UL 2251

Underwriters Laboratories Inc.

Standard for Safety

Plugs, Receptacles and Couplers for Electric Vehicles

UL Standard for Safety for Plugs, Receptacles and Couplers for Electric Vehicles, UL 2251

First Edition, Dated February 28, 2002

Summary of Topics

This revision of UL 2251 changes the following requirements:

1. Addition of requirements to allow for a hang tag label on EV coupler equipment

2. Editorial change to the insulation resistance test

The revised requirements are substantially in accordance with Proposal(s) on this subject dated August 21, 2009.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

No Text on This Page

FEBRUARY 28, 2002
(Title Page Reprinted: December 22, 2009)

UL 2251

Standard for Plugs, Receptacles and Couplers for Electric Vehicles

First Edition

February 28, 2002

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

RATINGS

MARKINGS

CONFIGURATIONS

This page intentionally left blank.

INTRODUCTION

1 Scope

1.1 These requirements cover plugs, receptacles, vehicle inlets, and connectors, rated up to 800 amperes and up to 600 volts ac or dc, intended for conductive connection systems, for use with electric vehicles in accordance with National Electrical Code (NEC), ANSI/NFPA-70 for either indoor or outdoor nonhazardous locations.

1.2 This standard does not directly apply to the following but is able to supplement other applicable standards:

a) Devices produced integrally with flexible cord or cable that are covered by the Standard for Cord Sets and Power-Supply Cords, UL 817;

b) Devices solely intended for direct connection to the branch circuit in accordance with Articles 300, 400 and 410 of the NEC such as attachment plugs, cord connectors and receptacles, which can include 3 or more pilot contacts, that are covered by the Standard for Attachment Plugs and Receptacles, UL 498;

c) Single and multi-pole connectors, intended for connection to copper conductors, for use in data, signal, control and power applications within and between electrical equipment, where exposed, for use in accordance with the National Electrical Code, that are covered by the Standard for Attachment Plugs and Receptacles, UL 498;

d) Devices of the pin and sleeve type construction, intended to provide power from branch circuits to utilization equipment, or for direct connection of utilization equipment to the branch circuit, that are covered by the Standard for Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve Type, UL 1682;

e) Devices intended for use in hazardous locations that are covered by the Standard for Receptacle-Plug Combinations for Use in Hazardous (Classified) Locations, UL 1010;

f) Devices consisting of wiring terminals and supporting blocks intended for the connection of wiring that are covered by the Standard for Terminal Blocks, UL 1059;

g) Devices such as modular jacks and plugs that are intended for use with telecommunications networks, that are covered by the Standard for Telephone Equipment, UL 1459, and the Standard for Communications Circuit Accessories, UL 1863;

h)) Devices such as wire connectors and soldering lugs, that are covered by the Standards for Wire Connectors and Soldering Lugs for Use with Copper Conductors, UL 486A; Splicing Wire Connectors, UL 486C; or Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E;

i) Devices such as quick-connect terminals that are covered by the Standard for Electrical Quick-Connect Terminals, UL 310;

j) Products such as power outlet assemblies that are covered by the Standard for Power Outlets, UL 231;

k) Products such as switched interlocks that are covered by the Standard for Industrial Control Equipment, UL 508.

1.3 In the text of this standard, the term ″device″ refers to any product covered by this standard. The letters ″EV″ refer to an electric vehicle.

2 Glossary

2.1 For the purposes of this standard, the following definitions apply.

2.2 CONTACT – A conductive element in a component that mates with a corresponding element to provide an electrical path.

2.3 CONTROL CONTACT – A conductive element intended to carry an indicating or controlling signal.

2.4 CONTROL PILOT – The primary control conductor that is connected to the equipment earth through the control circuitry on the vehicle. It performs several functions, including assurance that the vehicle is present and connected, start/stop control, charging area ventilation requirements, supply equipment current rating, and provides for the continuous monitoring of the presence of the equipment earth.

2.5 DELAYED ACTION – An arrangement that delays the separation of device housings to reduce the likelihood of exposure of arcing contacts during the breaking of the circuit when the plug is withdrawn.

2.6 ENCLOSURE – The case or housing into which the insulator and contacts are assembled.

2.7 FIELD WIRING TERMINAL – A terminal to which power supply, control, or equipment grounding connections will be made in the field when the device is installed.

2.8 INSULATOR – That portion of a device that provides for separation and support of contacts.

2.9 INTERLOCKED RECEPTACLE – An outlet having a device, either electrical or mechanical, that is intended to reduce the likelihood of energizing the contacts before proper engagement with a plug, and that either is intended to reduce the likelihood of the plug being withdrawn while its contacts are energized or de-energizes the line contacts before separation.

2.10 LOCKING RETAINING DEVICE – A mechanical arrangement that holds a plug or connector in position when it is in proper engagement and is intended to reduce the likelihood of its unintentional withdrawal. It could also facilitate environmental sealing.

2.11 MEASUREMENT INDICATION UNIT (MIU) – The output voltage across the meter, in millivolts RMS, in the measurement instrument in Figure 30.2, divided by 500 ohms. [The instrument indication is equal to the RMS value in milliamperes when the frequency is 60 Hz (sinusoidal current)]. The reading may not be a direct indication of the RMS or other common amplitude quantifier of leakage current when the leakage current is of complex waveform or frequency other than 50 or 60 Hz.

2.12 PLUG – A device intended to receive power when inserted in a receptacle, which establishes connection between conductors of the attached flexible cord or cable and the conductors connected to the receptacle or connector.

2.13 RECEPTACLE – A device that is intended to provide power to an inserted plug, and that is usually installed as a fixed outlet or on equipment.

2.14 TERMINAL – A conductive part provided on a contact for connecting a conductor.

2.15 VEHICLE CONNECTOR – A portable receptacle that by insertion into an vehicle inlet, establishes an electrical connection to the electric vehicle for the purpose of providing power and information exchange, with means for attachment of flexible cord or cable. This device is a part of the coupler.

2.16 VEHICLE COUPLER – A means enabling the connection, at will, of a flexible supply cord to the equipment. It consists of a connector and a vehicle inlet.

2.17 VEHICLE INLET – The part incorporated in, or fixed to the vehicle or intended to be fixed to it, which receives power from a connector.

3 Components

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

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

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

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

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

4 Units of Measurement

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

5 References

5.1 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.

CONSTRUCTION

6 General

6.1 The ratings mentioned throughout this standard, including those mentioned in 59.2, represent maximum ampacity and voltage for a device. A device is considered to be for use on either alternating or direct current unless the rating includes a marking to restrict the use to alternating current. See 60.6.

7 Configurations

7.1 Configurations of various plug and receptacle and connector and vehicle inlet combinations are located in General, Section 62. Other combinations of plugs and receptacles that are investigated accordingly are not precluded by this requirement.

8 Insulating Materials

8.1 Flammability

8.1.1 All parts that act as the electrical insulation or enclosure of a device shall be of ceramic, or another insulating material permitted for the particular application. Hard rubber is not permitted.

8.1.2 Vulcanized fiber can be used for insulating washers, separators, and barriers, but not as the sole support for live parts. The material shall be moisture resistant in accordance with 29.1 and 29.2.

8.1.3 A polymeric material used for electrical insulation, an internal barrier necessary to maintain electrical spacings, or enclosure of live parts shall have a flame class rating of V-0, V-1, V-2, VTM-0, VTM-1, VTM-2, or HB in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

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

Exception No. 2: A small part meeting all the following criteria need not have a flame class rating:

a) Its volume does not exceed 2 cm^3 (0.122^3 inch), and

b) Its maximum dimension does not exceed 3 cm (1.18 inches), and

c) Its location is such that it cannot propagate flame from one area to another or act as a bridge between a possible source of ignition and other ignitable parts.

Exception No. 3: Fiber and similar material that is equal to or less than 0.25 mm (0.010 inch) thick need not have a flame class rating.

8.2 Electrical properties

8.2.1 A polymeric material used for electrical insulation, an internal barrier necessary to maintain electrical spacings, or enclosure of live parts shall comply with the requirements in Sections 25 – 27.

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 25.

Exception No. 2: A polymeric material having Hot Wire Ignition (HWI) performance level class values not greater than those shown in Table 8.1 for the applicable flammability classification need not comply with the Glow Wire Test, Section 26. For materials with other than VTM flammability classifications, the material shall be evaluated using the specimen thickness employed in the end product or minimum 3.0 mm (0.118 inch) 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 8.1 for the applicable flammability classification need not comply with the High-Current Arc Resistance to Ignition Test, Section 27. For materials with other than VTM flammability classifications, the material shall be evaluated using the specimen thickness employed in the end product or minimum 3.0 mm (0.118 inch) thickness, whichever thickness is greater.

Exception No. 4: The internal insulating systems of components where component requirements exist need not comply with the requirement in Sections 25 – 27.

Exception No. 5: A small part meeting all the following criteria need not comply with the requirements in Sections 27 – 29.

a) Its volume does not exceed 2 cm^3 (0.122 $inch^3$), and

b) Its maximum dimension does not exceed 3 cm (1.18 inches), and

c) Its location is such that it cannot propagate flame from one area to another or act as a bridge between a possible source of ignition and other ignitable parts.

Exception No. 6: Fiber and similar material that is equal to or less than 0.25 mm (0.010 inch) thick need not comply with the requirements in Sections 25 – 27.

Exception No. 7: A polymeric material used in an enclosure of a plug or connector which does not enclose live parts, or which encloses insulated live parts where the insulation thickness is greater than 0.071 mm (0.028 inch), need not comply with the requirements in the Glow Wire Test, Section 26.

Exception No. 8: A polymeric material used in an enclosure that is separated through air by more than 0.8 mm (1/32 inch) from uninsulated live parts and more than 12.7 mm (1/2 inch) from arcing parts need not comply with the requirements in Sections 25 – 27.

Table 8.1
Hot wire ignition (HWI) and high-current arc resistance to ignition (HAI) ratings of insulating materials

Flammability classification[a]	HWI[b,d]		HAI[c,d]	
	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.

8.3 Thermal properties

8.3.1 A polymeric material used for electrical insulation or enclosure of live parts shall have the relative thermal index ratings shown in Table 8.2 for the specific application of the insulating material.

Table 8.2
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,c] with impact	Mechanical[b,c] 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.

[c] For devices containing fuses, the minimum thermal indices shall be the values shown above or the temperature measured on the insulating material during the fuseholder temperature test, whichever is greater. See Fuseholder Temperature Test, Section 50.

9 Protection Against Corrosion

9.1 Parts of iron or steel other than stainless steel parts shall be protected against corrosion, in accordance with the Resistance to Corrosion Test, Section 54.

10 Enclosures

10.1 General

10.1.1 An enclosure shall be constructed so as to reduce the risk of unintentional contact with uninsulated live parts, see 13.1, and to provide internal parts with protection from specified external conditions.

10.2 Mechanical strength

10.2.1 An enclosure shall have adequate strength and rigidity for its intended use. It shall not permit any increase in shock or fire hazard due to total or partial collapse with resulting reduction in spacings, loosening, or displacement of parts, or other serious defects.

10.3 Nonmetallic enclosures

10.3.1 An enclosure can be made of a polymeric material if the material and design have been investigated and found suitable for the purpose.

10.3.2 A nonmetallic enclosure or a nonmetallic part of an enclosure shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and except as modified by this standard.

10.3.3 Among the factors taken into consideration when an enclosure is being judged are:

a) Mechanical strength,

b) Resistance to impact,

c) Moisture-absorptive properties,

d) Combustibility,

e) Resistance to distortion or physical damage at temperatures to which the material can be subjected under conditions of normal or abnormal usage, and

f) Resistance to atmospheric effects - rain and sunlight in the case of a device intended for outdoor use.

For a nonmetallic enclosure all of these factors are to be considered with respect to thermal aging.

10.3.4 If a nonmetallic enclosure or a nonmetallic part of an enclosure is used on a device intended for use outdoors, the performance of the enclosure material shall not be adversely affected by water, exposure to UV and other atmospheric effects. The enclosure shall comply with the requirements in the Standard for Polymeric Materials –- Use in Electrical Equipment Evaluations, UL 746C.

10.3.5 If a nonmetallic enclosure is identified as being intended to be exposed to specific chemicals, oils, acids, solvents, cleaning agents, and the like, the performance of the enclosure material shall not be adversely affected by such substances as determined by applicable tests as described in the Standard for Polymeric Materials – Short Term Property Evaluation, UL 746A.

10.3.6 Pliable, molded natural or synthetic rubber, or a combination thereof, or a pliable composition of which the basic constituent is vinyl chloride or a copolymer of vinyl chloride and vinyl acetate, in the finished device that complies with the Accelerated Aging Tests, Section 24, can be employed as an insulating material for the body of a plug, or a connector.

10.4 Metallic enclosures

10.4.1 An enclosure can be constructed of iron, steel, copper, brass, bronze, zinc, or aluminum alloys containing not less than 80 percent aluminum. Magnesium, or its alloys shall not be used.

Exception: Zinc or a zinc-based alloy shall not be used for an enclosure or parts of an enclosure which are in the primary grounding path.

10.5 Attachment plugs

10.5.1 An attachment plug shall not be provided with more than one cord-outlet hole, unless the additional holes are capable of being closed or do not expose live parts.

10.6 Specific enclosures

10.6.1 An enclosure marked with one or more enclosure type designations indicating the environmental conditions for which it is intended shall comply with the requirements applicable to the enclosure type number or numbers. See Enclosure Tests for Environmental Protection, Section 58, and 60.13.1 – 60.13.5.

