact.

47.7 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except that the resistance method is an alternate method for a coil that is inaccessible for mounting thermocouples, such as a coil immersed in sealing compound, wrapped with thermal insulation, or wrapped with more than two layers of material such as cotton, paper, or rayon more than 1/32 inch (0.8 mm) thick.

47.8 The temperature of a winding is determined by the resistance method by comparing the resistance of the winding at a temperature to be determined with the resistance at a known temperature according to the formula:

$$T = \frac{R}{r}(k + t) - k$$

in which:

T is the temperature of the winding in degrees C;

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

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

t is the room temperature in degrees C at the beginning of the test; and

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

The winding is to be at room temperature at the start of the test.

47.9 All temperature limit values in Table 47.1 are based on an ambient temperature of 104°F (40°C) for devices intended to be installed outdoors or on-board an EV and 77°F (25°C) for all other devices. However, with correction of temperature measurements, tests conducted in other ambients as described in Table 47.2 are allowed.

Table 47.2
Temperature measurement correction

Ambient temperature rating of unit	Test ambient temperature	Correction of observed temperature
1. 77°F (25°C)	Range of 50 – 104°F (10 – 40°C)	See note a
2. Range of 77 – 104°F (25 – 40°C)	Range of 68 – 104°F (20 – 40°C)	See note a
3. Above 104°F (40°C)	Rated ambient. See note b	See note c

[a] Correction of temperature shall not exceed the temperature limit specified in Table 47.1 as described below:

– An observed temperature is to be corrected by addition (when the test ambient temperature is lower than the rated ambient temperature or by subtraction (when the test ambient temperature is higher than the rated ambient temperature of the difference between the rated ambient temperature and the test ambient temperature.

[b] Allowable tolerances are:
Minus – not less than 9°F (5°C) below rated ambient. Plus – not specified.

[c] When the test ambient temperature equals rated ambient, no correction is to be made, and an observed temperature shall not exceed the temperature limit specified in Table 47.1. When the test ambient temperature is other than rated ambient, correction is made as described in note a.

47.10 When a device is rated for an ambient temperature higher than 77°F (25°C), the rating shall be indicated in the instruction manual in accordance with 78.3 (n).

47.11 Thermocouples are to consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ a temperature-indicating instrument with thermocouples consisting of 30 AWG iron and constantan wire. Such equipment is to be used whenever referee temperature measurements by thermocouples are required. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements for special thermocouples as listed in the table of limits of error of thermocouples in Temperature Measurement Thermocouples, ISA MC96.1.

47.12 A temperature is determined to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no continued rise.

48 Capacitor Discharge Test

48.1 In accordance with 9.3.1, a cord connected device that is provided with filtering capacitors, or other primary capacitors, shall comply with this test.

48.2 The device shall be connected to a supply source of rated voltage at 60 Hz. The output shall be connected to a suitable load such that rated current is drawn from the output of the device. A storage oscilloscope shall be connected across the point of disconnection of the supply.

48.3 The device is connected to the source of supply and energized. The power is then removed and the resulting discharge curve for the stored charge on capacitors is measured and captured on the oscilloscope. The value of the stored charge shall decay to less than 37 percent of its initial value within 1 second.

48.4 The test is to be repeated with all switches in all possible positions and combinations.

49 Dielectric Voltage Withstand Test

49.1 General

49.1.1 The test potential mentioned in 49.3.1 and 49.4.1 is to be obtained from any convenient source having a capacity of at least 500 volt-amperes. A lower capacity is allowed when a meter is located in the output circuit, and the test potential is maintained except in case of breakdown. The voltage of the source is to be continuously adjustable. Starting at zero, the applied potential is to be increased at a rate of 200 volts per second until the required test value is reached.

49.1.2 When a direct current potential is used for an ac circuit, a test potential of 1.414 times the applicable rms value of alternating current voltage specified in 49.3.1 and 49.4.1 is to be applied.

49.1.3 Printed-wiring assemblies and other electronic-circuit components that are damaged by application of the test potential or that short-circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are made. Testing for a representative subassembly is an alternative to testing an entire device. Semiconductor devices in the overall device are to be individually shunted before the test is made to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits.

49.2 Maximum voltage measurements

49.2.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand test potentials specified in 49.3.1 and 49.4.1 and determination of the minimum spacings specified in Spacings, Section 22, shall be determined in accordance with 49.2.2 and 49.2.3.

49.2.2 A connector or comparable part that is capable of being disconnected during intended operation is to be both connected and disconnected during the test so that the maximum voltage is obtained.

49.2.3 Where a complex voltage is present, the peak value of the voltage is to be measured and this value is to be used for calculation of the dielectric voltage-withstand potential and determination of the minimum spacings. For a sinusoidal or a direct current voltage, the rms or average values respectively is to be measured.

49.3 AC and DC power circuits (primary)

49.3.1 The ac and dc power circuits of a device shall withstand for 1 minute without breakdown the application of a 60 hertz sinusoidal potential with the device at the maximum operating temperature:

a) One thousand volts plus twice the maximum rated voltage between

1) The primary circuit and dead metal parts,

2) The primary and secondary circuits, and

3) All secondary windings, including any ferro-resonant windings.

b) Five hundred volts between a secondary circuit operating at 50 volts or less and dead metal parts; 1000 volts plus twice the maximum rated secondary circuit voltage between a secondary circuit, including any ferro-resonant windings, operating at more than 50 volts and dead metal parts.

c) One thousand volts plus the rated voltage of a capacitor between the terminals of a capacitor used for radio-interference elimination or arc suppression.

Exception: A dc circuit having a potential of 30 volts or less is not required to be tested.

49.3.2 With reference to 49.3.1, the test potential between ac power circuits and dead metal parts is to be based on the phase-to-ground voltage rating. The test potential for other points involving the ac power circuit is to be based on the highest operating voltage of the circuits involved.

49.4 Secondary circuits

49.4.1 Each secondary circuit, other than a power circuit covered in 49.3.1 and 49.4.1, shall withstand for 1 minute without breakdown the application of a test potential between primary and secondary circuits, between secondary circuits and grounded metal with grounding connections, where present, disconnected, and between isolated secondary windings of transformers. The device shall be at operating temperature during the test. The test potential shall be as indicated in Table 49.1.

Table 49.1
Magnitude of test potential for secondary circuits

Maximum voltage in the circuit[a,b]	Test potential
30 (42.4 peak), 60 dc, or less	No test
More than 30 (42.4 peak) but not more than 333.3 (471.3 peak) or more than 60 dc	Ten times maximum voltage in circuit (maximum of 1000 volts rms)
More than 333.3 (471.3 peak but not more than 1000 (1414 peak)	Three times maximum voltage in circuit
More than 1000 (1414 peak)	1750 volts plus 1.25 times voltage in circuit

[a] Where the peak voltage is greater than 120 percent of 1.414 times the rms voltage, the circuit shall be tested as if the voltage were peak voltage divided by 1.414.
[b] Values are rms unless otherwise indicated.

49.5 Induced potential

49.5.1 When an isolating power transformer waives the test outlined in Transformer burnout test, Section 50.2, in accordance with Exception No. 4 in that test, the following test described in 49.5.2 – 49.5.5 is to be conducted.

49.5.2 The primary winding of the transformer is to be subjected to an alternating potential of twice the rated voltage with the ends of all other windings opened. The potential is to be applied for 7200 cycles or for 60 seconds, whichever is less. A sinusoidal source is to be used, and the frequency of the service is to be in the range of 120- 1000 hertz where required to prevent saturation of the core.

49.5.3 Primary- and secondary-circuit wiring connected to the transformer is to be disconnected for this test.

49.5.4 A 3 phase transformer may be tested with a single phase voltage. The voltage mentioned in 49.5.2 is to be applied successively across each primary winding.

49.5.5 While in the heated condition obtained during the transformer overload test, the test voltage required in 49.5.2 is to be initiated at one-fourth or less of the full value and brought up gradually to the full value in not more than 15 seconds. After being held for the time specified, the voltage is to be reduced slowly, but within 5 seconds, to one-fourth of the maximum value or less, and the circuit opened. The results meet the intent of the requirement when there is no dielectric breakdown.

50 Abnormal Tests

50.1 General

50.1.1 A device shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons – see 50.1.3 – when subjected to the tests specified in 50.2 – 50.9. Separate samples are to be used for conducting these tests.

50.1.2 Following each test, a dielectric voltage-withstand test specified in Section 47 is to be conducted. The potential is to be applied across the points indicated in 49.3.1.

Exception: Conducting more than one abnormal test on a sample and then performing the dielectric voltage withstand test after completion of the abnormal tests for that sample, is allowed if agreed to by all parties.

50.1.3 A risk of fire, electric shock, or injury to persons exists when:

a) Flame, burning oil, or molten metal is emitted from the enclosure of the device as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper, or

b) The insulation breaks down when tested in accordance with 50.1.2 or live parts are made accessible;

50.1.4 During these tests the device is to be placed on a softwood surface covered with a white tissue paper and a single layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth running 14 – 15 yards per pound (26 – 28 m^2/kg), and having, for any square inch, a count of 32 threads in one direction and 28 in the other direction.

Exception: When it is impractical to drape the entire device, cheesecloth is required to be placed only over all ventilation openings.

50.1.5 For a device having supporting feet made of rubber or neoprene material, the requirement in 47.5 shall apply.

50.1.6 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 where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The test voltage and frequency are to be adjusted to the values specified in 43.1 and 43.2.

Exception: When a marking on the product indicates a specific branch circuit protection rating, such protection shall be used.

50.1.7 The enclosure of the device is to be connected directly to ground for these tests.

50.1.8 Each test is to be continued until further change as a result of the test condition is reduced significantly. When an automatically reset protector functions during a test, the test is to be continued for 7 hours. When a manual reset protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using the minimum resetting time, and not faster than 10 cycles of operation per minute. The following are examples of test terminations:

a) Opening or shorting of one or more components such as capacitors, diodes, resistors, solid state devices, printed wiring board traces, or similar devices.

b) Opening of the intended branch circuit overcurrent protection device described in 50.1.6 – see 50.1.9.

c) Opening of an internal fuse.

50.1.9 With reference to 50.1.8 (b), when the branch circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 78.3 (f).

50.2 Transformer burnout test

50.2.1 An adjustable resistive load is to be connected directly to the secondary winding of each transformer and adjusted to result in the load condition described in (a), (b), or (c) below. Opening of the intended branch circuit overcurrent protection device described in 50.1.6 or an internal overcurrent protection device connected in the primary-winding circuit is an example of when this test is terminated.

a) For a transformer having a single isolated secondary winding, the load is to be adjusted to result in maximum volt-ampere output but not resulting in more than three times the maximum normal alternating current to flow in the primary winding.

b) For a transformer having multiple isolated secondary windings, each secondary winding is to be tested separately; that is, with the winding under test loaded with an alternating current equal to three times the rms value of the secondary current flowing through that winding during maximum normal operation of the device and the other isolated windings, each loaded with an alternating current equal to the rms value of the secondary current flowing through their respective windings during maximum normal operation of the device.

c) For an autotransformer, the conditions specified in (a) are to be used with the supply voltage connected to the outer input legs and the load resistor connected to the outer output legs. See Figure 50.1.

Exception No. 1: A transformer supplied from either an inverter circuit or other means limiting the current to the transformer to less than three times rated current is to be loaded to a condition resulting in maximum obtainable input current without operation of overcurrent protection devices, where any are present.

Exception No. 2: A transformer employed in a switch-mode inverter or converter circuit shall be subjected to the transformer overload test described in 50.3.5 in lieu of the transformer burnout test.

Exception No. 3: Any transformer, including a control circuit transformer or a power transformer used for the transfer of either the input or output power of the device, having overcurrent protection described in 28.2.6 is not required to comply with this requirement.

Exception No. 4: A transformer that is protected by the intended branch circuit protection device that is sized in accordance with the requirements in 28.2.6 and is provided in a device marked in accordance with 76.3(f) is not required to comply with this requirement.

Exception No. 5: An isolating power transformer used for the transfer of either the input or output power of the device and complying with the Standard for Specialty Transformers, UL 506 or the Standard for Dry-Type General Purpose and Power Transformers, UL 1561, or shall be subjected to the transformer overload and induced potential tests described in 49.5.1 – 49.5.5 and 50.3.1 – 50.3.4, in lieu of the transformer burnout test.

Exception No. 6: A transformer subjected to the transformer overload and induced potential tests described in 49.5.1 – 49.5.5 and 50.3.1 – 50.3.4, in lieu of the Transformer burnout test.