11 Current-Carrying Parts

11.1 A current-carrying part shall be of silver, copper, or a copper alloy, or other material 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.

Exception No. 1: Stainless steel can be employed for a part not subject to arcing.

Exception No. 2: Pressure wire terminal screws can be made of plated iron or steel.

11.2 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.

11.3 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.

11.4 Uninsulated live parts shall be secured in place so that a reduction in the clearances and creepage distances below those required in 12.1 and 12.2 is not likely.

11.5 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.

12 Clearances and Creepage Distances

12.1 The clearances and creepage distances between field wiring terminals of opposite polarity and the clearances and creepage distances between a field wiring terminal and any other uninsulated metal part, dead or live, not of the same polarity shall not be less than 6.4 mm (1/4 inch).

Exception: If the field wiring terminals are intended for solder connections only, using solid or tinned stranded wire, the clearances and creepage distances between the terminals are as specified in Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840. See 60.11.2.

12.2 In all circuits other than at field wiring terminals, the acceptability of the clearances and creepage distances between an uninsulated live part and any other uninsulated metal part, dead or live, not of the same polarity shall be as specified in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

12.3 The dead metal mentioned in 12.2 includes a metal surface (a metal face plate in the case of a flush receptacle) on which the device is mounted in the intended manner. A dead-metal screw head, rivet, or the like is not considered to be exposed to contact by persons after the device is installed in the intended manner, if it is located in a hole so that the dead metal cannot be contacted by the probe illustrated in Figure 13.1.

12.4 Clearances and creepage distances shall be measured in accordance with the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840. In determining the pollution degree and overvoltage category, the end-use application is to be considered and could modify those characteristics given in 12.7 and 12.8.

12.5 Clearances and creepage distances are to be measured in all conditions of use, both with and without mating devices of the intended configuration installed and any movable parts displaced to the position of a minimum spacing.

12.6 The clearances and creepage distances required in 12.1 shall be measured through air and over insulating and conductive surfaces with the device wired as intended with the maximum anticipated conductor size. They shall be measured from any point on the terminal that is able to contact the clamped conductor as in the case of a wire-binding-screw terminal, or from any point on the perimeter of an opening to receive a conductor in the case of an enclosed terminal.

12.7 The level of pollution expected or controlled for indoor use equipment shall be pollution degree 3. For outdoor use equipment, pollution degree 4 is expected, unless protection is afforded by a suitable enclosure appropriate for the installation in which case a lower pollution degree is capable of being achieved. The interior of equipment with enclosure types 3, 3S, 4, 4X, 6 and 6P or Marine type is to be considered pollution degree 3. Hermetically sealed or encapsulated enclosures are considered pollution degree 1.

12.8 Plugs, connectors, inlets and other cord connected devices shall be rated overvoltage Category II and receptacles and other devices connected to fixed wiring will be rated overvoltage Category III as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

13 Accessibility of Live Parts

13.1 To reduce the likelihood of unintentional contact that could involve a risk of electric shock from uninsulated live parts, a live part shall not be contacted by the probe illustrated in Figure 13.1. See 13.6.

13.2 The probe illustrated in Figure 13.1 is to be applied to any depth that the recessing will permit; and is to be rotated, changed in configuration or angled before, during and after application to any position that is necessary to examine the device.

13.3 The probe mentioned in 13.1 is to be used as a measuring instrument to judge the accessibility provided by the recessing and not as an instrument to judge the strength of a material; it is to be applied with a 13.3 N (3 lbf) to determine accessibility.

13.4 During the examination of a product to determine whether it complies with the requirements in 13.1, the device is to be wired and assembled in accordance with the manufacturer's instructions. Any other part that is able to be opened or removed by the user without using a tool is to be opened or removed.

13.5 Plug and receptacle combinations shall be examined to determine that the plug shroud (sleeve) enters the receptacle before the plug contacts become energized.

13.6 Mating devices shall not have exposed live contacts when fully mated or during engagement or withdrawal.

13.7 Compliance with 13.6 is to be determined with the use of the probe shown in Figure 13.1 in every possible position. See 13.2.

14 Grounding and Dead Metal Parts

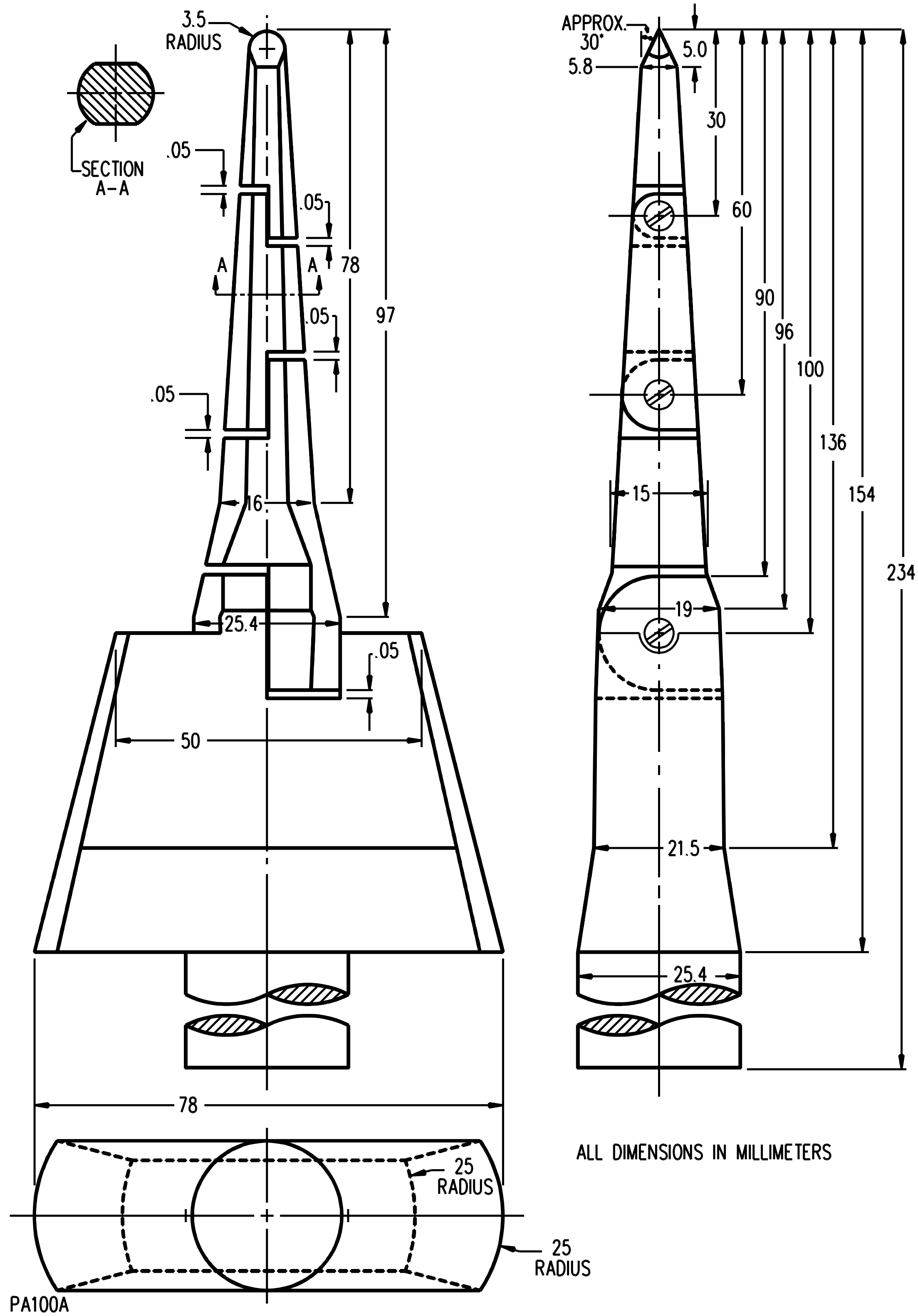
14.1 A receptacle, plug, connector, or vehicle inlet shall be of a grounding type and shall have a separate contact for interconnection of the equipment grounding conductor.

14.2 The equipment grounding terminal or lead and its corresponding pin or contact of a male inlet or equipment outlet intended for permanent installation shall be conductively connected to the mounting means, housing, hood, shell, or other dead metal parts of a device that can come into contact with the equipment or vehicle enclosure.

Exception No. 1: The conductive connection need not be provided if the mounting means, housing, hood, or shell is constructed of an insulating material and the lack of ground continuity to the equipment enclosure is readily apparent.

Exception No. 2: The conductive connection need not be provided if the device is marked in accordance with 60.3.1.

Figure 13.1
Articulate probe with web stop



14.3 A metal shell of a device that is used as the grounding contact member shall be as follows:

a) The surface of the shell that is depended upon for grounding continuity shall not be painted or otherwise subjected to conditions that could result in loss of grounding continuity;

b) One or more separate spring type components are incorporated to provide grounding path continuity;

c) The components are protected against damage; and

d) The shell complies with the requirements of the Grounding Path Current Test, Section 41.

14.4 The grounding contact shall be located and formed so that the path of electrical continuity to the grounding contact of the plug or connector and its mating device, is completed before continuity is established between any other contact and its respective contact on the plug or inlet.

14.5 The grounding contact path, except for the metal housing or mounting, shall be of copper or a copper alloy or equivalent material. If a metal housing is a part of the primary equipment grounding path, it shall not be of zinc or a zinc based alloy.

14.6 A copper-based alloy rivet, which is used to hold parts together in the grounding-contact path or forms a part of the grounding path, shall contain not less than 80 percent copper.

14.7 A connection in the grounding-contact path shall be secured by riveting, bolting, welding or by an equivalent mechanical means of securement, capable of complying with the requirements of the Grounding Path Current Test, Section 41.

14.8 In mating devices provided with an equipment-grounding contact, the grounding contact shall not be capable of touching a line-side phase contact, independent of any polarization feature of the enclosure. Such devices shall comply with the requirements of the Polarization Integrity Test, Section 53.

14.9 All exposed non-current-carrying metal parts of a device that are likely to become energized, shall be conductively connected to the equipment ground.

14.10 Grounding and other dead metal parts shall be secured in place so that a reduction in spacings below those required in 12.1 is not likely.

15 Grounding Connections

15.1 The grounding conductors of a device shall not be smaller in size than indicated in Table 15.1.

Table 15.1
Minimum acceptable sizes of grounding conductors

Device rating, amperes (Not exceeding)	Copper grounding conductors AWG (mm^2)
20	12 (3.3)
30	10 (5.3)
40	10 (5.3)
60	10 (5.3)
100	8 (8.4)
200	6 (13.3)
300	4 (21.2)
400	3 (26.7)
500	2 (33.6)
600	1 (42.4)
800	1/0 (53.5)

15.2 An integral grounding lead shall not be shorter than 152 mm (6 inches).

15.2 revised February 23, 2007

15.3 A terminal provided for the field connection of a grounding conductor shall:

a) Employ a mechanical clamping means that does not depend upon solder for the connection of the wire, and

b) Be capable of securing a conductor of the minimum size indicated in Table 15.1.

16 Terminal Parts

16.1 Devices shall be provided with suitable terminals or leads for the connection of conductors having an ampacity not less than the current rating for which they are intended. See 60.1.2 – 60.1.4, Table 16.1, and Table 16.2.

Table 16.1
Minimum acceptable size of wire leads

Wire size		Ampacity[a,d] of insulated conductors		Ampacity[b,d] of flexible cord	
AWG	mm^2	60°C (140°F)	75°C (167°F)	A	B
18	0.88	–	–	7	10
16	1.3	–	–	10	13
14	2.1	15	15	15	18
12	3.3	20	20	20	25
10	5.3	30	30	25	30
8	8.4	40	50	35	40
6	13.3	55	65	45	55
4	21.2	70	85	60	70
3	36.7	85	100	–	–
2	33.6	95	115	80	95
1	42.4	110	130	–	–
1/0[c,e]	53.5	125	150	–	–
2/0[c,e]	67.4	145	175	–	–
3/0[c,e]	85.0	165	200	–	–
4/0[c,e]	107.2	195	230	–	–
kcmil					
250[c,e]	127	215	255	–	–
300[c,e]	152	240	285	–	–
350[c,e]	177	260	310	–	–
400[c,e]	203	280	335	–	–
500[c,e]	253	320	380	–	–
600[c,e]	304	355	420	–	–
700[c,e]	355	385	460	–	–
750[c,e]	380	400	475	–	–
800[c,e]	405	410	490	–	–
900[c,e]	456	435	520	–	–
1000[c,e]	506	455	545	–	–
1250[c,e]	633	495	590	–	–
1500[c,e]	760	520	625	–	–
1750[c,e]	887	545	650	–	–
2000[c,e]	1013	560	665	–	–

[a] These values of ampacity apply only if not more than three current carrying conductors are employed in a raceway or in a cable. Where the number of current carrying conductors intended to be installed in a raceway or in a cable exceeds three, the ampacities shall be reduced in accordance with Article 310-15 (b)(2)(a) of the National Electrical Code, ANSI/NFPA 70. Where the number of current carrying conductors in a flexible cord exceeds three, the ampacities shall be reduced in accordance with Article 400 of the National Electrical Code, ANSI/NFPA 70.

[b] The ampacities under subheading A apply to 3-conductor cords and other multiconductor cords connected to utilization equipment so that only 3 conductors are current carrying. The ampacities under subheading B apply to 2-conductor cords and other multiconductor cords connected to utilization equipment so that only 2 conductors are current carrying.

[c] For wire sizes 1/0 AWG and larger, it is assumed that wire with at least 75°C (167°F) temperature rating will be used at full 75°C (167°F) ampacity, unless marked with a minimum conductor size. See 60.1.2 and 60.1.4.

[d] The ampacity of 90°C (194°F) wire shall be considered to be the same as:

1) 60°C (140°F) for wire ratings 100 amperes or less, unless the device is identified for use with 75°C (167°F) conductors, and

Table 16.1 Continued on Next Page

Table 16.1 Continued

Wire size		Ampacity[a,d] of insulated conductors		Ampacity[b,d] of flexible cord	
AWG	mm^2	60°C (140°F)	75°C (167°F)	A	B

2) 75°C (167°F) wire for devices rated over 100 amperes.

See 60.1.2 and 60.1.4.

[e] For a multiple conductor (parallel) connector at a terminal, the ampacity value is to be multiplied by the number of conductors that the terminal will accommodate [1/0 AWG (53.5 mm^2) and larger conductors only].

16.2 Pressure wire and set screw terminals used with single or multipole conductors shall comply with the applicable requirements in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

16.3 A terminal plate that has a tapped hole for a soldering lug or pressure-wire connector shall be at least 1.27 mm (0.050 inch) thick and shall not have fewer than two full threads in the metal for a terminal screw.

16.4 Wiring terminals of a receptacle shall be located or protected so they are not likely to be forced against the wiring in the terminal box or compartment during installation.

Table 16.2
Ampacity of cable types W and G[b,c]

AWG	Size mm^2	60°C (140°F) D[a]	60°C (140°F) E	60°C (140°F) F	75°C (167°F) D[a]	75°C (167°F) E	75°C (167°F) F
8	8.4	60	55	48	70	65	57
6	13.3	80	72	63	95	88	77
4	21.2	105	96	84	125	115	101
3	26.7	120	113	99	145	135	118
2	33.6	140	128	112	170	152	133
1	42.4	165	150	131	195	178	156
1/0[d]	53.5	195	173	151	230	207	181
2/0[d]	67.4	225	199	174	265	238	208
3/0[d]	85.0	260	230	201	310	275	241
4/0[d]	107.2	300	265	232	360	317	277
kcmil							
250[d]	127	340	296	259	405	354	310
300[d]	152	375	330	289	445	395	346
350[d]	177	420	363	318	505	435	381
400[d]	203	455	392	343	545	469	410
500[d]	253	515	448	392	620	537	470

[a] The ampacities under subheading D are the allowable ampacity for single-conductor Types W cable only where the individual conductors are not installed in raceways and are not in physical contact with each other except in lengths not to exceed 610 mm (24 inches) where passing through the wall of an enclosure. The ampacities under subheading E apply to 2-conductor cables and other multiconductor cables connected to equipment so that only 2 conductors are current-carrying. The ampacities under subheading F apply to 3-conductor cables and other multiconductor cables connected to equipment so that only 3 conductors are current-carrying.

[b] For wire sizes 1/0 AWG and larger, it is assumed that wire with at least a 75°C (167°F) temperature rating will be used at full 75°C (167°F) ampacity, unless marked with a minimum conductor size. See 60.1.2 – 60.1.4.

[c] The ampacity of 90°C (194°F) wire shall be considered to be the same as:

Table 16.2 Continued on Next Page

Table 16.2 Continued

AWG	Size mm^2	60°C (140°F)			75°C (167°F)		
		D[a]	E	F	D[a]	E	F
1) 60°C (140°F) wire for ratings 100 amperes or less, unless the device is identified for use with 75°C (167°F) conductors, and 2) 75°C (167°F) wire for devices rated over 100 amperes. See 60.1.2 – 60.1.4. [d] For a multiple conductor (parallel) connector at a terminal, the ampacity value is to be multiplied by the number of conductors that the terminal will accommodate [1/0 AWG (53.5 mm^2) and larger conductors only].							

16.5 Crimp type terminals can be provided with an inspection hole at the end of the crimp well to assure the full insertion of the conductor. Devices with crimp terminals shall be installed in accordance with the manufacturer's recommendations and be used with stranded conductors only.

16.6 Wire binding screws used in making electrical connections shall not be smaller than indicated in Table 16.1. Wiring terminal screws shall have no fewer than two threads of engagement into metal.

Table 16.3
Minimum sizes of wire binding screws

Contact rating, amperes	Minimum size of screw	Minimum head diameter[a]	Maximum number of threads per inch (per 25.4 mm)
15 or 20	6	7.0 mm (0.276 inch)	36[b]
up to 35	8	8.3 mm (0.327 inch)	32[b]
[a] A No. 6 (M3) terminal screw, minimum head diameter 6.3 mm (1/4 inch), may be used on devices not intended for permanent installation and rated at 15 A. [b] No. 8 or larger screws having more than the number of threads per inch (per 25.4 mm) indicated may be used for terminals if the assembly is capable of withstanding a tightening torque of 1.8 N·m (16 lbf-in) applied to the wire-binding. screw without stripping either the screw threads or the terminal plate threads, or damaging the slot in the heads of the screw. See 16.7.			

16.7 A binding screw that has 32 or more threads per inch (per 25.4 mm) with a terminal plate formed from stock 0.76 mm (0.030 inch) thick, can have the metal extruded at the tapped hole to provide two full threads for the binding screw.

16.8 The terminals of a device intended to accommodate No. 8 AWG or larger wire shall comply with the applicable requirements in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

16.9 The tightening torque for the field wiring terminals of the devices mentioned in 16.3 and 16.8 shall be specified by the device manufacturer and shall be marked as described in 60.11.1. The specified tightening torque shall not be less than 90 percent of the value employed in the static heating test in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, for the maximum wire size corresponding to the ampere rating of the device.

Exception: A lesser torque value is able to be assigned if the connector is investigated in accordance with the Standard for Wire Connectors and Soldering Lugs for Use with Copper Conductors, UL 486A, or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E using the lesser assigned torque value.

16.10 Terminal parts that are able to carry current and that come into contact with branch circuit conductors other than the grounding conductor, shall not have a coating of zinc or cadmium.

17 Contacts

17.1 Contacts shall be made of gold, silver, copper, or an alloy of these metals, or equivalent material.

17.2 A receptacle or connector shall have protection for exposed live contacts and terminals, when assembled as intended.

18 Assembly

18.1 A device incorporating two or more pieces shall be of such design that any intended grounding contact polarization will not be defeated by improper assembly during installation.

18.2 Screws upon which the permanent assembly of a device depends shall not loosen under normal use.

18.3 A sealing compound, if used, and in contact with live parts, shall be of an insulating, waterproof material that will not melt or flow at a temperature lower than 60°C (140°F) for a device intended to be wired with conductors rated 60°C (140°F), or at a temperature lower than the temperature rating of the conductors for a device intended to be wired with conductors rated higher than 60°C (140°F).

19 Separation of Circuits

19.1 Factory wiring

19.1.1 Insulated conductors of different circuits, see 19.1.2, within a unit, 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, if each conductor is provided with insulation acceptable for the highest of the circuit voltages, no barriers or segregation are necessary.

19.1.2 For the purpose of the requirement in 19.1.1, 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 input power and AC output power circuits,

f) AC input power and DC power circuits, and

g) AC output power and DC power circuits.

Exception: Power circuits specified in (e), (f), and (g) that are derived from the taps of an autotransformer, or the like, that does not provide isolation are not considered to be different circuits.

19.1.3 Segregation of insulated conductors can be accomplished by clamping, routing, or an equivalent means that will maintain permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

19.2 Separation barriers

19.2.1 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 of internal materials specified in Subsection 8.1, and no less than 0.71 mm (0.028 inch) thick, and supported so that it cannot be readily deformed so as to defeat its purpose.

19.2.2 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 1.6 mm (1/16 inch) from the enclosure walls and interior mechanisms, component-mounted panels, and other parts that serve to provide separated compartments.

19.3 Field wiring

19.3.1 The equipment shall be constructed so that a field-installed conductor of a circuit shall be separated as specified in 19.3.2 or separated by barriers as specified in 19.2.1 and 19.2.2 from:

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

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

c) Field-installed conductors connected to any other circuit unless both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3 and both circuits will be insulated for the maximum voltage of either circuit.

Exception: A field-installed conductor need not be separated from a field wiring terminal of a different circuit if the field wiring will be insulated for the maximum voltage of either circuit and both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3.

19.3.2 Separation of a field-installed conductor from another field-installed conductor and from an uninsulated live part connected to another circuit is capable of being 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 6.4 mm (1/4 inch). In determining whether a unit having such openings complies with this requirement, it is to be wired as in service including 152.4 mm (6 inches) 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.

19.3.3 With reference to 19.3.2, if the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the unit, and if each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening will be connected to the terminal opposite that opening. If 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 likelihood of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit, is to be investigated.

20 Devices Intended to Accommodate a Fuse

20.1 Devices shall be constructed so that they will accommodate an enclosed fuse or fuses having a voltage rating not less than the voltage rating of the device.

20.2 The arrangement for holding the fuse shall comply with the requirements in the Standard for Fuseholders, UL 512.

20.3 A device shall include provision for a fuse in each ungrounded conductor, but there shall not be any provision for a fuse in any other conductor.

20.4 The removal or replacement of a fuse shall not expose any live parts in a device to personal contact.

20.5 The construction of a plug shall be such that the fuse(s) will not be removable when the plug is engaged in an outlet.

20.6 An enclosure shall be provided for the fuse or fuses in a device intended to accommodate such components. All of the following are to be complied with. An enclosure:

- a) Shall be of a moisture-resistant material in accordance with the Moisture Absorption Resistance Test, Section 29.
  - 1) Fiber and similar absorptive materials are not be considered as having moisture-absorptive properties acceptable for use as the enclosure of a fuse.
  - 2) Molded phenolic and similar thermosetting polymeric materials are to be considered as having moisture-absorptive properties acceptable for use as the enclosure of a fuse.
- b) Shall reduce the likelihood of persons unintentionally contacting uninsulated live parts of the fuse and fuse holder.
- c) Shall confine the effects of a fuse rupture to the interior of the enclosure.
- d) Shall comply with the requirements for insulating materials in 8.1.3, 8.2.1 and 8.3.1.

21 Cord or Cable Grip

21.1 A cord or cable grip on a plug or cord connector shall be provided that:

a) Permits the flexible supply cord or cable to be readily replaced; and

b) Does not permit a strain to be transmitted to the conductor connections within the terminal enclosure.

Exception No. 1: The cord or cable grip on a molded-on plug or connector need not permit the flexible supply cord or cable to be readily replaced

Exception No. 2: Devices provided with a suitable flexible conduit adapter or threaded inlet need not comply with the requirement.

21.2 If the cord or cable grip is threaded to the enclosure, it shall form a tight engagement. When assembled in the intended manner, the cord or cable entry shall not turn or loosen. The grip and cord or cable entry shall be smooth and free from sharp edges that are able to damage the jacket of the flexible cord or cable.

21.3 The cord or cable grip shall comply with the Cord or Cable Secureness Test in Section 36.

22 Sharp Edges

22.1 An enclosure, a frame, a guard, a handle, or the like shall not be sufficiently sharp to constitute a risk of injury to persons in normal maintenance and use.

Exception: This requirement does not apply to a part or portion of a part that needs to be sharp to perform a working function.

22.2 Whenever referee measurements are necessary to determine that a part as mentioned in 22.1 is not sufficiently sharp to constitute a risk of injury to persons, the method described in the Standard for Tests for Sharpness of Edges on Equipment, UL 1439, is to be employed.

PERFORMANCE

23 Representative Devices

23.1 Prior to initial electrical testing, all devices shall be tightened in accordance with the manufacturer’s instructions. Testing with the use of a 60 Hz supply voltage is considered to represent testing with the use of a higher frequency supply voltage not exceeding 400 Hz. A 60 Hz test current shall be considered to represent a 50 Hz rating.

23.2 Unless stated otherwise, the test potential of a test circuit is not to be less than the test potential in volts corresponding to the voltage rating of devices as indicated in Table 23.1.

23.3 The total number of representative devices for testing to determine compliance may be reduced if certain tests are repeated on previously tested representative devices when:

a) The test is capable of being repeated using different portions of a previously tested device, and

b) Agreeable to all parties concerned.

23.4 Devices are to be subjected to the appropriate tests outlined in Tables 23.2.

Table 23.1
Voltage for tests

Voltage rating of device[a]	Test potential in volts
110 – 120, ac	120, ac
110 – 125, dc	125, dc
208, ac	208, ac
220 – 240, ac	240, ac
220 – 250, dc	250, dc
265 – 277, ac	277, ac
440 – 480, ac	480, ac
550 – 600, ac	600, ac
550 – 600, dc	600, dc

[a] If the rating of the device does not fall within any of the indicated voltage ranges, it is to be tested at its rated voltage.