Exception No. 7: An isolating power transformer used for the transfer of either the input or output power of the device complying with the requirements in either of the following standards:

a) 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, UL 5085-3,

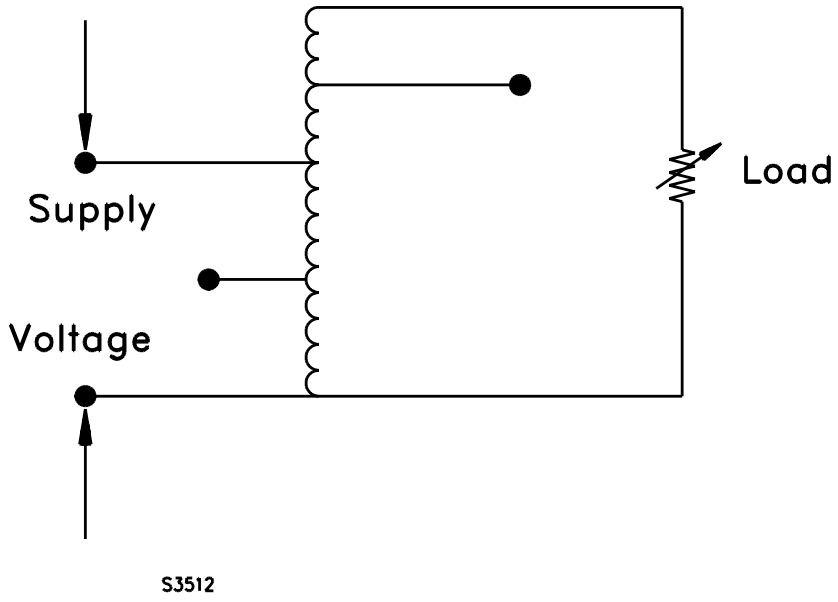
b) The Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.

Exception No. 8: A signal or gate-drive transformer that is rated 10 watts or less and having a secondary circuit that does not extend out of the device is not required to comply with this requirement.

50.2.2 A ferro-resonant transformer is to be tested in accordance with 50.2.1 with the secondary winding loaded to maximum input current. The transformer is to be operated continuously until ultimate conditions are observed.

50.2.3 During the tests described in 50.2.1 and 50.2.2, secondary circuit protective devices that are external to the transformer are to be bypassed. Primary circuit protective devices are to be left in the circuit.

Figure 50.1
Autotransformer burnout test



NOTE – See 50.2.1(c) for description of test.

50.3 Transformer overload test

50.3.1 When an isolating power transformer is to be tested in accordance with Exception No. 6 to 50.2.1, the tests described in 50.3.2 – 50.3.4 are to be conducted. When a transformer employed in a switch-mode inverter or converter circuit is to be tested in accordance with Exception No. 2 to 50.2.1, the test described in 50.3.5 is to be conducted.

50.3.2 A resistive load is to be connected directly to each transformer secondary winding and adjusted to a value so each secondary winding carries 50 percent of rated load until temperatures of the transformer core become stabilized. The load is then to be increased to 200 percent of the rated value; no further adjustment of the overload current is to be made. The duration of the overload is to be as specified in Table 50.1. The short circuit method as described in the Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C57.12 is one method used to obtain the 200 percent of rated load current. Where the short-circuit test method is used, all secondary windings are to be shorted and the voltage applied to the primary windings is to be adjusted to result in rated current to flow in the secondary windings.

Table 50.1
Overload test times

Insulation class	Overload time, minutes
105	30
130	30
155	30
180	26
200	23
220	20

50.3.3 With reference to the requirement in 50.3.2, testing of a transformer rated more than 500 kilovolt-amperes is not required when the test has already been performed with results that meet the intent of the requirement on a smaller transformer rated not less than 500 kilovolt-amperes, when the smaller transformer has the same insulation system and same general construction as the larger transformer, and the temperatures recorded during the temperature test are no greater for the larger transformer than those recorded during the temperature test for the smaller transformer

50.3.4 Within 1 hour following the overload test, the transformer shall perform as intended in a repeated dielectric voltage-withstand test except that the test value is to be at 65 percent of value specified in Dielectric Voltage-Withstand Test, Section 49, and the induced potential test described in 49.5.1 – 49.5.5.

50.3.5 For a device tested in accordance with Exception No. 2 to 50.2.1, the power circuit supplied by the transformer is to be connected to a resistive load that draws maximum obtainable output power without causing operation of internal overcurrent protection devices or a protection circuit or resulting in opening of a circuit component such as a diode, resistor, sold state device, or similar device.

50.4 Short circuit test

50.4.1 The device is to be tested as described in 50.4.2. The device shall comply with the requirement in 50.1.1.

50.4.2 With reference to 50.4.1, fuses and other protective devices provided as part of the device are to remain in the circuit. The output connections of the device are to be short-circuited and the device connected to a source of supply adjusted to its highest test voltage – see Table 43.1. The test is to be continued until the internal protection opens, constant temperatures are attained, or the transformer winding opens. When an automatically reset protector is provided, the test is to be continued for 7 hours. When a manually reset protector is provided the test is to be continued until the protector operates for 50 cycles.

50.5 Capacitor fault test

50.5.1 Where required by Exception No. 2 to 27.1.6, a device having a bottom-ventilated enclosure containing oil-filled capacitors shall be subjected to the performance tests specified for protected, oil-filled capacitors in the Standard for Capacitors, UL 810. These tests are to be conducted with the capacitors mounted in the device enclosure as intended, and oil leakage from the capacitors passing through the enclosure, where present shall be extinguished – see 50.1.3 (a).

50.6 Forced ventilation test

50.6.1 A device having forced ventilation is to be operated with the fan disconnected. For a device having more than one fan, the test is to be conducted with each fan disconnected, one at a time, or with two or more fans disconnected if they are controlled or powered by the same connection.

50.6.2 A device having filters over ventilation openings is to be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked 50 percent, then to be repeated under fully blocked condition.

50.7 Component fault tests

50.7.1 A component, such as a capacitor, diode, solid state device, or similar device, connected in the input and output power circuits are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including start-up. This test is not required:

a) Where circuit analysis indicates that no other component or portion of the circuit is overloaded.

b) For electromagnetic radio frequency interference capacitors subjected to the dielectric voltage-withstand test across their terminals in accordance with 49.3.1, resistors, transformers, inductors, and optical isolators.

50.8 Electrolytic capacitor fault test

50.8.1 For a device having dc electrolytic storage capacitors operating above 60 vdc, the fault test described in 50.8.2 shall be conducted.

Exception: This requirement does not apply to a capacitor that complies with the requirements in the Standard for Capacitors, UL 810. The capacitor shall have an available fault current rating of 10,000 amperes or a lower value where a circuit analysis indicates that because of a series impedance, the lower value is applicable.

50.8.2 With reference to the requirement in 50.8.1, a fault in one of the capacitors in the storage capacitor bank is to be simulated. This is to be accomplished by connecting the capacitor under test in reverse while the input ac supply to the device is not energized. The device is then to be energized and operated as in normal operation.

50.9 Vibration test

50.9.1 A device intended to be permanently mounted in an EV or transported on an EV shall be subjected to a vibration test. After the device is subjected to the vibration test described in 50.9.2:

a) The device shall comply with the requirements in 50.1.1;

b) There shall be no loosening of parts, and

c) The device shall operate normally.

50.9.2 The vibration test shall consist of vibration for 48 hours at a frequency of 22 cycles per second with a displacement of 1/4 inch (6.4 mm) in a vertical plane. The device is to be mounted as intended during the test.

51 Flanged Bobbin Transformer AbnormalTest

51.1 A flanged bobbin transformer required to be tested as provided in (c) of Exception No. 1 to 29.2.3 – also see 29.2.4 – shall operate for 15 days with the secondary winding or windings loaded to the conditions described below in (a) - (c). A risk of fire or electric shock shall not result from:

a) Short-circuiting the secondary winding;

b) Loading the secondary winding to a current equal to maximum normal current plus X percent of the difference between the short-circuit current and the rated current - where X equals 75, 50, 25, 20, 15, 10, and 5, respectively; and

c) Loading the secondary winding to maximum normal current.

Exception No. 1: A flanged bobbin transformer used in a circuit where isolation is not required or where the secondary circuit does not extend out of the device – see 29.1.3 – is not required to be subjected to this test.

Exception No. 2: A transformer complies with this requirement when it complies with the requirements in either of the following:

a) 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.

b) The Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.

51.2 The results of the test do not meet the intent of the requirement when the cheesecloth glows, or flames, is charred or a breakdown occurs when the test described in 51.4 is conducted.

51.3 Samples for the 15-day abnormal operation tests are to be prepared as follows:

a) The transformer is to be mounted either in the device enclosure as intended under the conditions described in 50.1.4 or on a test bench with the cheesecloth mentioned in 50.1.4 draped over the transformer.

b) All secondary windings are to be loaded to rated current before the abnormal condition is introduced; and the loads, other than that connected to the winding to be overloaded, are not to be readjusted thereafter.

51.4 While still in a heated condition from the tests described in 51.1, a transformer shall withstand the dielectric voltage-withstand test applied between the primary winding and the secondary winding. The dielectric voltage-withstand-test potential is to be applied to the transformer 1 minute after completion of the abnormal-operation test.

51.5 The abnormal tests are to be conducted with a protective device built into the transformer or with an external protective device used with the transformer in the device connected in either the primary or secondary circuit, or in both. A protective device that is relied upon to open the circuit as a result of an abnormal test is to be one that has been investigated and found to meet the intent of the requirement.

51.6 For the purpose of these requirements, each secondary winding tap and each primary winding tap that is used to supply power to a load in the device are the equivalent of a secondary winding.

51.7 For the sequence of tests described in 51.1, when an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests are not required to be conducted. For example, when the test described in 51.1 (a) continues for 15 days, the tests described in 51.1 (b) and (c) are not required to be conducted.

51.8 To determine whether a transformer complies with the requirement in 51.1, three separate samples are to be subjected to each condition described in 51.1 (a) - (c). For a transformer that employs more than one secondary winding, each of the secondary windings is to be loaded for each condition specified in 51.1 with the other windings loaded to rated current. The test conditions are to be as described in 51.9 – 51.13.

51.9 To determine the short-circuit current value for conducting the tests described in 51.1 (b), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, where provided by the manufacturer, is to be short-circuited during the measurement of the short-circuit current. When the line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is that value recorded just before the line fuse or winding opens. The short-circuit current of any one winding is to be measured with the other secondary windings open-circuited.

51.10 For the loading conditions, a variable resistor is to be connected across the secondary winding. Each test described in 51.1 (a) – (c) is to be continued until a risk of fire develops, the 3-ampere fuse opens, a winding of the transformer or a protective device opens or 15 days have passed. In conducting the tests described in 51.1 (a) – (c), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, where required 1 minute after voltage is applied to the primary winding.

Exception: For a switch-mode transformer, the load is to be connected to the output of the power supply connected to the transformer.

51.11 When short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 51.1 (b) and (c) that continues for 15 days is to have the variable load resistor reduced to zero impedance at the end of the 15 days to cause the transformer to burn out.

51.12 For a transformer that is provided with a protective device built into the transformer or that is being tested in conjunction with an external protective device, a test described in 51.1 (a) – (c) is to be discontinued when the protective device opens the circuit and the next test in the sequence is to be started. The protective device mentioned above includes automatic recycling type, manual reset type, or a replaceable type.

51.13 When a protective device opens the circuit or a winding on any sample opens during the 15-day abnormal-operation tests while the samples are unattended, the variable resistor load on the other samples is to be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the samples are subjected to the dielectric voltage-withstand test described in 51.4 while in a heated condition. The next test in the sequence in 51.1 (b) and (c) that continues for 15 days is to be conducted.

52 Strain Relief Tests

52.1 General

52.1.1 The following tests apply to the flexible power cord connection to the EV supply equipment.

52.1.2 All of the tests can be performed on the same sample, but each test is performed one at a time.

52.1.3 The internal connections are to be disconnected or cut prior to the tests in 52.2 and 52.3.

52.2 Pull strain relief test

52.2.1 After the test outlined in 52.2.2, the flexible power cord shall not have been longitudinally displaced by more than 0.08 inch (2 mm) nor shall there be any indication of strain at the connections due to displacement of the cord, and spacings shall not be reduced, as described in Spacings, Section 22.

52.2.2 The flexible power cord is subjected to a steady pull of 35 pounds force (150 N), applied in the most unfavorable direction for a period of 1 minute.

52.2.3 During the test, the flexible power cord shall not be damaged as verified by visual inspection.

52.2.4 A wiring lead intended for field wiring connection shall withstand without damage or displacement a direct pull of 20 pounds (89 N) for 1 minute applied to a lead extending from the enclosure and 10 pounds (45 N) for 1 minute applied to a lead within a wiring compartment.

52.3 Push back strain relief test

52.3.1 A flexible power cord shall be tested in accordance with 52.3.2 without occurrence of mechanical damage to the flexible power cord, exposure of the cord to temperatures higher than the temperature rating of the cord, or reduction of spacings in accordance with Spacings, Section 22.

52.3.2 The flexible power cord is to be held 1 inch (25.4 mm) from the point where the flexible power cord emerges from the product and is then attempted to be pushed back into the device. When a removable bushing that extends further than 1 inch is present, it is to be removed prior to the test. When the bushing is an integral part of the flexible power cord, then the test is to be carried out by holding the bushing. The flexible power cord is to be pushed back into the product in I inch increments until the flexible power cord buckles or the force to push the flexible power cord into the product exceeds 6 lbf (26.7 N). The flexible power cord within the product is to be manipulated to determine compliance with 52.3.1.

53 EV Cable Secureness Test

53.1 EV cables provided with EV supply equipment, and permanently attached to this equipment, or EV cables provided with EV plugs or EV connectors, shall be subjected to the test outlined in 53.2 – 53.4. After this test, there shall be no axial displacement of the supply conductors, conductor insulation, or outer jacket of the EV cable from the assembled condition exceeding the maximum allowed displacement as specified in Table 53.1. In addition, there shall be no evidence of damage to the EV cable, the enclosure of live parts, the strain relief means, or the grounding path integrity.

53.2 The device is to be assembled as intended onto a 12 inch (300 mm), or longer, length of cable with its conductors positioned as if the conductors were to be connected to the terminals. Screws, nuts, or other hardware are to be tightened according to the manufacturer's instructions. The cable is to be cut at a right angle to its major axis but not stripped.

53.3 The cable clamp is to be held firmly in place. A force of 150 lb/in^2 (1034 kPa) times the cross sectional area of the EV cable (rounded up to the nearest 5 pound increment), but not less than 35 lbs (155.7 N), is to be applied gradually to the EV cable at a point not less than 6 inches (150 mm) from the cable grip in a direction perpendicular to the plane of the opening and in line with the cable. The force is to be applied and sustained for one minute.

53.4 A torque is also to be applied to the EV cable at a point 6 inches (150 mm) from the cable grip as specified in Table 53.1 for one minute in the direction least favorable to the clamp construction.

Table 53.1
Cable secureness test values

Device rating amperes	Torque ft-lb (N·m)	Maximum displacement inches (mm)
15	0.3 (0.41)	3/32 (2.38)
16 – 20	0.4 (0.54)	3/32 (3/32)
21 – 35	0.5 (0.68)	3/32 (2.38)
36 – 70	1.0 (1.4)	3/32 (2.38)
71 – 125	2.0 (2.7)	3/32 (2.38)
126 – 200	4.0 (5.4)	3/32 (2.38)
201 – 400	8.0 (10.8)	3/16 (4.76)
401 – 800	12.0 (16.3)	3/16 (4.76)

54 Grounding Tests

54.1 Ground impedance test

54.1.1 The impedance at 60 hertz between the point of connection of the equipment-grounding means and the metal part that is required to be bonded to ground shall not be more than 0.1 ohm when measured in accordance with 54.1.2. The resistance of the equipment grounding conductor of a power supply cord shall not be included in the resistance measurement.

54.1.2 Compliance with 54.1.1 is to be determined by passing a current of 25 amperes derived from a 60 hertz source with a no-load voltage not exceeding 6 volts between the following points and measuring the voltage across these points: the equipment grounding connection and the metal part in question.

54.2 Ground continuity test

54.2.1 The ground path for EV supply equipment provided with a permanently attached length of EV cable, shall be continuous when required for grounding of the vehicle. Compliance is determined in accordance with the test in 54.2.2.

54.2.2 The ground path, from the main ground terminal of the EV supply equipment to the ground pin at the EV connector, shall be connected in series with an ac or dc source of voltage less than 30 V, and a means of indicating an unbroken circuit (e.g., an incandescent lamp, a bell, a buzzer). Operation of the indicator shall be evidence of continuity of the ground path under test.

55 Impact Test

55.1 After the test described in 55.2 – 55.4, there shall not be any cracking, breakage, or deformation of the enclosure to the extent that results in making uninsulated live parts or internal wiring accessible to contact in accordance with Protection of Users – Accessibility and User Servicing, Section 8.

55.2 A solid, smooth steel sphere, 2 inches (51 mm) in diameter, and weighing approximately 1.18 pounds (0.54 kg), is to fall freely from rest through a vertical distance of 51 inches (1.3 m) onto the enclosure as shown in Figure 55.1.

55.3 For surfaces other than the top of the enclosure, the sphere specified in 55.2 is to be suspended by a cord and is to fall as a pendulum dropping a vertical distance of 51 inches (1.3 m) as shown in Figure 55.2. The enclosure is to be placed so that the surface tested is vertical and in the same vertical plane as the point of support for the pendulum. Parts of the enclosure that may interfere with the cord of the pendulum are to be removed. During the test, the enclosure is to be placed against a vertical wall.

Exception: A horizontal impact on vertical or sloping surfaces may be performed in place of the pendulum impact in 55.2, by mounting the sample at 90 degrees to its normal position and applying the vertical impact test from 55.2.

55.4 The test shall be performed on one sample at room temperature and on a second sample conditioned in a cold chamber at minus 22 ± 4°F (minus 30 ± 2°C) for 24 hours. For the conditioned sample, the sample shall be removed from the chamber prior to being subjected to the impact force. Gloves shall be worn when handling the conditioned sample to minimize heat transfer.

Figure 55.1
Vertical impact test

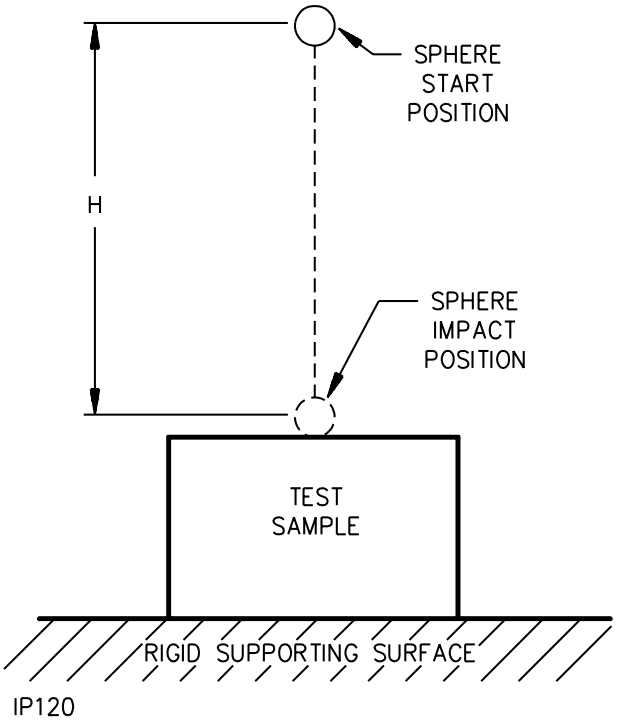
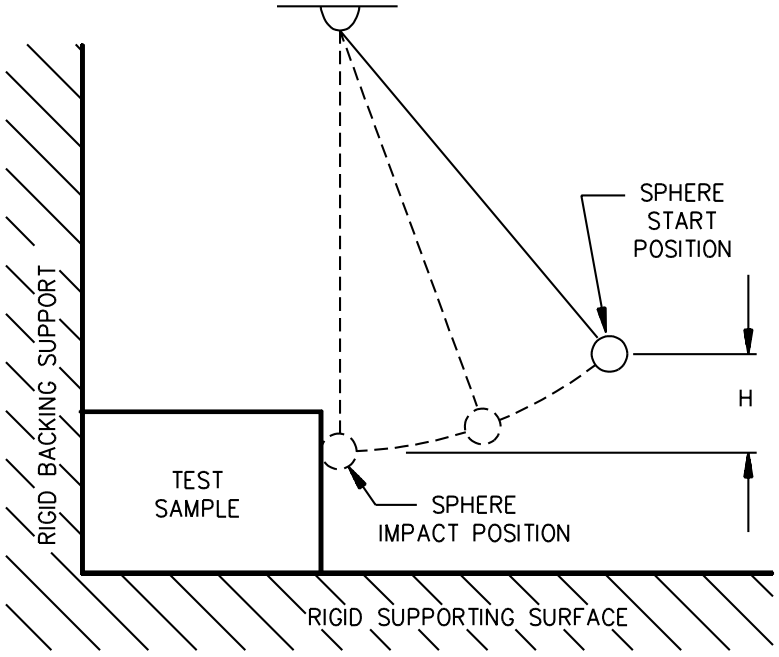


Figure 55.2
Pendulum impact test



IP 160

56 Vehicle Drive Over Test

56.1 As a result of the test outlined in 56.2, there shall not be any cracking, breakage, or deformation of the enclosure to the extent that results in any of the following:

a) Making uninsulated live parts or internal wiring accessible to contact in accordance with Protection of Users – Accessibility and User Servicing, Section 8; or

b) Any other evidence of damage that could increase the risk of fire or electric shock.

56.2 Each of three enclosures, wired as intended, are to be subjected to this test. The enclosures are to be placed on a concrete floor in any normal position of rest. A crushing force of 1100 lbf (4893 N) is to be applied by a conventional automotive tire, P225/75R15 or an equivalent tire suitable for the load, mounted on a steel rim and inflated to a pressure of 32 ± 2 psi (218 ± 13 kPa). The wheel is to be rolled over the enclosure at a speed of 5 ± 1.25 mph (8 ± 2 kmph). Each enclosure is to be oriented in a natural resting position before applying the force. Any position that the product can rest in without outside supports is considered a “natural resting position” for this test. For the test, the device under test shall be held or blocked in the natural resting position so that it does not move substantially during the application of the applied force.

57 Drop Test

57.1 After the test described in 57.2 and 57.3, there shall be no access to hazardous live part in accordance with Protection of Users – Accessibility and User Servicing, Section 8.

57.2 The test shall be performed on one sample at room temperature (nominal 25°C or 77°F) and on a second sample conditioned in a cold chamber at minus 22 ± 4°F (minus 30 ± 2°C) for 24 hours. For the conditioned sample, the sample shall be removed from the chamber prior to being subjected to the drop test. Gloves shall be worn when handling the conditioned sample to minimize heat transfer.

57.3 Two samples are to be subjected to three impacts that result from being dropped onto a concrete surface in positions likely to produce the most adverse results. The height of the drop shall be 39.4 inches (100 cm). Each drop should impact a different part of the sample.

58 Strength of Terminal Insulating Base and Support

58.1 An insulating base or support is considered to comply with the test described in 58.2 when there are no cracks in insulating base materials, no rotation of the insulating base, bosses or recesses or other means to prevent turning perform their intended function, or the like. Minor deformation or deterioration is allowed as long as the performance of the connection is not affected.

58.2 An insulating base or support shall be subjected to the force created when the connectors, securing short lengths of conductors sized as described in 12.1.1.3, are torqued to 110 percent of the value marked on the device.

59 Impact on Glass Covers

59.1 With reference to 7.5.8.1 (b), a glass covered opening shall withstand a 2-1/2 foot-pound (3.38 J) without cracking or breaking to the extent that a piece is released or dropped from its normal position.

59.2 The impact specified in 59.1 is to be applied by means of a smooth, solid steel sphere 2 inches (50.8 mm) in diameter and having 1.18 pounds (535 g) mass. The sphere is to fall freely from rest through a vertical distance of 25 inches (63.5 cm).

60 Bonding Conductor Tests

60.1 General

60.1.1 If tests are required to determine the acceptability of the bonding conductor, the bonding connection or conductor shall comply with the tests of 60.2 and 60.3.

60.2 Current test

60.2.1 A bonding conductor shall not open when carrying a current that equals twice the branch circuit protective device rating but not less than 40 amperes, for the time specified in Table 60.1.

Table 60.1
Duration of current flow, bonding conductor test

Rating or setting of branch-circuit overcurrent protective device, amperes	Test time, minutes	
	135 percent of current	200 percent of current
0 – 30	60	2
31 – 60	60	4
61 – 100	120	6
101 – 200	120	8

60.3 Limited short circuit test

60.3.1 A bonding conductor shall not open when subjected to the limited short circuit test described in 60.3.2 and 60.3.3.