Table 23.2
Electric Vehicle coupler test sequence

Test		Product (applicable tests)			
		Plugs	Connectors	Receptacles	Inlets
Accelerated Aging Test (Section 24)	a, j	X	X	X	X
Ultraviolet Light Exposure (UL 746C, Section 28)	a, b	X	X	X	X
Comparative Tracking Index Test (Section 25)	b	X	X	X	X
Glow Wire Test (Section 26)	b	X	X	X	X
High-Current Art Resistance to Ignition Test (Section 27)	b	X	X	X	X
Mold Stress Relief Test (Section 28)	a	X	X	X	X

Table 23.2 Continued on Next Page

Table 23.2 Continued

Test		Product (applicable tests)			
		Plugs	Connectors	Receptacles	Inlets
Water Exposure and Immersion (UL 746C, Section 29)	b	X	X	X	X
Moisture Absorption Resistance (Section 29)	a, b	X	X	X	X
Leakage Current Test (Section 30)	a	X	X	X	X
Leakage Current Test Follwoing Humidity Conditioning (Section 31)	c	X	X	X	X
Insulation Resistance Test (Section 32)	c	X	X	X	X
Dielectric Withstand Test (Section 33)	c	X	X	X	X
Dew Point Test (Section 34)	a	X	X	X	X
Conductor Secureness Test (Section 35)	a	X	X		
Cord or Cable Secureness Test (Section 36)	a	X	X		
Impact Test – Plugs and Connectors (Section 37)	a	X	X		
Crushing Test (Section 38)	a	X	X		
Vehicle Driveover Test (Section 39)	a	X	X		
Withdrawal Force Test (Section 40)	a		X	X	
Ground Path Current Test (Section 41)	a, e	X	X	X	X
Short Circuit Test (Section 42)	a, h	X	X	X	X
Strength of Insulating Base and Support Test (Section 43)	a			X	X
No-Load Endurance Test (modified, 10K cycles total) (Section 44)	a, h		X	X	
– Conditioning 55 percent Salt-Sand Solution	h		X	X	
– Repeated No-Load Endurance Test (modified)	h		X	X	
Endurance with Load Test (Section 45)	a, g		X	X	
Overload Test (Section 46)	a, g		X	X	
– Power Contacts (46.3 excluded)	a				
– Electromagnetic Test (Section 48)	a				

Table 23.2 Continued on Next Page

Table 23.2 Continued

Test		Product (applicable tests)			
		Plugs	Connectors	Receptacles	Inlets
Control-Pilot Contact Resistance Test (Section 47)	a, h		X	X	
– Contact Resistance (ASTM B539–96 Method C)			X	X	
– NO_2–Cl_2–H_2S Conditioning			X	X	
– Repeated Contact Resistance (ASTM B539–96 Method C)			X	X	
Temperature Rise Text (Section 49)	a, g	X	X	X	X
Fuseholder Temperature Test (Section 50)	a	X	X	X	X
Surface Temperature (Section 51)	a	X	X	X	X
Resistance to Arcing Test (Section 52)	g		X	X	
Polarization Integrity Test (Section 53)	h	X	X	X	X
Resistance to Corrosion Test (Section 54)	a	X	X	X	X
Vibration Test (Section 55)	a				X
Accelerated Aging Gasket Test (Section 56)	a	X	X	X	X
Moisture Resistance Test (Section 57)	a	X	X	X	X
Enclosure Tests for Environmental Protection (Section 58)	i	X	X	X	X

[a] Each of these tests shall be performed on a separate device.

[b] Based on properties of insulating materials. See construction requirements.

[c] The leakage current after humidity, insulation resistance and dielectric strength tests shall be performed on the same device.

[d] Factory-wired devices only.

[e] Required for specific grounding constructions only. Refer to test description.

[f] These tests are performed alternately on the same device.

[g] For devices intended for current interruption only, the overload, temperature rise and resistance to arcing tests shall be performed on the same device.

[h] Mated pairs shall be provided.

[i] For device enclosures identified by a Type no. or nos. for environmental protection.

[j] Pliable rubber or pliable vinyl chloride elastomeric devices only.

24 Accelerated Aging Tests

24.1 Rubber compounds

24.1.1 Each of three molded-rubber attachment plugs, or cord connectors shall not show any apparent deterioration and no greater change in hardness than ten numbers as the result of exposure for 70 hours in a full-draft circulating-air oven at a temperature of 100 ±1.0°C (212.0 ±1.8°F).

24.1.2 If possible, the molded rubber device is to be used complete. The hardness of the rubber is to be determined as the average of five readings with an appropriate gauge, such as the Rex hardness gauge or the Shore durometer. The device is to be allowed to rest at room temperature for four or more hours after removal from the oven. The hardness is to be determined again as the average of five readings. The difference between the average original hardness reading and the average reading taken after exposure to the heat conditioning is the change in hardness.

24.1.3 The accelerated-aging tests mentioned in 24.1.1 and 24.1.2 are to be made on each color of rubber and on each basic rubber compound employed for the device.

24.2 PVC compounds

24.2.1 Each of three devices having a body of molded plasticized polyvinyl chloride or a copolymer thereof shall not show any cracks, discoloration, or other visible signs of deterioration as the result of exposure for 96 hours in a full-draft circulating-air oven at a temperature of 100.0 ±1.0°C (212.0 ±1.8°F).

25 Comparative Tracing Index Test

25.1 A polymeric material used for electrical insulation, an internal barrier necessary to maintain electrical spacings or enclosure of live parts 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, shall not have a performance level class value greater than 3.

26 Glow Wire Test

26.1 After being tested in accordance with this section, a polymeric material used for electrical insulation, an internal barrier necessary to maintain electrical spacings, or enclosure of live parts shall demonstrate its resistance to ignition from overheated conductors caused by circuit overloads.

26.2 Each of three finished devices 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 insulating material during 30 seconds of application of the probe.

27 High-Current Arc Resistance to Ignition Test

27.1 A polymeric material used for electrical insulation, an internal barrier necessary to maintain electrical spacings, or enclosure of live parts when tested as described in 27.2 – 27.5 shall not ignite within the number of arcs specified in Table 27.1 for the flame class of the insulating material. In addition, there shall be no dielectric breakdown caused by formation of a permanent carbon conductor path.

Exception No. 1: An insulating material used in the face of a female outlet device that has been subjected to the Resistance to Arcing Test described in 52.1 and 52.2 need not be subjected to this test.

Exception No. 2: An insulating material that has previously been accepted for use in the face of a female outlet device in accordance with Exception No. 1 can be judged acceptable for use in other applications without being subjected to this test.

Arcing criteria	
Flame class	**No. of arcs**
V-0, VTM-0, V-1, VTM-1	15

27.2 Three fully assembled devices are to be tested. When preparing devices for test, the condition that will cause the greatest arcing near the material being tested in the device is to be simulated. For example, if the material being tested is used in the face of an inlet, one line blade is to be connected to the test circuit described in 27.3.

27.3 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-up across 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.

27.4 Immediately following the completion of the arcing portion of the test, the device is to be subjected to a 50 to 60 Hz essentially sinusoidal potential applied as described in 27.5 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.

27.5 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.

27.6 If the output of the test-equipment transformer is less than 500 volt-amperes, the equipment is to include a voltmeter in the output circuit to indicate the test potential directly.

28 Mold Stress Relief Test

28.1 As a result of temperature conditioning specified in 28.2, there shall not be any warpage, shrinkage or other distortion that results in any of the following:

a) Making uninsulated live parts, other than exposed wiring terminals, or internal wiring accessible to contact, by the probe illustrated in Figure 13.1. See 13.2.

b) Defeating the integrity of the enclosure so that acceptable mechanical protection is not afforded to the internal parts of the device.

c) Interference with the operation, function or installation of the device.

d) A condition that results in the device not complying with the strain relief requirements, if applicable.

e) A reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal below the minimum acceptable values.

f) Any other evidence of damage that could increase the risk of fire or electric shock.

Exception: Devices employing only thermosetting materials need not be subjected to this test.

28.2 Three devices are to be placed in a circulating air oven maintained at a temperature of at least 10°C (18°F) higher than the maximum temperature of the device measured during the temperature test described in the Temperature Rise Test, Section 49, but not less than 80°C (176°F). The devices are to remain in the oven for 7 hours. The devices are to be removed from the oven and allowed to cool to room temperature before determining compliance.

28.3 Immediately following the completion of this test, the devices are to be subjected to a repeated dielectric voltage withstand test as described in the Dielectric Withstand Test, Section 33.

29 Moisture Absorption Resistance

29.1 Moisture-resistant insulating materials shall not absorb more than 6 percent of water by mass.

29.2 The material is to be:

a) Dried at 105 ±5°C (221 ±9°F) for 1 hour,

b) Weighed (W_1),

c) Immersed in distilled water at 23 ±1°C (73 ±1.8°F) for 24 hours,

d) Removed from the distilled water and the excess surface moisture wiped off, and

e) Reweighed (W_2).

29.3 The moisture absorbed by the material is to be calculated as:

$$\frac{W_2 - W_1}{W_1} \times 100\%$$

Exception: A material tested in accordance with the Method for Measuring Water Absorption of Polymeric Materials (ASTM D 570) described in the Standard for Polymeric Materials - Short Term Property Evaluations, UL 746A, need not be subject to this requirement.

30 Leakage Current

30.1 A device rated for a nominal 250-volt or less supply shall be tested in accordance with 30.2 – 30.7. Leakage current shall not be more than:

a) 0.5 MIU for a two-wire cord- and plug-connected device;

b) 0.5 MIU for a three-wire (including grounding conductor) cord-and plug-connected device.

30.2 All accessible conductive parts are to be tested for leakage currents. Leakage currents from these parts are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one part to another if simultaneously accessible. A part is considered to be accessible unless it is guarded by an enclosure that is acceptable for protection against the risk of electric shock as defined in 30.5. Conductive parts are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible conductive parts are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current can be measured between the grounding conductor of the product and the grounded supply conductor.

30.3 If 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 10 by 20 centimeters in contact with the surface. If the conductive surface has an area less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is to conform to the shape of the surface but is not to remain in place long enough to affect the temperature of the product.

30.4 Typical measurement circuits for leakage current with the ground connection open are illustrated in 30.1. The measurement instrument is defined in Figure 30.2, The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument; 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 measure 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 30.2.

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 30.2. V_3 is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts can be converted to MIU by dividing the reading by 500 Ω and then multiplying the quotient by 1,000. The mathematic equivalent is to simply multiply the RMS voltage reading by 2.

30.5 Unless the measurement instrument is being used to measure leakage current from one part of a product 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.

30.6 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 considerable extraneous voltage introduced, an isolating transformer can reduce the effects of extraneous voltages.

30.7 A sample of the device is to be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except as may 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 the Figure 30.1 measurement circuit:

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 product switching devices in all their normal operating positions.

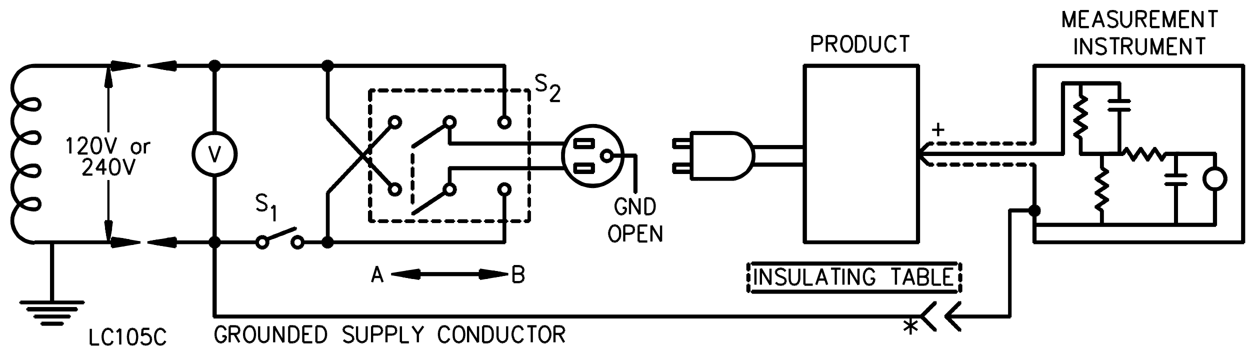
b) Switch S1 is then to be closed, energizing the device. Within 5 seconds, the leakage current is to be measured using both positions of switch S2 and with the device switching devices in all their normal operating positions.

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.

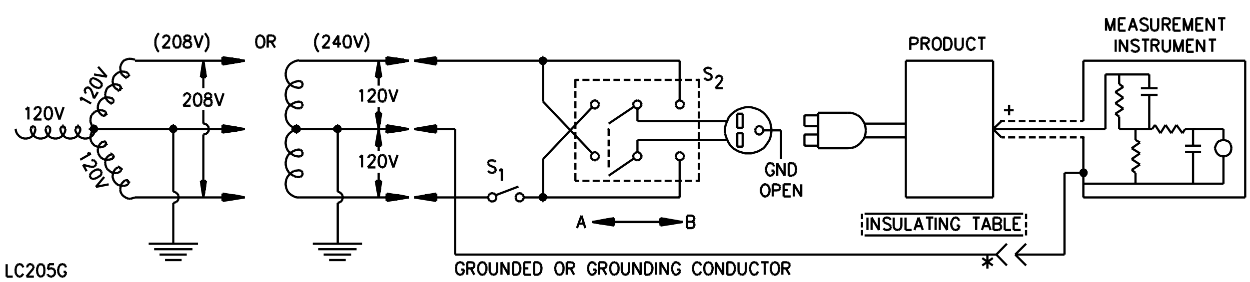
d) The leakage current is also to be monitored with switch S1 open while the device is at operating temperature and while cooling.

30.8 Normally a sample will be subjected to the entire leakage current test, as specified in 30.7, without interruption for other tests. With the concurrence of those concerned, the leakage current test may be interrupted to conduct other nondestructive tests.