60.3.2 Three samples of the bonding conductor are to be subjected to the test. The current is to be as specified in Table 60.2. The test circuit is to have a power factor of 0.9 – 1.0 and is to be limited to the current specified in Table 60.2. The open circuit voltage of the test circuit is to be 100 – 105 percent of the rated voltage of the equipment. The bonding conductor is to be connected to the circuit by a series connected nonrenewable fuse that does not open in less than 12 seconds when carrying twice its rated current. One test is to be performed on each sample.

60.3.3 The fuse specified in 60.3.2 is to have a current rating equal to that of the branch circuit overcurrent protective device to which the equipment is intended to be connected, but not less than 20 amperes.

Table 60.2
Circuit capacity for short circuit test

Rating of unit, volt-ampere		Volts	Capacity of test circuit, amperes
Single phase	3-phase		
0 – 1176	0 – 832	0 – 250	200
0 – 1176	0 – 832	251 – 600	1000
1177 – 1920	833 – 1496	0 – 600	1000
1921 – 4080	1497 – 3990	0 – 250	2000
4081 – 9600	3991 – 9145	0 – 250	3500
9601 or more	9146 or more	0 – 250	5000
1921 or more	1497 or more	251 – 600	5000

61 Evaluation of Reduced Spacings on Printed Wiring Boards

61.1 Printed-wiring board traces on printed wiring boards with deficient spacings are to be short-circuited, one location at a time, and the test is to be conducted in accordance with 50.1.1 – 50.1.3, 50.1.5, 50.1.7, and 50.1.8. As a result of this test:

a) The overcurrent protection associated with the branch circuit to the device shall not open, and

b) A wire or printed wiring board trace shall not open.

When the circuit is interrupted by opening of a component, not including overcurrent protective device, the test is to be repeated twice using new components as required. The same component shall interrupt the test in each iteration.

62 Mounting Means Test

62.1 The mounting means of a permanently secured product shall withstand a force of four times the weight of the equipment, but not less than 10 lbs (4.5 kg), without malfunction of or damage to the mounting means, including any bracket, securing means, or the equipment. When tested as described, the equipment and mounting means shall remain in place with no evidence of damage to the mounting means or the equipment.

62.2 To determine if the equipment complies with 62.1, the equipment is to be mounted in accordance with the manufacturer's installation instructions, using the hardware and construction as prescribed by the manufacturer. If the details of mounting are not specified, 3/8 inch (9.5 mm) thick plasterboard (drywall) on nominal 2 by 4 inch trade size (5 by 10 cm) wood studs spaced on 16 inch (406 mm) centers is to be used as the support surface. The hardware is to be applied as specified in the instructions, and if not otherwise indicated, the securing screws are to be positioned between the studs and secured into the plasterboard. Adjustable equipment is to be adjusted to the position that will give the maximum progression from the wall. The force is to be applied through a 3 inch (76 mm) wide strap at the dimensional center of the equipment and is to be increased over a 5 to 10 second interval, until a load equal to the weight of the device plus a force of three times the weight if the device, but not less than 10 lbs (4.5 kg), is applied to the mounting means. The load is to be maintained for one minute.

63 Strength of Handles

63.1 A handle specifically intended for lifting or carrying a portable product shall withstand a force equal to four times the weight of the equipment without breaking when tested in accordance with 63.2.

63.2 The force is to be applied with the handle in the intended carrying position, over a 3 inch (76 mm) length at the center of the handle. The force is to be applied gradually such that the required value is attained in 5 to 10 seconds and then maintained for 1 minute. If more than one handle is provided, the force is to be determined by the percentage of the device weight sustained by each handle with the device in the intended carrying position. If a device with more than one handle can be carried using only one handle, then each handle shall sustain the entire test weight in separate tests.

64 Mold Stress Test

64.1 A previously unused sample of the enclosure is subjected to the test as outlined in 64.2. After this test, the sample shall not show any signs of distortion, deterioration, shrinkage, warping, or softening, or access to live parts.

64.2 The sample shall be placed in an air circulating oven at a temperature equal to 10 degrees higher than the maximum temperature observed on the enclosure during the temperature test, but not less than 70°C (158°F). The sample is to be conditioned in the oven for 7 hours.

65 Environmental Tests

65.1 General

65.1.1 The following tests as applicable shall be performed on a sample of the enclosure. Internal parts or frames are not required to be provided as part of this test, however, may be required to complete or strengthen an enclosure for the test.

65.1.2 The tests shown in 65.2 through 65.16, are to be applied based on the enclosure type that will be marked on the product. See Table 65.1 for a summary of the test requirements.

65.2 Drip test

65.2.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Drip Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, there is no accumulation of water within the enclosure, and no water has entered the enclosure at a point higher than the lowest live part. Either Method A or Method B can be used.

Table 65.1
Environmental test requirements summary

Test name	Enclosure Type											
	1	2	3	3S	4	4X	5	6	6P	12	12K	13
Drip Test, 65.2		X		X								
Dust Test, 65.3[a]			X									
Indoor Settling Dust, 65.4[i]							X					
Indoor Circulating Dust, 65.5[j]										X	X	
External Icing, 65.6[b]			X	X	X	X		X	X			
Hosedown Test, 65.7[f]					X	X						
Indoor Corrosion Protection, 65.8[c]	X	X					X			X	X	X
Outdoor Corrosion Protection. 65.9[c]			X	X	X	X		X	X			
Additional Corrosion Protection, 65.10						X			X			
Submersion Test. 65.11[g]								X				
Pressure Test, 65.12[h]									X			
Gasket Tests, 65.13[d]		X	X	X	X	X	X	X	X	X	X	X
Water Exposure Test, 65.14[e]			X	X	X	X		X	X	X	X	
UV Exposure Test, 65.15[e]			X	X	X	X		X	X	X	X	
Chemical Exposure Test, 65.16[e]	X	X	X	X	X	X	X	X	X	X	X	X

[a] The Dust Test is intended to simulate windblown dust. The Dust Blast Method and the Hose Method are alternate Dust Test methods. An enclosure that meets the requirements for the Dust Test is considered to be acceptable for exposure to rain.

[b] The External Icing Test is intended to simulate freezing rain, sleet, and snow. Enclosure Types 3, 3R, 4, 4X, 6, and 6P with no external cavities to trap water are considered to comply without test. A Type 3S enclosure shall be subjected to this test due to external mechanisms.

[c] These tests are only required if using a metallic enclosure that is not provided with suitable corrosion protection in accordance with Section 9.

[d] These tests are only required if the gasket material is question has not been shown to comply with the tests previously.

[e] These tests are only required on nonmetallic enclosure materials that have not previously been shown to comply.

[f] The Hosedown Test is intended to simulate hosedown conditions. An enclosure that meets this requirement is considered to comply with the Dust Test.

[g] The Submersion Test is intended to simulate temporary submersion at a limited depth. An enclosure that meets this requirement is considered to comply with the Dust Test and the Hosedown Test.

[h] The Pressure Test is intended to simulate prolonged submersion at a limited depth. The Internal Pressurization Method and the External Pressurization Method are alternate pressure test methods. An enclosure that meets this requirement is considered to comply with the Submersion Test.

[i] The Settling Dust Test is intended to simulate an indoor environment of settling airborne dust, lint, fibers, and flyings. The dust method and the atomized water method are alternate settling dust methods. An enclosure that meets the requirements of the Settling Dust Test is considered to comply with the Drip Test.

Table 65.1 Continued on Next Page

Table 65.1 Continued

Test name	Enclosure Type											
	1	2	3	3S	4	4X	5	6	6P	12	12K	13
[j] The Indoor Circulating Dust Test is intended to simulate an indoor environment or circulating dust, lint, fibers, and flyings. The dust method and the atomized water method are considered alternate circulating dust test methods An enclosure that meets the requirements of the Indoor Circulating Dust Test is considered to comply with the Indoor Settling Dust Test and the Drip Test.												

65.3 Dust test

65.3.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Dust Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, no dust or water has entered the enclosure, corresponding to the Dust Blast Method or the Hose Method respectively.

65.4 Indoor settling dust test

65.4.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Indoor Settling Dust Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, no dust or water has entered the enclosure, corresponding to the Dust Method or the Atomized Water Method respectively.

65.5 Indoor circulating dust test

65.5.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Indoor Circulating Dust Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, no dust or water has entered the enclosure, corresponding to the Dust Method or the Atomized Water Method respectively.

65.6 External icing test

65.6.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the External Icing Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, when:

a) For a Type 3S enclosure:

1) External operating mechanisms are operable while ice laden and there is no damage to the mechanism or enclosure, or

2) After the ice is removed using the provided auxiliary mechanism or by following the manufacturer's instructions, the external operating mechanisms are operable and there is no damage to the mechanism or the enclosure.

b) For a Type 3, 3R, 4, 4X, 6, or 6P enclosure – there is no damage to the enclosure after the ice has melted.

65.7 Hosedown test

65.7.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Hosedown Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, no water has entered the enclosure.

65.8 Indoor corrosion protection

65.8.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Indoor Corrosion Protection Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, there is no rust, except at points where protection is impractical, such as mating surfaces of cast enclosures, hinges, and the like.

65.9 Outdoor corrosion protection

65.9.1 The enclosure is considered to comply with this test if at the conclusion of both the 600 Hour Salt Spray Test Method and the 1200 Hour Moist Carbon Dioxide – Sulfur Dioxide – Air Test Method in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, the enclosure complies with (a) and (b):

a) If after the 600 Hour Salt Spray Test the enclosure does not show any pitting, cracking, or other deterioration more severe than that from a similar test on G90 galvanized sheet steel.

b) If after the 1200 Hour Moist Carbon Dioxide – Sulfur Dioxide – Air Test the specimens:

1) Do not show more than light corrosion beneath the coating, with no visual pitting of substrate and only incipient buildup or weeping of corrosion products (except for the scribe);

2) Comply with Table 65.2; and

3) Do not exhibit an average creepage distance from the scribe greater than Rating No. 6 [1/16 – 1/8 inch (1.6 – 3.2 mm)] as designated in Procedure A, Method 2, as specified in the Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments, ASTM D 1654, with maximum isolated spot not exceeding 3/8 inch (9.5 mm).

Table 65.2
Blister size and frequency

Maximum size[a]	Maximum frequency
2	None
4 or 6	Medium
8	Medium dense
Note – Compliance is to be determined in accordance with Annex B, Ref. No. 5, of UL 50E.	
[a] The largest blister size is Number 2 and the smallest blister size is Number 8.	

65.10 Additional corrosion protection

65.10.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Additional Corrosion Protection Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, the enclosure does not show evidence of pitting, cracking, or other deterioration more severe than that resulting from a similar test on passivated American Iron and Steel Institute Type 304 Stainless Steel.

65.11 Submersion test

65.11.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Submersion Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, no water has entered the enclosure.

65.12 Pressure test

65.12.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Pressure Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, the enclosure meets (a) or (b) below.

a) Internal Pressurization Test Method – the internal pressure is a minimum of 4 psig (26 kPa) and there is not permanent deformation of the enclosure, or

b) External Pressurization Test Method – no water has entered the enclosure.

65.13 Gasket test

65.13.1 The enclosure is considered to comply with this test if at the conclusion of both the test method for the Tensile Strength and Elongation Test and the test method for the Compression Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, and the material meets (a) and (b):

a) The gasket material is considered to comply with the Tensile Strength and Elongation Test if the tensile strength is at least 75 percent of the unaged tensile strength, and the elongation is at least 60 percent of the unaged elongation. In addition, there shall be no visible deterioration, deformation, melting, or cracking of the material, and the material shall not harden as determined by normal hand flexing, and

b) The gasket material is considered to comply with the Compression test if the compression set does not exceed 50 percent of the original thickness.

65.14 Water exposure test

65.14.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the Water Exposure Test in the Standard for Electrical Equipment, Environmental Considerations, UL 50E, if all the minimum property retention requirements in Table 65.3 are met.

Table 65.3
Minimum property retention limitations after water immersion conditioning

Property	Water immersion[a]
Flammability Classification	Unchanged
Tensile or Flexural Strength[b]	50 percent
Tensile, Izod, or Charpy Impact[b]	50 percent

[a] 7 days at 70°C

[b] For functional support, the test methods are Tensile Strength and Flexural Strength. For impact resistance, the test methods are Tensile, Izod, or Charpy Impact

65.15 UV exposure

65.15.1 The enclosure is considered to comply with this test if at the conclusion of the test method for the UV Exposure Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, if all the minimum property retention requirements in Table 65.3 are met.

65.16 Chemical exposure

65.16.1 Three samples of the material used to form the enclosure shall be subjected to this test. The material shall not show any indication of cracking, deterioration or other signs of deformation after exposure to the following:

a) One sample shall be subjected to a 7 day vapor exposure of a solution of dilute sulfuric acid having a specific gravity of 1.2 at 100°F (38°C). The enclosure shall be placed in a 100 ± 4°F (38 ± 2°C) ambient.

b) One sample shall be subjected to a 40 hour immersion in ASTM IRM 903 oil (ASTM D 471 test fuel representing diesel fuel, heating oil, kerosene, etc.).

c) One sample shall be subjected to a 40 hour immersion in ASTM Reference Fuel C (ASTM D 471 test fuel consisting of 50 percent toluene and 50 percent isooctane and representing gasoline).

66 Tests for Permanence of Cord Tags

66.1 After being tested as described in 66.2 – 66.5, a tag used for a marking is considered to be permanently affixed to a flexible cord if there is no:

a) Tearing at any point for more than 1/16 in (1.6 mm);

b) Movement of the tag more than 1/2 in (12.7 mm) along the length of the flexible cord;

c) Shrinkage, wrinkling, cracking, or other deformation that renders the marking illegible; or

d) Visible curling or loosening around the edges of a tag with an adhesive back.

66.2 Nine samples of a cord tag are to be tested as described in 66.5. Each sample is to consist of a length of flexible cord to which the tag has been attached in the intended manner. If the tag is secured by an adhesive, the test is to be conducted no sooner than 24 hours after application of the tag. Three samples are to be tested as received; the additional samples are to be conditioned as described in 66.3 and 66.4 prior to testing.

66.3 Three samples are to be conditioned for 240 hours in an air-circulating oven maintained at a uniform temperature of 188.6 ± 1.8°F (87.0 ± 1.0°C). Following removal from the oven, the samples are to remain at a temperature of 73.4 ± 3.6°F (23.0 ± 2.0°C) and a relative humidity of 50 ± 5 percent for 30 minutes before testing.

66.4 Three additional samples are to be conditioned for 72 hours at a temperature of 89.6 ± 3.6°F (32.0 ± 2.0°C) and a relative humidity of 85 ± 5 percent. The samples are to be tested within 1 minute after being removed from the humidity chamber.

66.5 Each sample of flexible cord with attached tag is to be tightly suspended and clamped at each end in a vertical plane with the attachment plug pointing upward. A 5 pound force (22.2 N) force is to be applied for 1 minute at the uppermost corner of the tag furthest from the cord and within 1/4 inch (6.4 mm) of the vertical edge of the tag. The force is to be applied vertically downward in a direction parallel to the major axis of the cord. Following the test, the sample shall comply with the requirements in 66.1. Manipulation of the tag, such as straightening by hand, is permitted.

67 Tests on Transformer Insulating Materials

67.1 Where required by note (c) or (g) of Table 29.1 the transformer insulating material shall be subjected to the test described in 67.2.

67.2 The insulating material is to be placed between two opposing electrodes. The electrodes are to be cylindrical brass or stainless steel rods 1/4 inch (6.4 mm) in diameter with edges rounded to a 1/32-inch (0.8 mm) radius. The upper movable electrode is to weigh 50 ±2 grams to exert sufficient pressure on the specimen to provide good electrical contact. The test potential is to be increased to the test value and the maximum test potential is to be maintained for 1 second. The result complies when there is no dielectric breakdown.

68 Harmonic Distortion

68.1 A device rated for a harmonic factor (HF) or total harmonic distortion (THD) of the supply current is to be tested as described in 68.2 and 68.3. With the device energized at the input voltage and frequency in accordance with 43.1 and 43.2, HF or THD shall not be more than 10 percent over the manufacturer's rating for the device when controlling the maximum intended battery load.

68.2 The supply for the test is to have a voltage distortion of less 0.5 percent. Since the source (supply) voltage affects the magnitude of the harmonics, for measuring purposes, the supply impedance for cord-connected devices rated 240 volts or less shall be 0.08 ohm or less and the supply impedance for other devices shall not exceed a value that affects the results of the test.

68.3 The magnitude of the various harmonics of the supply frequency is to be recorded to the thirty-third (33) harmonic. The harmonic distortion factor is the ratio of the harmonic content to the rms value of the fundamental. The harmonic factor (HF) is to be calculated as follows:

$$HF = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{I_{fundamental}}$$

The total harmonic distortion (THD) is to be calculated as follows:

$$THD = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{\sqrt{I_1^2 + I_2^2 + I_3^2 + I_4^2 + \ldots}}$$

where

I1 = 100 percent at the fundamental frequency,

I2 = magnitude, in percent of the fundamental, of the second harmonic

I3 = magnitude, in percent of the fundamental, of the third harmonic

69 Metallic Coating Thickness Test

69.1 The solution to be used for this test is to be made from distilled water and is to contain 200 grams per liter of chemically pure chromic acid (CrO_3); and 50 grams per liter of chemically pure concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of chemically pure concentrated sulfuric acid, specific gravity 1.84, containing 96 percent of H_2SO_4.

69.2 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube of approximately 0.025 inch (0.64 mm) inside bore and 5.5 inches (140 mm) long. The lower end of the capillary tube is to be tapered to form a tip, the drops from which are to be approximately 0.025 milliliters. To maintain an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that the rate of dropping is 100 ±5 drops per minute when the stopcock is open. When desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

69.3 The sample and the test solution are to be kept in the test room long enough to acquire the temperature of the room maintained at an ambient temperature of 70 – 90°F (21.1 – 32.2°C).

69.4 Each sample is to be thoroughly cleaned before testing. All grease, lacquer, paint and other nonmetallic coatings are to be removed completely by means of solvents. Samples then are to be thoroughly rinsed in water and dried. The cleaned surface is not to contact the hands or any foreign material.

69.5 The sample to be tested is to be supported from 0.7 – 1 inch (18 – 25 mm) below the orifice, so that the drops of solution strike the point to be tested and run off. The surface to be tested is to be inclined approximately 45 degrees from horizontal.

69.6 The stopcock is to be opened and the time, in seconds, required for the dropping solution to dissolve the protective metallic coating and expose the base metal is to be measured. Exposure of the base metal is to be considered as the first appearance of the base metal recognizable by the change in color at that point.

69.7 Each sample of a test lot is to be tested at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface, and at an equal number of points on the outside surface, at places on both surfaces where the metallic coating may be expected to be the thinnest. On enclosures made from precoated sheets, the external corners that are subjected to the greatest deformation may have thin coatings.

69.8 The thickness of the coating being tested is to be calculated by selecting from Table 69.1 the thickness factor appropriate for the temperature at which the test was conducted, and multiplying that thickness factor by the time, in seconds, required to expose base metal as noted in 69.6.

Table 69.1
Thickness of coatings

Temperature, degrees F (C)		Thickness factors, 0.00001 inch (0.0003 mm) per second	
		Cadmium platings	Zinc platings
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

70 Comparative Tracking Index Test

70.1 A polymeric material used to enclose live parts shall be tested in accordance with the Comparative Tracking Index and Comparative Tracking Performance Level Class of Electrical Insulation Materials test described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. The material shall not have a performance level class value greater than 3.

71 Glow Wire Test

71.1 After being tested in accordance with this paragraph, a polymeric material used to enclose live parts shall demonstrate its resistance to ignition from overheated conductors caused by circuit overloads.

71.2 Each of three finished enclosures or less, if appropriate, is to be subjected to the Glow Wire Ignition Test described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. As a result of this test, there is not to be any ignition of the material during 30 seconds of application of the probe.

72 High Current Arc Resistance to Ignition Test

72.1 A polymeric material used to enclose live parts, when tested as described in 72.2 – 72.5, shall not ignite within 15 arcs. In addition, there shall be no dielectric breakdown caused by formation of a permanent carbon conductive path.

72.2 Three fully assembled enclosures are to be tested. When preparing devices for test, the condition that will cause the greatest arcing near the material being tested is to be simulated.

72.3 The test circuit is to provide test currents and test voltages equal to the current and voltage ratings of the device to be tested. The test arc is to be established between the live parts and any adjacent part where breakdown is likely to occur. The arc is to be used to attempt to ignite materials forming parts of the enclosure or to ignite materials located between the parts of different potential. The arc is to be established by means of a copper or stainless steel conductive probe. The conductive probe is to be used to break through insulation, create arc tracking or create a carbon build-upacross the surface of the insulating material at the rate of 30 – 40 arc separations per minute. The arc length developed with the probe is not to exceed the creepage distances specified in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

72.4 Immediately following the completion of the arcing portion of the test, the device is to be subjected to a 60 Hz essentially sinusoidal potential applied as described in 40.5 between live parts of opposite polarity and between live parts and dead metal parts. The test potential is to equal twice the rated voltage of the device plus 1000 V.

72.5 The device is to be tested by means of a 500 VA or larger capacity transformer whose output voltage is essentially sinusoidal and is capable of being varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for one minute. The increase in the applied potential is to be at a uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter.

72.6 If the output of the test equipment transformer is less than 500 VA, the equipment is to include a voltmeter in the output circuit to indicate the test potential directly.

73 Overcurrent Protection Calibration Test

73.1 A fuse, or circuit protective device, provided in the primary of a transformer for protection of the secondary circuit shall operate to open the circuit in not more than the time indicated in Table 73.1 when the transformer is delivering the specified secondary current.

Table 73.1
Maximum time to open

Rated secondary potential, volts	Secondary test current, amperes	Maximum time for overcurrent protective device to open, minutes
20 or less	10	2
20 or less	6.75	60[a]
Over 20	$200/V_{max}$	2
Over 20	$135/V_{max}$	60[a]

[a] After 15 minutes of operation, the current is to be readjusted to the value shown.

73.2 To determine when a fuse or circuit protective device complies with the requirement in 73.1, the transformer is to deliver the test current to a resistance load with the primary connected to a circuit as described in 43.1. During the 2-minute test, the load is to be adjusted continuously to maintain the required test current. During the 60-minute test, the load is to be adjusted once after 15 minutes of operation and the test is to be continued without further adjustment.

73.3 When the fuse or circuit protective device is used to protect more than one secondary winding or taps, each winding or partial winding is to be tested as indicated in 73.1 or 73.2 with the remaining windings delivering rated load.

MARKING

74 General

74.1 A device shall be legibly and permanently marked, where readily visible during use, with:

a) The manufacturer's name, trade name, or trademark or other descriptive marking by which the organization responsible for the device is able to be identified;

b) The catalog number or an equivalent designation, where practicable;

c) The electrical rating in both volt and amperes for the input and output of the device;

d) For devices incorporating either fuses or circuit breakers, the interrupting rating in amperes;

e) Ambient temperature rating, if higher than 40°C (104°F); and

f) The date or other dating period of manufacture not exceeding any three consecutive months.

Exception: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer, provided that the code:

a) Does not repeat in less than 20 years, and

b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.

74.2 When a manufacturer produces devices at more than one factory, each device shall have a distinctive marking, to identify it as the product of a particular factory.

74.3 All EV supply equipment shall be marked with the words “For use with Electric Vehicles.” This marking shall be visible during intended use.

74.4 All EV supply equipment shall be marked with the words “Ventilation Not Required.” This marking shall be visible during normal use.

74.5 Markings may be located on a tag that is attached to the power supply cord and complies with the requirements in Tests for Permanence of Cord Tags, Section 66.

74.6 A pressure sensitive label or a label secured by cement or adhesive shall comply with the applicable requirements for indoor and outdoor use labels in the Standard for Marking and Labeling Systems, UL 969.

74.7 A marking that is required to be permanent shall be molded, die-stamped, paint-stenciled, stamped, or etched metal that is permanently secured, or indelibly applied lettering on a label secured by adhesive that, upon investigation, is found to be suitable for the application. Ordinary usage, including likely exposure to weather and other ambient conditions, handling, storage, and the like, of the equipment is considered in the determination of the acceptability of the application.

74.8 With reference to the requirement in 74.1 (c), the symbols described in (a) and (b) are used for markings:

a) A circuit intended to be connected to an alternating-current supply shall be identified by markings indicating that the supply shall be alternating current. The markings shall include the supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz). The symbol illustrated in Figure 74.1 is an example for this marking. See 74.9.

b) The number of phases shall be indicated if the device is designed for use on a polyphase circuit. The symbol illustrated in Figure 74.2 is an alternative for the word “phase.” See 74.9.