Figure 30.1
Typical leakage current measurement circuits



Device intended for connection to a 120-volt or an end-grounded 2-wire, 240-volt power supply



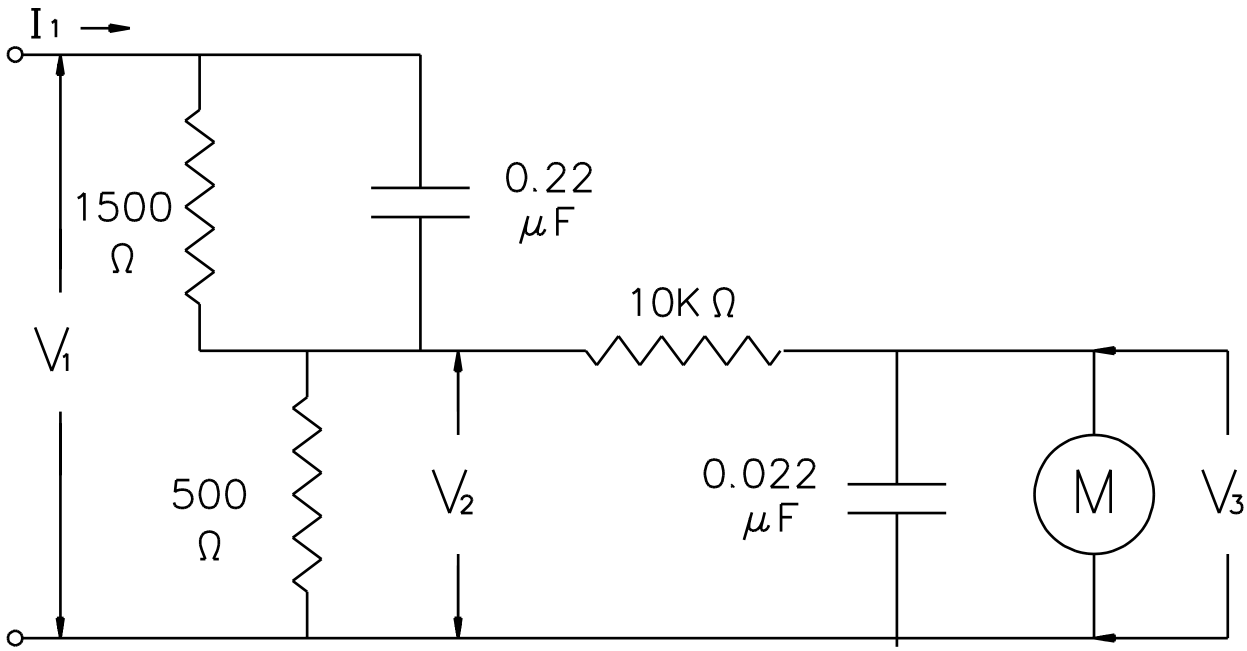
Device intended for connection to a 3-wire, 208-volt or a 3-wire 240-volt grounded neutral power supply. See 30.6 and 30.7.

\+ – Probe with shielded lead.

* – Separated and used as a clip when measuring currents from one part of an appliance to another.

NOTE: The configurations above are examples. Actual configurations may vary.

Figure 30.2
Measurement instrument for reaction (leakage) current



S3263B

31 Leakage Current Test Following Humidity Conditioning

31.1 Equipment shall not be adversely affected by humid conditions which can occur in anticipated use.

31.2 Compliance is checked by repeated leakage current measurements and humidity conditioning described herein, followed immediately by the measurement of the insulation resistance and by the dielectric withstand test, specified in Sections 32 and 33. Cable entries, if any, are left open. If knock-outs are provided, one of them is to be opened.

31.3 Each of three previously untested devices is to be used for this test. Two of the three devices are to be mated. For the remaining device, covers which are capable of being removed without the aid of a tool, are to be removed and subjected to the humidity conditioning with the main part; spring lids are to be open during this conditioning.

31.4 The devices are to be placed into an environmental chamber maintained at a relative humidity of 93 ±2 percent, and at a temperature (t) of 32 ±2.0°C (89.6 ±3.6°F).

31.5 Before being placed in the humidity cabinet, the devices are brought to a temperature between t and t + 4°C.

31.6 The devices are kept in the cabinet for:

a) 2 days (48 hours) for equipment intended for use indoors only, and

b) 7 days (168 hours) for equipment intended for outdoor use.

31.7 In most cases, the devices can be brought to the temperature specified, by keeping them at this temperature for at least 4 hours before the humidity treatment.

31.8 A relative humidity between 91 and 95 percent is capable of being obtained by placing in the humidity cabinet a saturated solution of sodium sulphate (Na_2SO_4) or potassium nitrate (KNO_3) in water, having a sufficiently large contact surface with the air.

31.9 In order to achieve the specified conditions within the cabinet, it is necessary to ensure constant circulation of the air within and, in general, to use a cabinet which is thermally insulated.

31.10 Immediately following the conditioning, the specimens are to be removed from the humidity chamber and tested unenergized as described in 30.7. One mated specimen is then to be energized and tested as described in 30.7 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

31.11 After this conditioning, the remaining two devices are to be subjected to the Insulation Resistance Test, Section 32, and the Dielectric Withstand Test, Section 33.

32 Insulation Resistance Test

32.1 The insulation resistance of the two devices remaining after conditioning as indicated in the Leakage Current Test Following Humidity Conditioning, Section 31, shall not be less than 5 megohms.

32.2 Compliance is to be checked by the tests made immediately after the humidity test in the humidity cabinet or in the room in which the devices were brought to the prescribed temperature, after reassembly of covers which were removed.

32.3 Devices employing thermoplastic material are to be subjected to the plug and receptacle mating test. See 33.5.

32.4 For the purpose of these tests, the neutral contact and pilot contacts are each considered as a pole.

32.5 The insulation resistance is to be measured with a dc voltage of approximately 500 V applied, the measurement being made 1 minute after application of the voltage.

32.6 For receptacles, the measurement shall be made with and without a plug in engagement. For connectors, the measurement shall be made with and without an inlet in engagement. In each case, the insulation resistance is to be measured consecutively:

a) Between all poles connected together and the body;

b) Between each pole in turn and all others, these being connected to the body, with a plug or inlet in engagement; and

c) Between any metal enclosure and metal foil in contact with the inner surface of its insulating lining, if any, a gap of approximately 3.8 mm (0.15 inch) being left between the metal foil and the edge of the lining.

32.7 For plugs and inlets, the insulation resistance is to be measured consecutively:

a) Between all poles connected together and the body;

b) Between each pole in turn and all others, these being connected to the body; and

c) Between any metal enclosure and metal foil in contact with the inner surface of its insulating lining, if any, a gap of approximately 3.8 mm (0.15 inch) being left between the metal foil and the edge of the lining.

32.8 The term ″body″ includes all accessible metal parts, metal foil in contact with the outer surface of external parts of insulating material, other than the engagement face of connectors and plugs, fixing screws of bases, enclosures and covers, external assembly screws and grounding terminals, if any.

32.8 revised December 22, 2009

33 Dielectric Withstand Test

33.1 Devices intended for permanent or fixed installation shall withstand without breakdown a 50 – 60 Hz essentially sinusoidal potential applied in accordance with Table 33.1 for one minute between:

a) Live parts of opposite polarity with a test voltage of 2000 or 3000 V;

b) Live parts, including secondary circuits, and ground with a test voltage of 2000 or 3000 V for live parts and 500 V for secondary circuits; and

c) Secondary circuits and live parts with a test voltage of 2000 or 3000 V;

immediately following the Leakage Current Test Following Humidity Conditioning, Section 31, and the Insulation Resistance Test, Section 32.

Table 33.1
Dielectric withstand test voltage

Device rating, volts	Test voltage, volts
Up to and including 50	500
Over 50 up to and including 300	2000
Over 300 up to and including 600	3000

33.2 Each of the two devices utilized in the Insulation Resistance Test, Section 32, 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.

33.3 If the output of the test-equipment transformer is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to indicate the test potential directly.

33.4 Devices intended for other than fixed or permanent installation and devices intended for installation on flexible cords, shall be capable of withstanding the application of an ac potential of 1000 V plus 2 times the rated voltage applied for a period of one minute between live parts of opposite polarity and between live parts and grounding or dead metal parts.

33.5 Immediately after the test, it shall be possible to engage mating plugs and receptacles, and connectors and inlets, any of which are made of thermoplastic materials. It shall be impossible to mate the plug with its intended receptacle or connector with its intended inlet in any but the correct polarization. There shall not be any deformation that results in the exposure of live parts, or to the extent affecting the intended and proper functioning of the device.

34 Dew Point Test

34.1 Each of three devices shall not have a leakage current greater than 2.0 mA after being conditioned as described in 34.2 and 34.3. Following conditioning, a device that exceeds 0.5 mA shall be retested after a minimum of 10 hours storage at room temperature and normal humidity, or after being operated at rated load for 1 hour, after which the leakage current shall not exceed 0.5 mA.

34.2 The device is to be conditioned in a cold chamber at 5.0 ±2.0°C (41.0 ±3.6°F) for at least 4 hours, then transferred from the cold chamber to a humidity chamber at a relative humidity of 93 ±2 percent and 32.0 ±2.0°C (89.6 ±3.6°F). The transfer time shall not exceed 1 minute.

34.3 The leakage current is to be measured collectively (connected together) from line to all exposed conductive surfaces and all grounding or dead metal parts, including live parts of different circuits (communications, control pilot circuits, and the like), at 120 V or 240 V depending on the rating of the device. The leakage current shall be monitored closely beginning from the time of transfer from the cold chamber to the humidity chamber until the leakage current stabilizes or drops. See 30.2 and 30.6.

34.4 If part or all of the exposed surfaces of a device is of material other than metal, then a rectangular piece of metal foil measuring 100 by 200 mm (4 by 8 inches) is to be placed on the surface of the product so that all of the foil is in contact with the surface of the device. In each case, the foil is to be placed anywhere on the product that is accessible and moved to the location which produces the maximum indication of leakage current. The foil is not to remain in place long enough to affect the temperature of the product during the leakage current measurement.

35 Conductor Secureness and Pullout Test

35.1 A conductor of a flexible cord, cable or wiring assembly is to be connected to each of four elements (male or female contact) of a device before the element has been assembled into the device, the connection shall not break or loosen under a stress applied between the element and the conductor before the element has been assembled into the device.

35.2 While the test mentioned in 35.1 is being performed, the angle between the element and the conductor is to be that used in the completely assembled device. Conductors shall comply with the requirements for Secureness and Pullout in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

Exception: Conductor sizes Nos. 20 AWG (0.52 mm^2) or smaller need not be subjected to a Secureness test.

36 Cord or Cable Secureness Test

36.1 Each of three cord or cable connected devices shall not show any evidence of damage to the flexible cord or cable, the enclosure of live parts, the strain relief means, or grounding path integrity after a force of 150 lb/in^2 times the cross-sectional area of the cord (rounded up to the nearest five lb increment), but not less than 35 lbs is applied and removed. It is to be tested using both the maximum and minimum diameter flexible cord or cable that the cable grip is designed to accommodate. After being subjected to each test described and with the force removed, there shall be no axial displacement of the supply conductors, conductor insulation, or outer jacket of the flexible cord or cable from the assembled condition exceeding the maximum allowed displacement as specified in Table 36.1.

36.2 The device is to be assembled as intended onto a 305-mm (12-inch), or longer, length of flexible cord or cable placed in the device 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 flexible cord or cable is to be cut at a right angle to its major axis but not stripped.

36.3 The cord or cable clamp is to be held firmly in place. The force is to be applied gradually and sustained for a period of one minute to the flexible cord or cable, at a point not less than 150 mm (6 inches) from the cord or cable grip, in a direction perpendicular to the plane of the opening and in line with the flexible cord or cable.

36.4 A torque is also to be applied to the flexible cord or cable at a point 150 mm (6 inches) from the cord or cable grip as specified in Table 36.1 for 1 minute in the direction least favorable to the clamp construction.

Table 36.1
Cord or cable secureness test values

Device rating amperes	Torque N·m (ft-lb)	Maximum displacement mm (inches)
15	0.41 (0.3)	2.38 (3/32)
16 – 20	0.54 (0.4)	2.38 (3/32)
21 – 35	0.68 (0.5)	2.38 (3/32)
36 – 70	1.4 (1.0)	2.38 (3/32)
71 – 125	2.7 (2.0)	2.38 (3/32)
126 – 200	5.4 (4.0)	2.38 (3/32)
201 – 400	10.8 (8.0)	4.76 (3/16)
401 – 800	16.3 (12.0)	4.76 (3/16)

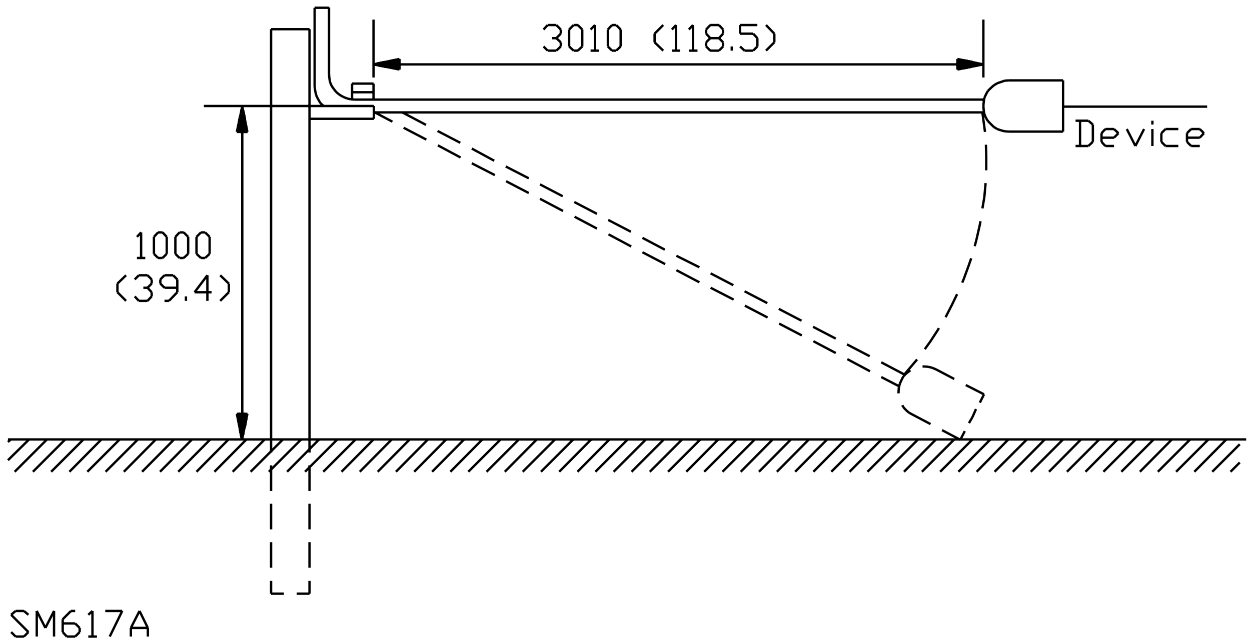
37 Impact Test (Plugs and Connectors)

37.1 Each of three plugs or connectors wired with a length of the maximum size extra-hard usage flexible cord or cable that corresponds to the rating of the device is to be tested.