Figure 74.1
Alternating current supply symbol

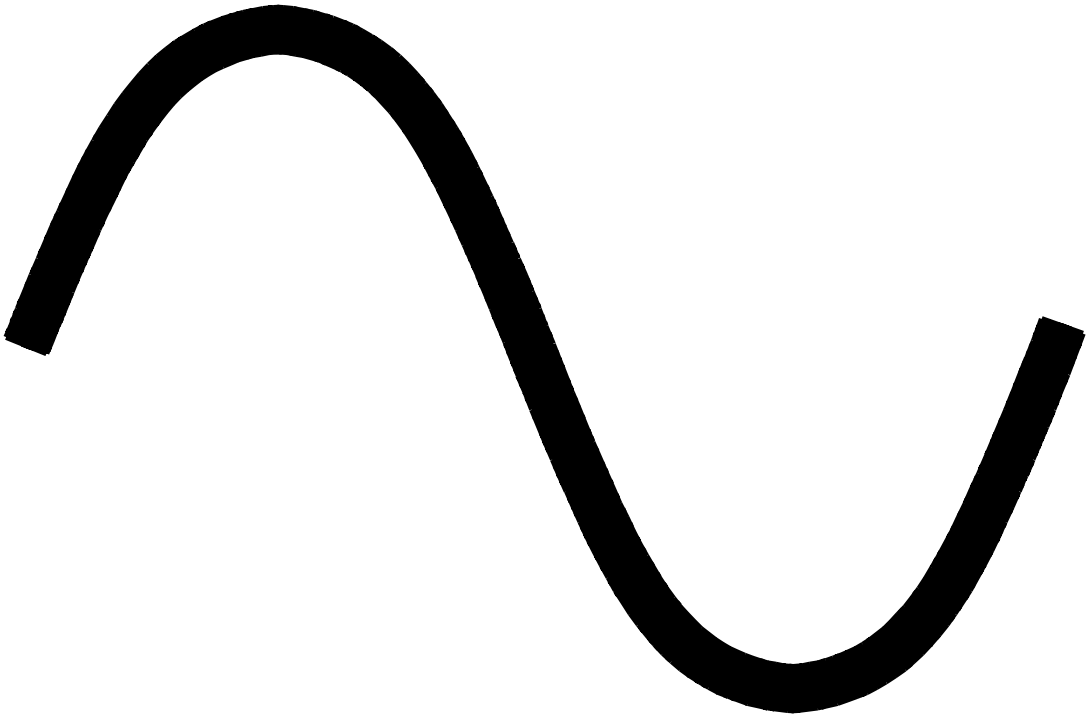
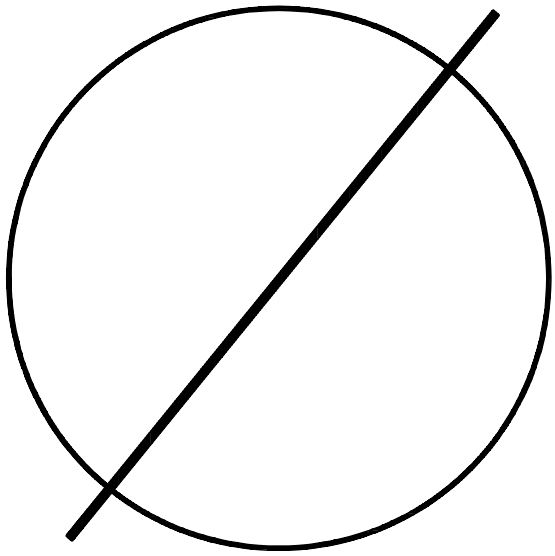


Figure 74.2
Phase symbol



SM510

74.9 When the symbol referenced in 74.8 (a) or (b) is used, the information described in 78.3 (k) shall be provided.

74.10 The operating positions of a handle, knob, or other means intended for manual operation by the user shall be marked.

74.11 Wiring terminals shall be marked to indicate the proper connections for the device, or a wiring diagram coded to the terminal marking shall be securely attached to the equipment.

74.12 Equipment field-wiring terminals shall be marked:

a) "Use Copper Conductors Only" when the terminal is intended only for connections to copper wire.

b) "Use Aluminum Conductors Only" or "Use Aluminum or Copper-Clad Aluminum Conductors Only" when the terminal is intended only for connection to aluminum wire.

c) "Use Copper or Aluminum Conductors" or "Use Copper, Copper-Clad Aluminum, or Aluminum Conductors" when the terminal is intended for connection to either copper or aluminum wire.

74.13 A device employing pressure terminal connectors for field wiring connections shall be provided with a marking making reference to the instruction manual for the tightening torque to be applied to the wiring terminals. See 78.3 (j).

74.14 A terminal for the connection of a grounded conductor shall be identified by means of a metallic plated coating white in color, and shall be readily 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 a marking on the unit, an indication on a wiring diagram attached to the unit, or information provided in the instruction manual. Where field wiring leads are provided, the lead intended to be grounded shall have a white or gray color and shall be readily distinguishable from other leads.

74.15 Where required by 12.1.3.4, a device containing a field-wiring lead that is connected to a wire binding screw located in the field-wiring compartment shall be marked with information clearly indicating the intended use of the lead.

74.16 A device having a manually operated user accessible test circuit for a ground fault protective device shall be marked with instructions indicating the test circuit shall be operated before each use.

74.17 Products provided with a 12 inch (300 mm) long power cord are to be marked with the word “WARNING” and the following or the equivalent, “To avoid a risk of fire or electric shock, do not use this device with an extension cord.”

75 Environmental Enclosure Markings

75.1 A device enclosure shall be marked with the rated enclosure type.

75.2 The marking required in 75.1 shall be visible during normal use.

75.3 Device enclosures are permitted to be provided with the following additional markings:

a) A Type 3, 3R, 3S, 4, 4X, 6 or 6P enclosure may be marked “Raintight”;

b) A Type 4, 4X, 6, or 6P enclosure may be marked “Watertight”; or

c) A Type 3 or 3S enclosure may be marked “Dusttight”.

76 Cautionary Markings

76.1 A product having a hidden or unexpected risk of injury shall be marked to inform the user of the risk.

76.2 A cautionary marking shall be permanent and legible in accordance with 74.5 and 74.6, and it shall be located on a permanent part of the product.

76.3 A cautionary marking intended to instruct the operator shall be legible and visible during intended operation. Other such markings for service or for making settings and adjustments shall be legible an visible to the individual when such work is being done.

76.4 A marking intended to inform the user of a risk of injury, including shock, shall be prefixed by a signal word “CAUTION,” “WARNING,” or “DANGER.” The marking shall be in letters not less than 3/32 inch (2.4 mm) high. The signal word shall be more prominent than any other required marking on the product.

76.5 A device shall be plainly marked with the word “CAUTION” and the following or the equivalent: “To reduce the risk of electric shock, connect only to properly grounded outlets.”

76.6 A device shall be marked with the word “CAUTION” and the following or equivalent: “ Do not use this product if there is any damage to the flexible power cord or the EV cable.”

76.7 A device enclosure shall be marked with the word “CAUTION” and the following or the equivalent: “Risk of electric shock. Do not remove cover or attempt to open the enclosure. No user serviceable parts inside. Refer servicing to qualified service personnel.”

76.8 There shall be a marking for each fuse that complies with the requirements in this standard, indicating the ampere, voltage, and ac or dc rating of the fuse to be used for replacement. The marking shall be located so that it is obvious as to which fuse or fuseholder the marking applies. A marking that consists of a pictorial identifying the rating of one or more fuses is allowed. In addition, the following prominent marking shall be provided - a single marking for a group of fuses is allowed - with the word “WARNING” and the following or the equivalent: “To reduce the risk of fire, replace only with same type and ratings of fuse.”

76.9 Devices that incorporate arcing or sparking parts shall be marked with the word “WARNING” and the following or the equivalent: “Risk of explosion. This equipment has arcing or sparking parts that should not be exposed to flammable vapors. This equipment should be located at least 18 inches (460 mm) above the floor.”

Exception No. 1: For devices that are encapsulated, this marking is not required.

Exception No. 2: For devices that have been evaluated for use in a Class 1, Division 2 Hazardous Location, this marking is not required.

76.10 Movable, floor supported devices that incorporate arcing or sparking parts located 18 inches (460 mm) above the floor level shall be marked with the word “WARNING” and the following or equivalent: “Risk Of Explosion. This Equipment Has Internal Arcing Or Sparking Parts Which Should Not Be Exposed To Flammable Vapors. It Should Not Be Located In A Recessed Area Or Below Floor Level.”

76.11 Devices that are intended for use in indoor use only, stationary applications, shall be marked with the word “CAUTION” and the following or the equivalent: “To reduce the risk of electric shock, use indoors only.” This marking shall also be included in the instruction manual.

76.12 EV cord sets and EV Charging Stations shall be marked with the word “WARNING” and the following or the equivalent: “This device is intended only for charging vehicles not requiring ventilation during charging.”

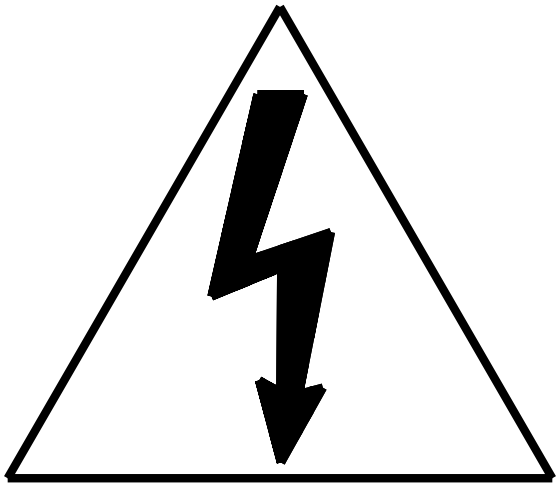
76.13 The symbol illustrated in Figure 76.1 is an alternative for the cautionary statement “Risk of electric shock.” The other markings required by the referenced paragraphs shall be provided in addition to the symbol. When the symbol is used, the information described in 76.3 (q) shall be provided in the instruction manual.

76.14 In accordance with 13.1.5, 13.1.11, and 13.1.12, devices that are intended for use with a specific vehicle shall be marked with the word “WARNING” and the following or the equivalent wording: “Risk of electric shock and fire. This device is only suitable for use with the (Make) (Model). It is not intended for use with any other vehicles.” The “make” and “model” of the vehicle shall be added into the marking.

76.15 A unit provided with single-pole circuit breakers in the input circuit in accordance with the Exception to 28.1.6 shall be marked internally with the word “CAUTION” and the following or the equivalent: “To reduce the risk of electric shock and fire - Do not connect to a circuit operating at more than 150 volts to ground.”

76.16 A part that is capable of being mistaken for dead metal, renders a risk of electric shock or electrical energy - high current levels, and is not guarded, as specified in 32.7, shall be marked with the word “CAUTION” and the following or the equivalent: “Risk of electric shock (or fire as applicable) - Plates (or other word describing the type of part) are live. Disconnect EV battery charger before servicing.” The marking shall be located on or near the live part so as to make the risk of fire or electric shock known before the part is capable of being touched. A single marking for multiple number of parts is allowed.

Figure 76.1
Symbol for "Risk Of Electrical Shock" statement



SA1965

IEC Publication 60417, Symbol 5036

INSTRUCTIONS

77 General

77.1 A device shall be provided with legible installation, operation, and, as applicable, user-maintenance instructions and moving and storage instructions; and instructions pertaining to a risk of fire or electric shock associated with the use of the device.

77.2 The instructions mentioned in 77.1 shall be:

a) In separate manuals, or

b) Combined in one or more manuals when the instructions pertaining to a risk of fire or electric shock are separated in format and emphasized to distinguish them from the rest of the text.

77.3 An illustration is allowed with a required instruction to clarify the intent but shall not replace the written instruction.

77.4 The following items shall be entirely in upper case letters or shall be emphasized to distinguish them from the rest of the text:

a) The headings for the installation, operation, user-maintenance, and moving and storage instructions;

b) The heading for the instructions pertaining to a risk of fire or electric shock; and

c) he opening and closing statements of the instructions specified in 78.3 – "IMPORTANT SAFETY INSTRUCTIONS" and "SAVE THESE INSTRUCTIONS" or the equivalent.

77.5 Unless otherwise indicated, the text of all instructions shall be in the words specified or words that are equivalent, clear, and understandable. Substitution of the signal word "DANGER" for "WARNING " is allowed, when the risk associated with the device is such that a situation exists which, if not avoided, will result in death or serious injury.

Exception: For other than the signal words "DANGER" and "WARNING," if a specific conflict exists in the application of such wording to a device, modified wording is allowed.

78 Instructions Pertaining to Risk of Fire, Electric Shock, or Injury to Persons

78.1 Instruction pertaining to a risk of fire or electric shock shall warn the user of reasonably foreseeable risks and state the precautions to be taken to reduce such risks. Such instructions shall be preceded by the heading "INSTRUCTIONS PERTAINING TO A RISK OF FIRE OR ELECTRIC SHOCK" or the equivalent.

78.2 Numbering the items in the list in 78.3 and including other instructions pertaining to a risk of fire or electric shock that the manufacturer determines to be necessary and that do not conflict with the intent of the instructions are acceptable.

78.3 The instructions pertaining to a risk of fire or electric shock shall include those items in the following list that are applicable to the device. The statement "IMPORTANT SAFETY INSTRUCTIONS" or the equivalent shall precede the list, and the statement "SAVE THESE INSTRUCTIONS" or the equivalent shall either precede or follow the list. The word "WARNING" shall be entirely in upper case letters or shall be emphasized to distinguish it from the rest of the text.

IMPORTANT SAFETY INSTRUCTIONS

WARNING – When using electric products, basic precautions should always be followed, including the following:

a) Read all the instructions before using this product.

b) This device should be supervised when used around children.

c) Do not put fingers into the electric vehicle connector.

d) Do not use this product if the flexible power cord or EV cable are frayed, have broken insulation, or any other signs of damage.

e) Do not use this product if the enclosure or the EV connector are broken, cracked, open, or show any other indication of damage.

f) In accordance with 12.1.2.4 (a), when pressure terminal connectors or the fastening hardware are not provided on the device as shipped, the instruction manual shall indicate which pressure terminal connector or component terminal assemblies are for use with the device.

g) With reference to (f), the terminal assembly packages and the instruction manual shall include information identifying wire size and manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identified.

h) When a pressure terminal connector provided in the device [or in a terminal assembly covered in 12.1.2.4 (d) for a field installed conductor requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any required instructions for using the tool shall be included in the instruction manual.

i) A device provided with a wire connector for field installed wiring shall be provided with instructions specifying that the connector provided is to be used in making the field connection.

j) A device employing pressure terminal connectors for field wiring connections shall be provided with instructions specifying a range of values or a nominal value of tightening torque to be applied to the clamping screws of the terminal connectors. The minimum specified tightening torque shall not be less than 90 percent of the value specified in Tables 78.1 or 78.3 as applicable for the wire size determined by the requirement described in 12.1.1.3.

Exception: The minimum specified tightening torque of 90 percent does not apply when the connector is investigated in accordance with the lesser assigned torque value 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.

k) When a symbol is used for compliance with marking requirements mentioned in 74.9, the instruction manual shall identify the symbol.

l) The instruction manual for a device that exceeds the temperature limits in the third item of Table 39.1 shall specify that the device is to be installed so that the risk of contact by people is reduced.

m) A device having primary circuit filtering to meet EMC regulations and which is required to comply with (b) of the Exception to 44.1, shall include mention of all the following conditions of installation in the instruction manual:

1) An insulated grounding conductor that is identical in size, insulation material, and thickness to the grounded and ungrounded branch-circuit supply conductors except that it is green with or without one or more yellow stripes is to be installed as part of the branch circuit that supplies the device or system.

2) The grounding conductor described in item 1 is to be grounded to earth at the service equipment or, when supplied by a separately derived system, at the supply transformer.

n) In accordance with 47.10, the instruction manual for a device having an ambient temperature rating higher than 77°F (25°C) shall indicate the maximum ambient temperature rating.

o) For a device having a single equipment field-wiring terminal that is intended for connection of more than one conductor, the instruction manual shall include information identifying the number of conductors and range of conductor sizes.

p) For a device provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 1, 2, 3, or 4 of Table 78.4 or with equivalent wording, when it is:

1) Intended for use on a supply circuit rated 110 amperes or less, or

2) Intended for field connection with conductors larger than 1 AWG (42.4 mm^2) or smaller conductors.

q) For a device provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 3 or 4 of Table 78.4, or with equivalent wording, when it is:

1) Intended for use on a supply circuit rated more than 110 amperes, or

2) Intended for field connection with conductors larger than 1 AWG (42.4 mm^2).

r) The instruction manual for a 3-phase device shall include the electrical ratings for delta or wye phase configuration when the device is limited to only one configuration.

s) The instruction manual for a device that, in accordance with 50.1.8, the abnormal test is terminated by operation of the intended branch circuit over current protective device, shall include the word “CAUTION” and the following or equivalent: “To reduce the risk of fire, connect only to a circuit provided with _____ amperes maximum branch circuit overcurrent protection in accordance with the National Electrical Code, ANSI/NFPA 70 .” The blank space is to be filled in with the applicable ampere rating of branch circuit overcurrent protection described in 50.1.6.

t) When a symbol is used for compliance with marking requirements mentioned in 76.13, the instruction manual shall illustrate and explain the meaning of the symbol; for example, the lightning flash with arrowhead within a triangle is intended to tell the user that parts inside the product are a risk of shock to persons.

SAVE THESE INSTRUCTIONS

Table 78.1
Tightening torque for pressure wire connectors having screws

Size of wire that is to be used for connection of the unit		Tightening torque, pound-inches (N·m)							
		Slotted head No. 10 and larger[a]				Hexagonal head - external drive socket wrench			
		Slot width - 0.047 inch (1.2 mm) or less and slot length 1/4 inch (6.4 mm) or less		Slot width - over 0.047 inch (1.2 mm) or slot length-over 1/4 inch (6.4 mm)		Split-bolt connectors		Other Connections	
AWG /kcmil	(mm^2)								
18 – 10	(0.82 – 5.3)	20	(2.3)	35	(4.0)	80	(9.0)	75	(8.5)
8	(8.4)	20	(2.8)	40	(4.5)	80	(9.0)	75	(8.5)
6 – 4	(13.3 – 21.2)	35	(4.0)	45	(5.1)	165	(18.6)	110	(12.4)
3	(26.7)	35	(4.0)	50	(5.6)	275	(31.1)	150	(16.9)
2	(33.6)	40	(4.5)	50	(5.6)	275	(31.1)	150	(16.9)
1	(42.4)	–		50	(5.6)	275	(31.1)	150	(16.9)
1/0 – 2/0	(53.5 – 67.4)	–		50	(5.6)	385	(43.5)	180	(20.3)
3/0 – 4/0	(85.0 – 107.2)	–		50	(5.6)	500	(56.5)	250	(28.2)
250 – 350	(127 – 177)	–		50	(5.6)	650	(73.4)	325	(36.7)
400	(203)	–		50	(5.6)	825	(93.2)	325	(36.7)
500	(253)	–		50	(5.6)	825	(93.2)	375	(42.4)
600 – 750	(304 – 380)	–		50	(5.6)	1000	(113.0)	375	(42.4)
800 – 1000	(406 – 508)	–		50	(5.6)	1100	(124.3)	500	(56.5)
1250 – 2000	(635 – 1016)	–		–		1100	(124.3)	600	(67.8)

NOTE – Connectors having clamping screw with multiple tightening means (for example, a slotted, hexagonal head screw) are to be tested using both values of torque.

[a] For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length is to be measured at the bottom of the slot.

Table 78.2
SI equivalents

Pound-inches	(N·m)	Pound-inches	(N·m)	Pound-inches	(N·m)
15	1.7	110	12.4	375	42.4
20	2.3	125	14.1	385	43.5
25	2.8	135	15.3	400	45.2
30	3.4	150	16.9	500	56.5
35	4.0	165	18.6	550	62.1
40	4.5	180	20.3	600	67.8
45	5.1	200	22.6	650	73.4
50	5.6	225	25.4	675	76.3
60	6.8	250	28.2	800	90.4
65	7.3	275	31.1	825	93.2
75	8.5	300	33.9	900	111.7
80	9.0	315	35.6	1000	113.0
90	10.2	325	36.7	1100	124.3

Table 78.3
Tightening torque for pressure wire connectors having internal drive socket head screws

Socket size across flats, inch (mm)[a]		Tightening torque, pound-inches (N·m)	
1/8	(3.2)	45	(5.1)
5/32	(4.0)	100	(11.4)
3/16	(4.8)	120	(13.8)
7/32	(5.6)	150	(17.0)
1/4	(6.4)	200	(22.6)
5/16	(7.9)	275	(31.1)
3/8	(9.5)	375	(42.4)
1/2	(12.7)	500	(56.5)
9/16	(14.3)	600	(67.8)

[a] See NOTE in Table 78.1 for screws with multiple tightening means.

Table 78.4
Termination markings

Temperature rating of wire that is intended to be used for connection of the device	Copper conductors only	Aluminum conductors or copper-clad conductors[a]	
60 or 75°C	"Use either (b) AWG, 60°C or (c) AWG, 75°C copper wire"	Row 1	"Use 60°C wire, either (b) AWG copper or (b) AWG aluminum; or 75°C wire, either (c) AWG copper or (c) AWG aluminum"
60°C	"Use (b) AWG, 60°C copper wire"	Row 2	"Use 60°C wire, either (b) AWG copper or (b) AWG aluminum"
75°C	"Use (c) AWG, 75°C copper wire"	Row 3	"Use 75°C wire, either (c) AWG copper or (c) AWG aluminum"
90°C	"Use (c) AWG, 90°C copper wire"	Row 4	"Use 90°C wire, either (c) AWG copper or (c) AWG aluminum"

[a] Reference to copper wire is included when wiring terminals are applicable for only the conductors specified in 74.12(b).

[b] The wire size for 60°C wire is not required to be included in the marking; however, when it is included, it shall be based on the ampacities given in Table 310-16 of the National Electrical Code, ANSI/NFPA 70, for 60°C wire and the derating factor described in 12.1.1.3.

[c] The conductor size shall be no smaller than the larger of the following:

1) The conductor size used for the temperature test – see 47.3; or

2) The 75°C wire size based on the ampacities given in Table 310-16 of the National Electrical Code, ANSI/NFPA 70, and the derating factor described in 12.1.1.3.

78.4 The instructions pertaining to a risk of fire or electric shock, or the installation instructions shall include the following items in (a) and (b). If the instructions are included in the installation instructions, a reference to these instructions shall be included in the list mentioned in 78.3 as a separate line item. The word "WARNING" shall be entirely in upper case letters or shall be emphasized to distinguish it from the rest of the text.

a) For a grounded, cord connected product:

GROUNDING INSTRUCTIONS

This product must be grounded. If it should malfunction or breakdown, grounding provides a path of least resistance for electric current to reduce the risk of electric shock. This product is equipped with a cord having an equipment grounding conductor and a grounding plug. The plug must be plugged into an appropriate outlet that is properly installed and grounded in accordance with all local codes and ordinances.

WARNING – Improper connection of the equipment-grounding conductor is able to result in a risk of electric shock. Check with a qualified electrician or serviceman if you are in doubt as to whether the product is properly grounded. Do not modify the plug provided with the product – if it will not fit the outlet, have a proper outlet installed by a qualified electrician.

b) For a permanently connected product:

GROUNDING INSTRUCTIONS

This product must be connected to a grounded, metal, permanent wiring system; or an equipment-grounding conductor must be run with the circuit conductors and connected to the equipment grounding terminal or lead on the product.

79 Installation Instructions

79.1 Installation instructions shall contain all the information needed to install the product for use as intended, and shall be preceded by the heading “INSTALLATION INSTRUCTIONS” or the equivalent.

79.2 With reference to 79.1, for a device that is intended for, or capable of, being wall mounted, the instructions shall contain all statements required for proper mounting. This includes the type of wall surface that is acceptable, the proper mounting hardware that should be used, any preparation of surfaces, and the like.

79.3 A product that is marked for indoor use only, shall have the statement “This product is intended for indoor use only” or the equivalent appearing in the installation instructions.

79.4 In accordance with 7.5.7.4, for Type 1, 2, 3R, or 5 enclosures provided with mounting openings that are other than as specified in Table 7.9, the installation instructions shall contain specific and clear statements indicating how to maintain the environmental integrity of the enclosure after it is installed.

80 Operating Instructions

80.1 Operating instructions shall contain all the information needed to operate the product as intended, and shall be preceded by the heading “OPERATING INSTRUCTIONS” or the equivalent.

Exception: Instructions and warnings provided in accordance with the requirements for instructions pertaining to a risk of fire or electric shock in Section 78 need not be repeated in the operating instructions if there is a reference to the applicable instructions and warnings in the operating instructions.

80.2 Operating instructions shall explain and describe the location, function, and operation of each control provided on the product, and warn against tampering with such devices.

80.3 A product that is marked for indoor use only, shall have the statement “This product is intended for indoor use only” or the equivalent appearing in the operating instructions.

80.4 Type 2 and type 3R enclosures that are constructed in accordance with 7.5.6.2 shall have instructions indicating that the drainage hole plugs shall be removed for Type 2 applications and shall be in place for other applications.