37.2 The free end of the cord or cable, which is to be approximately 3010 mm (118.5 inches) long, is to be fixed to a wall at a height of 1000 mm (39.4 inches) above the floor, as shown in Figure 37.1.

Figure 37.1
Impact test equipment

Note: All dimensions given are in mm (inches)



37.3 The device is to be held so that the cord or cable is horizontal and then allowed to fall to a concrete floor eight times. The cord or cable is to be rotated about its axis approximately 45° from its previous orientation each time.

37.4 As a result of the applied impacts specified in 37.3, there shall be no cracking or breakage, deformation, loosening or detachment of parts, or other adverse effects that results in any of the following:

a) Making uninsulated live parts or internal wiring accessible to contact, by the probe illustrated in Figure 13.1. See 13.2.

b) Defeating the integrity of the enclosure so that acceptable mechanical protection is not afforded to the internal parts of the device or polarization of the device is defeated. Cracks, chips and dents that do not adversely affect the protection against electric shock or moisture shall be disregarded.

c) Interference with the operation, function or installation of the device. The locking retaining means used to hold mating devices together are permitted to sustain damage if it does not interfere with the operation or function of the devices, or it is obvious that they are damaged and must be replaced.

d) A condition that results in the device not complying with the strain relief requirements, if applicable.

e) A reduction of clearances and creepage distances between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal below the minimum acceptable values.

f) Any other evidence of damage that could increase the risk of fire or electric shock.

37.5 Immediately following the completion of this test, the devices are to be subjected to a repeated dielectric voltage-withstand test as described in the Dielectric Withstand Test, Section 33.

37.6 A device employing a nonmetallic enclosure or an enclosure of a zinc-based alloy is to be conditioned for 6 hours in air maintained at −30 ±1°C (−22 ±1.8°F). Immediately following removal from the conditioning chamber the devices are to be subjected to a repeated Impact Test as described in 37.1 – 37.5.

38 Crush Test

38.1 Each of three devices wired onto flexible cord is to be placed between a pair of rigid, flat, steel plates that are at least 457 mm (18 inches) long and are horizontal and parallel to one another. One plate is to be moved gradually toward the other at a rate of 10.0 ±2.5 mm (1/2 ±1/8 inch) per minute, until a crushing force of 890 N (200 lbf) is applied and held for one minute and then removed. Each device is to be oriented in a natural resting position before applying the force. The force is not to be applied to the projecting pins.

38.2 The flexible cord used to wire the device is to be the minimum size and type of flexible cord specified for use by the manufacturer in accordance with 60.1.2.

38.3 As a result of the applied force specified in 38.1, there shall not be any cracking or breakage, deformation, or other adverse effect that results in any of the following:

a) Making uninsulated live parts, other than exposed wiring terminals, or internal wiring accessible to contact, by the probe illustrated in Figure 13.1. See 13.2.

b) Defeating the integrity of the enclosure so that acceptable mechanical protection is not afforded to the internal parts of the device or polarization of the device is defeated.

c) Interference with the operation, function or installation of the device.

d) A condition that results in the device not complying with the strain relief requirements, if applicable.

e) A reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal below the minimum acceptable values.

f) Any other evidence of damage that could increase the risk of fire or electric shock.

38.4 Immediately following the completion of this test, the devices are to be subjected to a repeated dielectric voltage withstand test as described in the Dielectric Withstand Test, Section 33.

38.5 A device employing a nonmetallic enclosure or an enclosure of a zinc-based alloy is to be conditioned for 6 hours in air maintained at −30 ±1°C (−22 ±1.8°F). Immediately following removal from the conditioning chamber the devices are to be subjected to a repeated Crush Test as described in 38.1 – 38.4.

39 Vehicle Driveover Test

39.1 Each of three devices wired onto flexible cord is to be placed on a concrete floor in any normal position of rest. A crushing force of 4893 N (1100 lbf) 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 218 ±13 kPa (32 ±2 psi). The wheel is to be rolled over the connector or plug at a speed of 8 ±2 kmph (5 ±1.25 mph). Each device is to be oriented in a natural resting position before applying the force. The device under test shall be held or blocked in a fixed position so that it does not move substantially during the application of the applied force. In no case is the force to be applied to the projecting pins.

39.2 The flexible cord used to wire the device is to be the minimum size and type of flexible cord specified for use by the manufacturer in accordance with 60.1.2.

39.3 As a result of the applied force specified in 39.1, there shall not be any severe cracking, breakage, or deformation to the extent that results in any of the following:

a) Making uninsulated live parts, other than exposed wiring terminals, or internal wiring accessible to contact, by the probe illustrated in Figure 13.1. See 13.2.

b) Defeating the integrity of the enclosure so that acceptable mechanical protection is not afforded to the internal parts of the device or polarization of the device is defeated.

c) Interference with the operation, function or installation of the device.

d) A condition that results in the device not complying with the strain relief requirements, if applicable.

e)) A reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal below the minimum acceptable values.

f) Any other evidence of damage that could increase the risk of fire or electric shock.

39.4 Immediately following the completion of this test, the devices are to be subjected to a repeated dielectric voltage withstand test as described in the Dielectric Withstand Test, Section 33.

40 Withdrawal Force Test

40.1 The pressure exerted by mating contacts of a plug with a receptacle or connector, or an inlet with a connector, is not to be so great as to prevent easy insertion and withdrawal of the plug or connector, but sufficient to keep it from working out of the mating device in normal use. The force required to insert and withdraw the plug or connector into or from its mating part shall be measured. The force required to withdraw the plug or connector from its mating device shall be less than the force required to insert it and greater than the minimum withdrawal forces shown in Table 40.1.

Exception No. 1: If the plug, receptacle, and connector are of the delayed-action or interlocked type, the requirements in Table 40.1 do not apply.

Exception No. 2: If the plug, receptacle or connector is provided with a latch, the requirements in Table 40.1 do not apply.

40.2 Compliance is to be checked by determining the force necessary to withdraw the test plugs or test connectors from each of three mating devices, mounted so that the longitudinal axes of the contacts are vertical with the contact openings facing downward.

Table 40.1
Withdrawal force

	Minimum force[a]
Device rating, amperes	**Withdrawal N (lbf)**
15	18 (4)
16 – 20	22 (5)
21 – 32	27 (6)
33 – 63	27 (6)
64 – 125	27 (6)
126 – 800	27 (6)

[a] The withdrawal force includes the weight of the test plug or connector. If the weight of the mating device exceeds the specified withdrawal force, the mating device shall retain the test plug or connector.

41 Grounding Path Current Test

41.1 The assembly of mating grounding devices shall carry the current specified in Table 41.1 for the time specified in that table. The current is to be based on the minimum size equipment grounding conductor for the ampere rating of the device. The components in the grounding path shall not crack, break, or melt.

41.2 Each of three mating devices is to be mounted and assembled as intended. A grounding conductor of the maximum intended size, not less than 0.609 m (2 ft) long, is to be connected to the grounding terminal of each device, with the terminals employed to hold the conductor tightened using a torque specified in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, or as specified by the manufacturer, whichever is less. Receptacles and vehicle inlets are to be wired with the minimum allowable size copper conductor. Plugs and connectors are to be wired with flexible, stranded conductor from flexible cord or cable sized on the basis of the ampere rating of the device. The test current is to be passed through the mating devices and grounding wires in series. Two mating sets of devices are to be tested.

41.3 After having carried the current specified in 41.1, continuity shall exist on the test assembly when measured between the grounding conductors.

41.4 Any indicating device such as an ohmmeter, battery-and-buzzer combination, or the like, is able to be used to determine whether continuity exists.

Table 41.1
Short-time test currents

Device rating, amperes	Minimum size equipment grounding conductor (copper) AWG (mm^2)	Time, seconds	Test current, amperes
0 – 15	14 (2.1)	4	300
16 – 20	12 (3.3)	4	470
21 – 60	10 (5.3)	4	750
61 – 100	8 (8.4)	4	1180
101 – 200	6 (13.3)	6	1530
201 – 300	4 (21.2)	6	2450
301 – 400	3 (26.7)	6	3100
401 – 500	2 (33.6)	6	3900
501 – 600	1 (42.4)	6	4900
601 – 800	1/0 (53.5)	9	5050

42 Short Circuit Test

42.1 General

42.1.1 Each of three wiring devices rated more than 1.12 kW is to be subjected to short circuit tests in accordance with 42.2.1 – 42.3.4.11 when protected by a fuse or circuit breaker as specified in 42.2.1 and 42.2.2.

42.2 Protective devices

42.2.1 The fuses used for the tests are to be specified by the manufacturer in accordance with Table 42.1.

Table 42.1
Ratings of fuses used for test

Type of fuse[a]	Current, amperes	Maximum percent of rated motor full-load current[b]	Fuse size marking required
Non time-delay	0 – 600	400[c, d]	No
Non time-delay	0 – 600	< 400 but ≥ 300[e]	Yes
Non time-delay	0 – 600	< 300 but > 225[f]	Yes
Time-delay	0 – 600	≤ 225[g]	Yes

[a] Tests with 225 percent full load ampere time delay fuses are not considered representatives of tests with 400 percent full load ampere non time-delay fuses.

[b] These values are approximate and are to be used when the manufacturer does not specify fuse sizes but refers to a maximum percent level, such as ″Fuse not to exceed 300 percent of motor full load amps.″

[c] If the calculated value of the fuse is between two standard ratings as specified in 42.2.3, a fuse of the nearest standard rating but not more than four times the full-load motor-current rating is to be used. If the calculated value of the fuse is less than 1 ampere, a fuse rated 1 ampere is to be used, and no marking of fuse size is required on the product.

[d] Tests with 400 percent non time-delay fuses cover use with 225 percent time delay fuses.

[e] Tests with non time-delay fuses rated less than 400 percent, but equal to or greater than 300 percent cover use with 175 percent time delay fuses.

[f] Tests with less than 300 percent non time-delay fuses requires additional testing with 225 percent (or as marked) time-delay fuses.

[g] The product is marked to indicate the level of protection and that the branch-circuit protective device may need to be of the time-delay type.

42.2.2 An inverse-time circuit breaker used for the test described in 42.2.7 – 42.2.13 is to be specified by the manufacturer in accordance with the following:

a) The inverse-time circuit breaker can be rated four times the maximum full-load motor-current rating for full-load currents of 100 amperes or less or three times the maximum full-load motor-current rating for full-load currents greater than 100 amperes. If the calculated value of the circuit breaker is between two standard ratings as specified in 42.2.4, a circuit breaker of the nearest standard rating less than the calculated value is to be used. If the calculated value of the circuit breaker is less than 15 amperes, a circuit breaker rated 15 amperes is to be used. No marking of the circuit breaker rating is required on the product.

b) The inverse-time circuit breaker can have a rating less than that specified in (a) if the product is marked to indicate the limit of protection.

42.2.3 Standard ampere ratings for fuses are 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000.

42.2.4 Standard ampere ratings for inverse-time circuit breakers are 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000.

42.2.5 The marking referred to in 42.2.1, 42.2.2 and Table 42.1 can also be located in the installation instructions.

42.2.6 Each of three devices is to be tested in an enclosure judged to be representative of that likely to be encountered in service.

42.2.7 A receptacle is to be wired to the testing terminals by 1.2 m (4 ft) of wire. The wire is to be the smallest size having an ampacity of at least 125 percent of the maximum full-load motor-current rating of the device. The wire size is to be determined in accordance with Table 42.1 based on the wire temperature rating marked on the device. The type of insulation is to be T or TW for 60°C wire; THW or THWN for 75°C wire. If the terminal will not receive that size of wire the maximum allowable wire size is to be used. Two devices are to be tested. One device is to be wired with the load terminal leads connected together. For the second device, an attachment plug having its terminals shorted by a 1.2-m (4-ft) length of wire of the same wire size used for the receptacle is to be plugged into the receptacle.