80.5 Type 2 and Type 3R enclosures that are constructed in accordance with 7.5.6.3 shall have instructions indicating the method of providing drainage openings when the enclosure is being used for Type 2 applications.

81 User Maintenance Instructions

81.1 Instructions for user maintenance shall include explicit instructions for all cleaning and servicing that are intended to be performed by the user, and shall be preceded by the heading “USER MAINTENANCE INSTRUCTIONS” or the equivalent.

82 Moving, Transporting, and Storage Instructions

82.1 If improper moving or storage of the device is able to result in damage to the product that could result in a risk of fire or electric shock during subsequent use, the instructions shall describe the proper moving and storage procedure, and shall be preceded by the heading “MOVING AND STORAGE INSTRUCTIONS” or the equivalent.

82.2 Instructions for moving the device shall state that the device is not to be lifted or carried by either the flexible cord or the EV cable, if provided. The appropriate means for carrying and moving the device shall be described.

82.3 Instructions for the proper storage of the device, including location, temperature limits, and the like, shall be provided in the Moving, Transporting, and Storage Instructions.

APPENDIX A

Standards for Components

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard − UL Standard Designation

Attachment Plugs and Receptacles – UL 498
Capacitors – UL 810
Capacitors and Suppressors for Radio- and Television-Type Appliances – UL 1414
Class 2 Power Units – UL 1310
Conduit, Tubing, and Conduit Fittings – UL 514B
Cord Reels – UL 355
Cord Sets and Power-Supply Cords – UL 817
Dry-Type General Purpose and Power Transformers – UL 1561
Electrical Equipment, Environmental Considerations – UL 50E
Electromagnetic Interference Filters – UL 1283
Enclosures for Electrical Equipment – UL 50
Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors – UL 486E
Extruded Insulating Tubing – UL 224
Flexible Cords and Cables – UL 62
Gaskets and Seals – UL 157
General-Use Snap Switches – UL 20
Industrial Control Equipment – UL 508
Insulating Bushings – UL 635
Insulation Coordination, Including Clearances and Creepage Distances for Electrical Equipment – UL 840
Low Voltage Transformers, Part 1: General Requirements – UL 5085-1
Low Voltage Transformers, Part 3: Class 2 and Class 3 Transformers – UL 5085-3
Marking and Labeling Systems – UL 969
Metallic Outlet Boxes – UL 514A
Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures – UL 489
Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements – UL 2231-1
Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protection Devices for Use in Charging Systems – UL 2231-2
Plugs, Receptacles, and Couplers for Electric Vehicles – UL 2251
Polymeric Materials – Long Term Property Evaluations – UL 746B
Polymeric Materials – Short Term Property Evaluations – UL 746A
Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C
Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape – UL 510
Printed-Wiring Boards – UL 796
Reference Standard for Electrical Wires, Cables and Flexible Cords – UL 1581
Software in Programmable Components – UL 1998
Terminals, Electrical Quick-Connect – UL 310
Test for Surface Burning Characteristics of Building Materials – UL 723
Tests for Flammability of Plastic Materials for Parts in Devices and Appliances – UL 94
Tests for Safety Related Controls Employing Solid-State Devices – UL 991
Tests for Sharpness of Edges on Equipment – UL 1439
Thermal-Links – Requirements and Application Guide – UL 60691

Thermoplastic-Insulated Wires and Cables – UL 83
Transformers, Specialty – UL 506
Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances – UL 1411
Wire Connectors – UL 486A-486B

APPENDIX B

B.1 Test Sequences

B.1.1 Table B.1 and Table B.2 show the applicable tests that apply to product types covered by this outline. Based on final design and components used, the final test plan will include all of the indicated tests or a subset of those tests.

B.1.2 The Environmental Tests are dependent upon enclosure type. The tests in the Tables indicate that environmental tests are needed but does not detail which tests. For this information, see Sample Requirements, Section B.2 and Table 65.1.

B.1.3 Some tests may no be required if the test was performed as part of the component evaluation.

B.1.4 The mounting means test only applies to products that are wall or ceiling mounted. If the product is secured to the floor, then the mounting means test does not apply.

Table B.1
Cord set tests

Test name	Section No.	Portable cord set	Stationary cord Set, outdoor use	Stationary cord set, indoor use
Leakage Current Test	44	X	X	X
Humidity Conditioning	45	X	X	X
Input Test	46	X	X	X
Temperature Test	47	X	X	X
Capacitor Discharge	48	X	X	X
Dielectric Voltage Withstand	49	X	X	X
Transformer Burn Out	50.2			
Transformer Over Load	50.3			
Short Circuit	50.4	X	X	X
Capacitor Fault	50.5			
Forced Ventilation	50.6			
Component Faults	50.7	X	X	X
Electrolytic Capacitor Faults	50.8			
Vibration	50.9	X		
Flanged Bobbin Abnormal	51			
Pull Strain Relief Test	52.2	X	X	X
Push Back Strain Relief Test	52.3	X	X	X
EV Cable Secureness Test	53	X	X	X
Ground Impedance	54.1	X	X	X
Ground Continuity	54.2	X	X	X
Impact Test	55	X	X	X
Vehicle Drive Over Test	56	X		
Drop Test	57	X		
Strength of Insulating Base	58			
Impact of Glass Covers	59	X	X	X
Bonding Conductor Tests	60	X	X	X
Reduced Spacing Tests	61	X	X	X
Mounting Means Test	62		X	X
Strength of Handles Test	63	X	X	X
Mold Stress Test	64	X	X	X

Table B.1 Continued on Next Page

Table B.1 Continued

Test name	Section No.	Portable cord set	Stationary cord Set, outdoor use	Stationary cord set, indoor use
Environmental Tests	65	X	X	X
Permanence of Cord Tags	66	X	X	X
Transformers Insulation Test	67			
Harmonic Distortion	68	X	X	X
Metal Coating Thickness Test	69	X	X	X
Comparative Tracking Index	70	X	X	X
Glow Wire Test	71	X	X	X
High Current Arc Resistance	72	X	X	X
Overcurrent Calibration Test	73			

Table B.2
Cord set tests

Test name	Section No.	Movable charge stations, outdoor use	Movable charge stations, indoor use	Permanent charge stations, outdoor use	Permanent charge stations, indoor use
Leakage Current Test	44	X	X		
Humidity Conditioning	45	X	X		
Input Test	46	X	X	X	X
Temperature Test	47	X	X	X	X
Capacitor Discharge	48	X	X		
Dielectric Voltage Withstand	49	X	X	X	X
Transformer Burn Out	50.2	X	X	X	X
Transformer Over Load	50.3	X	X	X	X
Short Circuit	50.4	X	X	X	X
Capacitor Fault	50.5		X		X
Forced Ventilation	50.6		X		X
Component Faults	50.7	X	X	X	X
Electrolytic Capacitor Faults	50.8	X	X	X	X
Vibration	50.9				
Flanged Bobbin Abnormal	51	X	X	X	X
Pull Strain Relief Test	52.2	X	X		
Push Back Strain Relief Test	52.3	X	X		
EV Cable Secureness Test	53	X	X	X	X
Ground Impedance	54.1	X	X	X	X
Ground Continuity	54.2	X	X	X	X
Impact Test	55	X	X	X	X
Vehicle Drive Over Test	56				
Drop Test	57	X	X		
Strength of Insulating Base	58			X	X
Impact of Glass Covers	59	X	X	X	X
Bonding Conductor Tests	60	X	X	X	X
Reduced Spacing Tests	61	X	X	X	X
Mounting Means Test	62			X	X
Strength of Handles Test	63	X	X		
Mold Stress Test	64	X	X	X	X
Environmental Tests	65	X	X	X	X

Table B.2 Continued on Next Page

Table B.2 Continued

Test name	Section No.	Movable charge stations, outdoor use	Movable charge stations, indoor use	Permanent charge stations, outdoor use	Permanent charge stations, indoor use
Permanence of Cord Tags	66	X	X	X	X
Transformers Insulation Test	67	X	X	X	X
Harmonic Distortion	68	X	X	X	X
Metal Coating Thickness Test	69	X	X	X	X
Comparative Tracking Index	70	X	X	X	X
Glow Wire Test	71	X	X	X	X
High Current Arc Resistance	72	X	X	X	X
Overcurrent Calibration Test	73	X	X	X	X

B.2 Sample Requirements

B.2.1 Type tests

B.2.1.1 The tests in Table B.3 may be performed using more samples to expedite testing; or the tests may be performed on fewer samples than indicated if doing so is acceptable to all those involved, but compounded damage shall not be considered when judging compliance.

B.2.1.2 Some test are required to be repeated at the conclusion of other tests in order to determine compliance. For example, the Dielectric Withstand Test is required as a type test, but is also required after the Component Fault Test. Table B.3 will only indicate the Dielectric Withstand Test once in the sample selection information, however, the test will be performed multiple times.

B.2.1.3 Tests that indicate “special samples” are in reference to the sample requirements shown for that test under the Performance section of this outline.

Table B.3
Type test sample requirements

Test name	Section No.	Portable cord set								
		1	2	3	4	5	6	7	8	9
Leakage Current Test	44	X								
Humidity Conditioning	45	X								
Input Test	46	X								
Temperature Test	47	X								
Capacitor Discharge	48	X								
Dielectric Voltage Withstand	49	X								
Transformer Burn Out	50.2	Special Samples								
Transformer Over Load	50.3	Special Samples								
Short Circuit	50.4		X							
Capacitor Fault	50.5			X						
Forced Ventilation	50.6				X					
Component Faults[a]	50.7					X				
Electrolytic Capacitor Faults	50.8						X			
Vibration	50.9							X		

Table B.3 Continued on Next Page

Table B.3 Continued

Test name	Section No.	Portable cord set								
		1	2	3	4	5	6	7	8	9
Flanged Bobbin Abnormal	51	Special Ssamples								
Pull Strain Relief Test	52.2	X								
Push Back Strain Relief Test	52.3	X								
EV Cable Secureness Test	53	X								
Ground Impedance	54.1	X								
Ground Continuity	54.2	X								
Impact Test	55	X	X							
Vehicle Drive Over Test	56			X	X	X				
Drop Test	57						X	X		
Strength of Insulating Base	58	X								
Impact of Glass Covers	59	X								
Bonding Conductor Tests	60	Special Samples								
Reduced Spacing Tests	61								X	
Mounting Means Test	62	X								
Strength of Handles Test	63	X								
Mold Stress Test	64								X	
Permanence of Cord Tags	66	Special Samples								
Transformers Insulation Test	67	Special Samples								
Harmonic Distortion	68									X
Metal Coating Thickness Test	69	Special Samples								
Overcurrent Calibration Test	73	X								

[a] This test may require multiple samples to complete all test conditions.

B.2.2 Environmental tests

B.2.2.1 The tests indicated in Table B.4 are to be performed on separate enclosure samples unless agreed upon by all involved.

B.2.2.2 The tests shall be performed as required. See Table 65.1.

Table B.4
Environmental test requirements summary

Test name	Enclosure type[d]												
	1	2	3	3R	3S	4	4X	5	6	6P	12	12K	13
Drip Test		1											
Dust Test,			1		1								
Indoor Settling Dust								1					
Indoor Circulating Dust											1	1	
External Icing			2	1	2	1	1		1	1			
Hosedown Test						2	2						
Indoor Corrosion Protection	1	2						2			2	2	1
Outdoor Corrosion Protection			3	2	3	3	3		2	2			
Additional Corrosion Protection							4			3			
Submersion Test									3				
Pressure Test										4			
Water Exposure Test			4	3	4	4	5		4	5	3	3	
UV Exposure Test			5	4	5	5	6		5	5	4	4	
Chemical Exposure Test[a]	2	3	6	5	6	6	7	3	6	7	5	5	2
Gasket Tests[b,c]		4	7	6	7	7	8	4	7	8	6	6	3

[a] Chemical exposure test requires three separate samples, one sample for each exposure.

[b] Gasket tests for all types except 12, 12K, and 13 require 6 samples of the gasket material for the tensile strength and elongation test, and 3 samples for the compression test.

[c] Gasket tests for types 12, 12K, and 13 require the same samples as note B, but also require 3 samples for the oil immersion test.

[d] The table contains columns for each enclosure type. Reading down a column will tell you what samples are needed. For example, for type 2 enclosures, the first sample is used for the Drip Test, the second sample for the Indoor Corrosion Protection Test, the third (set of three) sample is used for the Chemical Exposure Test, and the fourth (set of 9) sample is used for the gasket tests.

B.2.3 Material tests

B.2.3.1 The tests in Sections 70 through 72 are required to be performed on samples of the enclosure material. A minimum of seven samples of the material are required for these tests.