42.2.8 For an attachment plug, connector or inlet, each assembly is to be tested as assembled. The wire, cord or cable used to connect each device is to be determined in accordance with Table 16.1 or Table 16.2 based on the wire temperature rating and the minimum conductor size, if applicable, marked on the device. The grounding conductor is to be installed as intended. For this test:

a) An attachment plug is to be assembled to a 0.6-m (2-ft) length of flexible cord or cable. The load conductors are to be shorted together at the end. The plug is then to be inserted in a receptacle wired as described in 42.2.7.

b) A connector is to be assembled to a 1.2-m (4-ft) length of flexible cord or cable wired at one end to the testing terminals. An attachment plug, shorted as described in 42.2.7, is to be plugged into the connector.

c) An inlet is to be assembled and installed as intended. The load terminals are to be wired with a 0.6-m (2-ft) length of flexible cord or cable shorted at the end. The mating connector is to be wired to the testing terminals by 1.2 m (4 ft) of wire.

Exception: The test wires and cord can exceed the specified length if they are in the circuit during calibration.

42.2.9 The grounding conductor or the metal enclosure is to be connected through a non time-delay, 30-ampere, cartridge fuse to the electrical supply live pole judged least likely to strike to ground. The fuse referred to in 42.1.1 is to be connected in series with the pole judged most likely to strike ground. The fuse used is to have an interrupting rating at least equal to the test current specified in Table 42.2. The connection is to be made to the load side of the limiting impedance by a No. 10 AWG (5.3 mm^2) copper wire that is 1.22 – 1.83 m (4 – 6 ft) long.

Exception: : The connection can be made with No. 12 or 14 AWG (3.3 or 2.1 mm^2) copper wire if the branch-circuit conductors the equipment is intended to be connected to are No. 12 or 14 AWG, respectively.

Table 42.2
Short circuit test values

Device rating, kw	Test current, amperes[a]	Power factor[c]
1.2 – 37.3	5,000[b]	0.70 – 0.80
38 – 149	10,000	0.70 – 0.80
150 – 298	18,000	0.25 – 0.30

[a] Symmetrical rms amperes.
[b] 10,000 amperes at manufacturers option.
[c] Lower power factors may be used.

42.2.10 During the test using fuse protection, surgical cotton is to be placed at all openings, covers, flanges, joints, and the like, on the outside of the enclosure.

42.2.11 Equipment rated for direct current is to be tested using a direct current electrical source; alternating-current equipment is to be tested on a 60 Hz essentially sinusoidal current electrical source. The open-circuit voltage of the test circuit is to be 100 to 105 percent of the voltage rating of the overload relay, except that the voltage can exceed 105 percent of the rated voltage with the concurrence of those concerned. The test circuit is to be capable of delivering the current specified in Table 42.2 for a given rating when the system is short-circuited at the testing terminals to which the device under test is to be connected, and this is to be verified by means of an oscillograph.

42.2.12 For all test operations, the test circuit shall be closed on the mated devices. Two devices are to be tested. If an interlock is provided, the test shall be conducted with the interlock switch or circuit closed.

42.2.13 Air core type reactors are to be employed in the line to obtain the power factor in accordance with Table 42.2. The reactors can be connected in parallel, but no reactor is to be connected in parallel with a resistor; except that a reactor in any phase can be shunted by a resistor if the power consumed by the resistor is approximately 0.6 percent of the reactive volt-amperes in the reactor in that phase. The minimum value of the shunting resistance used with a reactor having negligible resistance is to be calculated from the equation:

$$R = 167 \frac{E}{I}$$

in which:

E is the voltage across the reactor with current I flowing as determined by oscillographic measurement during the short circuit calibration or by proportion from meter measurements at some lower current.

42.2.14 If a group of devices having different ratings are of the same construction and material and are intended for use with one size of fuse, tests on the lowest and highest ratings are to be considered to be representative of that group.

42.2.15 After the protective device has cleared the fault, the wiring device shall comply with the following:

a) There shall not be any discharge of parts. The contacts shall not disintegrate, evaporate or weld. There shall not be any damage to the device, the wiring terminals or other parts that would impair the function of the device.

b) There shall not be any breakage of insulating bases or supports to the extent that the integrity of the mounting or insulation of live parts is impaired.

c) There shall not be any ignition of the cotton, cord or cable insulation, or any other risk of a fire and the circuit breaker shall operate when the test circuit is closed.

d) The fuse connected between the live pole and the grounding pole of the enclosure shall not open.

42.3 Calibration of test circuits

42.3.1 General

42.3.1.1 The available current capacity of the circuit is to be at least the value required for the short-circuit-withstand rating of the device. The frequency of the test circuit is to be 60 ±12 Hz.

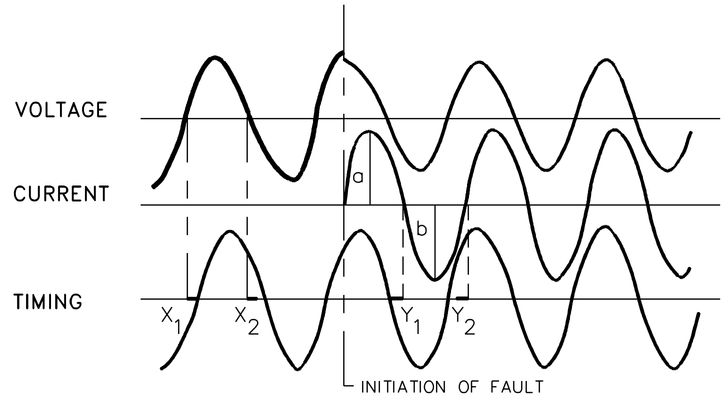
42.3.2 Available current of 10,000 amperes or less

42.3.2.1 For an alternating-current circuit intended to deliver 10,000 amperes or less, the current and power factor are to be determined as follows:

a) For a 3-phase test circuit, the current is to be determined by averaging the rms values of the first complete cycle of current in each of the three phases; the voltage to neutral is to be used to determine the power factor.

b) For a single-phase test circuit, the current is to be the rms value of the first complete cycle (see Figure 42.1) when the circuit is closed to produce an essentially symmetrical current waveform. The direct-current component is not to be added to the value obtained when measured as illustrated. In order to obtain the desired symmetrical waveform of a single-phase test circuit, controlled closing is recommended although random closing methods can be used. The power factor is to be determined by referring the open-circuit voltage wave to the two adjacent zero points at the end half of the first complete current cycle by transposition through a suitable timing wave. The power factor is to be computed as an average of the values obtained by using these two current zero points.

Figure 42.1
Determination of current and power factor for circuits of 10,000 amperes and less



$$\text{Current} = \frac{a+b}{2} \text{ rms calibration of instrument element}$$

$$\text{Power Factor} = \frac{\text{Cosine}[(Y_1 + X_1) \times 180°] + \text{Cosine}[(Y_2 + X_2) \times 180°]}{2}$$

in which:

X and Y values are fractions of the 1/2–cycle distance in which they occur.

SB0740A

42.3.3 Available current more than 10,000 amperes

42.3.3.1 For circuits intended to deliver more than 10,000 amperes, the current and power factor are to be determined in accordance with the requirements in 42.3.3.2 – 42.3.3.8. Instrumentation used to measure test circuits of over 10,000 amperes is to comply with the requirements in 42.3.4.1 – 42.3.4.11.

42.3.3.2 The rms symmetrical current is to be determined, with the supply terminals short-circuited by measuring the alternating-current component of the wave at an instant 1/2 cycle (on the basis of the test frequency timing wave) after the initiation of the short circuit. The current is to be calculated in accordance with Figure 7 in theTest Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis, ANSI/IEEE C37.09-1979(R1989).

42.3.3.3 For a 3-phase test circuit, the rms symmetrical current is to be the average of the currents in the three phases. The rms symmetrical current in any one phase is not to be less than 90 percent of the required test current.

42.3.3.4 The test circuit and its transients are to be such that:

a) 3 cycles after initiation of the short circuit, the symmetrical alternating component of current will not be less than 90 percent of the symmetrical alternating component of current at the end of the first 1/2 cycle, or

b) The symmetrical alternating component of current at the time at which the overcurrent-protective device will interrupt the test circuit is at least 100 percent of the rating for which the device is being tested.

In 3-phase circuits, the symmetrical alternating component of current of all three phases is to be averaged.

42.3.3.5 The power factor is to be determined at an instant 1/2 cycle (on the basis of the test frequency timing wave) after the short circuit occurs. The total asymmetrical rms amperes are to be measured in accordance with 42.3.3.2 and the ratio M_A or M_M is to be calculated as follows:

$$M_A \text{ (3 phase)} = \frac{\text{Average 3 phases} - \text{Asymmetrical rms Amperes}}{\text{Average 3 phases} - \text{Symmetrical rms Amperes}}$$

$$M_M \text{ (1 phase)} = \frac{\text{Asymmetrical rms Amperes}}{\text{Symmetrical rms Amperes}}$$

Using ratio M_A or M_M, the power factor is to be determined from Table 42.3.

Table 42.3
Short-circuit power factor

Short-circuit power factor, percent	Ratio M_M[a]	Ratio M_A[a]	Short-circuit power factor, percent	Ratio M_M[a]	Ratio M_A[a]
0	1.732	1.394	30	1.130	1.066
1	1.696	1.374	31	1.121	1.062
2	1.665	1.355	32	1.113	1.057
3	1.630	1.336	33	1.105	1.053
4	1.598	1.318	34	1.098	1.049
5	1.568	1.301	35	1.091	1.046
6	1.540	1.285	36	1.084	1.043
7	1.511	1.270	37	1.078	1.039
8	1.485	1.256	38	1.073	1.036
9	1.460	1.241	39	1.068	1.033

Table 42.3 Continued on Next Page

Table 42.3 Continued

Short-circuit power factor, percent	Ratio M_M[a]	Ratio M_A[a]	Short-circuit power factor, percent	Ratio M_M[a]	Ratio M_A[a]
10	1.436	1.229	40	1.062	1.031
11	1.413	1.216	41	1.057	1.028
12	1.391	1.204	42	1.053	1.026
13	1.372	1.193	43	1.049	1.024
14	1.350	1.182	44	1.045	1.022
15	1.330	1.171	45	1.041	1.020
16	1.312	1.161	46	1.038	1.019
17	1.294	1.152	47	1.034	1.017
18	1.277	1.143	48	1.031	1.016
19	1.262	1.135	49	1.029	1.014
20	1.247	1.127	50	1.026	1.013
21	1.232	1.119	55	1.015	1.008
22	1.218	1.112	60	1.009	1.004
23	1.205	1.105	65	1.004	1.002
24	1.192	1.099	70	1.002	1.001
25	1.181	1.093	75	1.0008	1.0004
26	1.170	1.087	80	1.0002	1.00005
27	1.159	1.081	85	1.00004	1.00002
28	1.149	1.075	100	1.00000	1.00000
29	1.139	1.070			

[a] See 42.3.3.5.

42.3.3.6 The power factor of a 3-phase circuit is able to be calculated by using controlled closing so that upon subsequent closings a different phase will be caused to have maximum asymmetrical conditions. The power factor of each phase could then be determined using the method described for single-phase circuits in 42.3.3.5. The power factor of the 3-phase circuit is considered to be the average of the power factors of each of the phases.

42.3.3.7 The recovery voltage is to be at least equal to the rated voltage of the device. The peak value of the recovery voltage within the first complete half cycle after clearing and for the next five successive peaks is to be at least equal to 1.414 times the rms value of the rated voltage of the device. Each of the peaks is not to be displaced by more than ±10 electrical degrees from the peak values of the open-circuit recovery voltage – that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage each of the first six, half cycles measured at the 45 degree and 135 degree points on the wave is to be not less than 85 percent of the rms value of the rated voltage of the device. The instantaneous value of recovery voltage measured at the 45 degree and 135 degree points of each of the first six, half cycles is in no case to be less than 75 percent of the rms value of the rated voltage of the device.

42.3.3.8 If there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow in a circuit that employs secondary closing, the detailed measurement of recovery voltage characteristics as indicated in 42.3.3.7 is not required.

42.3.4 Instrumentations for test currents above 10,000 amperes

42.3.4.1 The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing are to be of a type having a flat (±5 percent) frequency response from 50 – 1200 Hz. For fast acting fuses, current limiters, or motor-short-circuit protectors, a galvanometer should have a flat frequency response from 50 – 9000 Hz or an oscilloscope should be used to obtain accurate values of peak current, (I_p), and energy let-through, (I^2t).

42.3.4.2 Galvanometers are to be calibrated as described in 42.3.4.3 – 42.3.4.6.

42.3.4.3 When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage is to be applied so as to cause the galvanometer to deflect in both directions. Additional calibrations are to be made using approximately 50 percent and approximately 150 percent of the voltage used to obtain the deflection indicated above, except that if the anticipated maximum deflection is less than 150 percent, such as a symmetrically closed single-phase circuit, any other suitable calibration point is to be chosen. The sensitivity of the galvanometer circuit in volts per millimeter (or inch) is to be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per millimeter (or inch) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is to be used for the determination of the rms current as described in 42.3.3.2.

42.3.4.4 A 60 Hz sine-wave potential can be used for calibrating the galvanometer circuit, using the same general method described in 42.3.4.3. The resulting factor is to be multiplied by 1.414.

42.3.4.5 When a current transformer is used to determine the circuit characteristics, an alternating current is to be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short circuit current is flowing in the primary. Additional calibrations are to be made at approximately 50 percent and approximately 150 percent of the current used to obtain the deflection indicated above except that if the anticipated maximum deflection is less than 150 percent, such as in a symmetrically closed single-phase circuit, any other suitable calibration point is to be chosen. The sensitivity of the galvanometer circuit in rms amperes per millimeter (or inch) is to be determined in each case and the results averaged. The average sensitivity is to be multiplied by the current-transformer ratio and by 1.414 to obtain peak amperes per inch. This constant is to be used for the determination of the rms current as described in 42.3.3.2.

42.3.4.6 All the galvanometer elements employed are to line-up properly in the oscillograph, or the displacement differences are to be noted and used as needed.

42.3.4.7 The sensitivity of the galvanometers and the recording speed are to be such that the values of voltage, current, and power factor are capable of being determined accurately. The recording speed is to be at least 1.5 m (60 inches) per second.

42.3.4.8 With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found acceptable for use as a reference connected into the circuit, the tests described in 42.3.4.9 and 42.3.4.10 are to be conducted to verify the accuracy of the manufacturer's instrumentation.

42.3.4.9 With the secondary open-circuited, the transformer is to be energized and the voltage at the test terminals observed to see if rectification is occurring making the circuit unacceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings are to be made to demonstrate that residual flux in the transformer core will not cause rectification. If testing is done by closing the secondary circuit, it is permitted to omit this check providing testing is not commenced before the transformer has been energized for approximately 2 seconds, or longer if an investigation of the test equipment shows that a longer time is necessary.

42.3.4.10 With the test terminals connected together by means of a copper bar, a single-phase circuit is to be closed as nearly as possible at the moment that will produce a current wave with maximum offset. The short circuit current and voltage are to be recorded. The primary voltage is to be recorded if primary closing is used. The current measured by the reference shunt is to be within 5 percent of that measured using the manufacturer's instrumentation and there is to be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

42.3.4.11 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt is to be removed from the circuit. The reference coaxial shunt is not to be used during the final calibration of the test circuit nor during the testing of devices.

43 Strength of Insulating Base and Support Test

43.1 Each of three devices for field connection of fixed wiring shall not be damaged when 110 percent of the specified terminal tightening torque is applied to the wire securing means of a pressure wire connector securing the maximum intended size conductor.

43.2 Damage is considered to have occurred if any cracking, bending, breakage or displacement of the insulating base, current carrying parts, assembly parts, or device enclosure reduces electrical spacings to less than those required, exposes live parts, or otherwise impairs the intended secure installation and use of the device.

43.3 The terminal tightening torque to be used for this test is to be that assigned by the manufacturer and marked in accordance with 60.11.1 or, in the absence of an assigned torque, the torque specified in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

44 No-Load Endurance Test

44.1 Each of three plugs and receptacles, or connectors and inlets provided with a mechanical or electrical interlock (that is, a switch, circuit breaker or control pilot circuit), or intended for disconnect use only (not for current interrupting) shall be subjected to a no-load endurance test in which the plug or connector is to be completely inserted into its mating device (that is, the receptacle or inlet) in the intended manner to permit its operation and then completely withdrawn, either manually or mechanically, the interlock being locked and unlocked after each complete insertion of the device. The duration of the test shall be 10,000 insertions and withdrawals, at a rate no greater than ten per minute unless specified otherwise. During this test, the devices under test shall be subjected to exposure to contaminants, for a maximum of five seconds after each 1000 cycles of operation and allowed to dry completely before resuming the cycling test.

44.2 Cord or cable connected devices are to be dipped into a solution of 5 percent by volume of salt and 5 percent by volume of sand (ISO 12103-A4 – Coarse Grade Test Dust, or the equivalent) suspended in distilled water, for a maximum of five seconds and removed. A tank or vessel shall be filled with the solution to a depth of 25 ±5 mm (1 ±0.2 inch). The devices are to be dipped in a manner representing any natural position the device would come to rest if it fell to the ground. The vessel or tank shall be large enough to allow the device to come to rest on the bottom surface. Permanently mounted devices shall be dipped in a manner exposing any face of the device that is capable of being exposed to the elements during use to the contaminants.

44.3 Following the exposure to contaminants, the device is to be wiped dry externally and allowed to dry. Small parts or other mechanisms that are capable of being serviced without the use of special tools can be serviced periodically in accordance with the manufacturer’s recommended maintenance practices. Contacts are not to be adjusted, cleaned, lubricated, or otherwise conditioned before or during the test. There shall be no mechanical or visible damage to any of the parts including the interlocking mechanism.

44.4 These devices are to be marked in accordance with 60.4.1.

Exception No. 1: Devices need not be so marked if tested in accordance with the Endurance with Load Test, Section 45.

Exception No. 2: Devices provided with an interlocking mechanism or control pilot contact need not be so marked.

45 Endurance with Load Test

45.1 Each of three plugs, receptacles, connectors or inlets shall withstand (without excessive wear or other harmful effects) the mechanical, electrical and thermal stresses occurring in normal use.

45.2 A plug and a receptacle, or a connector and an inlet, intended for current interruption, shall be subjected to an endurance test in which the plug or connector is to be completely inserted into its mating device (that is, the receptacle or inlet) in the intended manner to permit its operation and then completely withdrawn, either manually or mechanically.

45.3 The duration of the test shall be 10,000 insertions and withdrawals with load at rated current and voltage. During this test, the devices under test shall be subjected to exposure to contaminants (5 percent by volume of salt and sand, ISO 12103-A4 – Coarse Grade Test Dust, suspended in distilled water) after each 1000 cycles of operation and allowed to dry completely before resuming the cycling test.

45.4 Devices under test are to be operated manually or mechanically at rated voltage and current at a rate no greater than 10 cycles per minute.

45.5 If the test is run mechanically, the rate of operation is not to be greater than 10 cycles per minute, with an average velocity of 0.76 ±0.8 m/s (30 ±3 inches/s) in each direction.

45.6 The test is to be conducted on direct current.

Exception: The test is to be conducted using alternating current if the device is marked in accordance with 60.5.1. When alternating current is used for the test, the power factor of the load is to be from 0.75 – 0.80.

45.7 For dual-rated devices, a test on ac can be waived if acceptable results have been obtained from an equivalent or higher volt-ampere test at a dc potential that is equal to or greater than the ac potential rating.

45.8 During the test, no sustained arcing shall occur. After the test, the devices shall not show:

a) Wear impairing in the further use of the device;

b) Deterioration of enclosures or barriers;

c) Damage to the entry holes for the plug contacts that might impair proper working;

d) Loosening of electrical or mechanical connections.

46 Overload Test

46.1 After being tested as described in this section, each of three receptacles or connectors and their mating devices shall not exhibit any electrical or mechanical failure of the device nor burning, pitting or welding of the contacts that would affect the intended function.

Exception: The requirement does not apply to a receptacle or connector mechanically or electrically interlocked where the interlocking means is opened or opens the circuit before the plug or connector is capable of being inserted or withdrawn.

46.2 An additional material that is provided with the intent to reduce or confine the arcing in the contact chamber of a plug and receptacle and that decomposes or is otherwise affected by the arcing is to be removed for all of the overload tests.

46.3 The device under test is to be operated manually or mechanically in the same manner as the Endurance With Load Test, Section 45, by inserting the plug into the receptacle or the connector into the inlet, while it is connected to a suitable load, and then withdrawing the plug or connector. The equipment grounding contact is to be connected to ground through a fuse. The device is to make and break 150 percent of its rated current for 50 cycles of operation at a rate not higher than 10 cycles per minute.

Exception: A device identified as not being for current interruption (interlocked or provided with a control pilot contact) is to be tested as described in 46.2 – 46.9, except that the device is to be tested three times as described in 46.2 – 46.9. For devices rated for both AC and DC operation, a separate specimen is to be tested on each circuit. There shall not be an electrical or mechanical failure that could increase the risk of a fire or electric shock. The device need not function after the completion of the test, and shall not be used for any further tests.

46.4 A separate set of mating devices is to be used for each overload test, except, upon request from the manufacturer, one device can be used for all of the overload tests.

46.5 The test on a combination of mating devices that have multiple voltage and ampere ratings is to be performed at:

a) 150 percent of the rated current that corresponds to the maximum rated voltage,

b) 150 percent of the maximum rated current at the corresponding rated voltage, and

c) 150 percent of the rated current at the corresponding rated voltage that results in maximum power per pole.

Exception No. 1: One or two of the preceding 150 percent tests can be waived, if it is fully represented by the other test or tests.

Exception No. 2: A test on alternating-current can be waived if adequate results have been obtained from an equivalent or higher volt-ampere test at a direct current potential that is equal to or greater than the alternating-current potential rating.

46.6 Contacts of the plug, connector, inlet or receptacle are not to be adjusted, lubricated, or otherwise conditioned before or during the test.

46.7 The device is to be mounted and wired to represent service conditions. Exposed metal parts are to be connected through a fuse to:

a) Ground,

b) The grounded conductor of the test circuit, or

c) A circuit conductor that differs by at least the rated potential from one or more of the remaining conductors in the circuit.

46.8 The fuse in the grounding conductor is to have a 15 ampere rating if the device under test is rated at 30 amperes or less. If the device under test is rated at more than 30 amperes the grounding fuse is to have a rating of 30 amperes. For the line fuse use the next higher commercial fuse rating than the value of the test current in the test circuit. Neither the line fuse or the grounding fuse shall open during the test.

46.9 The test is to be conducted using direct-current.

Exception: The test is to be conducted on alternating-current if the device is marked in accordance with 60.5.1. When alternating-current is used, the power factor of the load is to be from 0.75 – 0.80.

47 Control Pilot Contact Resistance Test

Section 47 effective February 28, 2003

47.1 The control pilot contact of a device shall have a contact resistance of not more than 10 milliohms after conditioning as described in 47.2 – 47.4, when measured in accordance with Standard Test Methods for Measuring Contact Resistance of Electrical Connections (ASTM B539-96), (Static Contacts) Method C.

47.2 Two representative mating devices, both coupled and uncoupled, shall be used for each exposure of 1200 hours (50 days) to a mixture of moist:

a) Carbon dioxide, sulfur dioxide, and air, and

b) Hydrogen sulfide and air

as described in 47.3 – 47.5.

47.3 The apparatus used for the moist carbon dioxide – sulfur dioxide – air hydrogen sulfide – air exposure is to consist of a chamber having a volume of at least 0.08 m^3 (3 ft^3) with a water jacket and thermostatically controlled heater to maintain a temperature of 35, +1.1, −1.7°C (95, +2, −3°F). The devices are to be placed on a platform approximately 50 mm (2 inches) above the bottom of the exposure tank.

47.4 Carbon dioxide and sulfur dioxide are to be supplied to the test chamber from commercial cylinders containing the gases under pressure. An amount of carbon dioxide equivalent to 1 percent of volume of the test chamber, and an equal volume of sulfur dioxide are to be introduced into the chamber each working day. Prior to introducing a new change of gas each day, the remaining gas-air mixture from the previous day is to be purged from the chamber. A small amount of water (approximately 10 ml/0.0003 m^3 of chamber volume) is to be maintained at the bottom of the chamber for humidity. The water is not to be changed during the exposure.

47.5 Hydrogen sulfide is to be supplied to the test chamber from a commercial cylinder containing the gas under pressure. An amount of hydrogen sulfide equivalent to 0.1 percent of volume of the test chamber is to be introduced into the chamber each working day. Prior to introducing a new change of gas each day, the remaining gas-air mixture from the previous day is to be purged from the chamber. A small amount of water (approximately 10 ml/0.0003 m^3 of chamber volume) is to be maintained at the bottom of the chamber for humidity. The water is not to be changed during the exposure.

48 Electromagnetic Test (Pilot Contacts)

48.1 The pilot contacts of each of three plugs, connectors, inlets and receptacles used for controlling a contact, relay or other magnetically-operated device shall perform satisfactorily when subjected to an overload test consisting of 50 operations, making and breaking the inrush current based on the contact rating, followed by 6,000 operations at normal rated current, in a circuit of 110 percent of the test potential in Table 23.1. The load is to consist of an electromagnet representative of the load that the device is intended to control. Except as noted in 48.2, the load is to be as indicated in Table 48.1.

48.2 A load other than one of those described in Table 48.1 can be used after due consideration of:

a) Need for a device to control an electromagnetic load having other characteristics.

b) The means utilized for matching the rating of the device to that of the load.

c) The manufacturer’s marked recommendations.

Table 48.1
Standard electromagnetic loads

	Standard duty		Heavy duty	
Test potential in volts	Normal current	Current inrush	Normal current	Current inrush
120 ac[a]	3.0	30	6.0	60
240 ac[a]	1.5	15	3.0	30
480 ac[a]	0.75	7.5	1.5	15
600 ac[a]	0.6	6	1.2	12
30 dc	3.0	30	6.0	60
125 dc[b]	1.1	–	2.2	–
250 dc[b]	0.55	–	1.1	–
600 dc[b]	0.2	–	0.4	–

Table 48.1 Continued on Next Page

Table 48.1 Continued

Test potential in volts	Standard duty		Heavy duty	
	Normal current	Current inrush	Normal current	Current inrush
[a] Power factor 0.35 or less.				
[b] Inductive loads, as specified in Section 125 of Industrial Control Devices, Controllers and Assemblies, ANSI/NEMA ICS2 - 1993, and the Standard for Industrial Control Equipment, UL 508.				

48.3 For the operations at rated load, the device under test is to be operated manually or mechanically in the same manner as the Endurance with Load Test, Section 45, by inserting the plug into the receptacle or the connector into the inlet while it is connected to a suitable load, and then withdrawing the plug or connector. The equipment grounding contact is to be connected to ground through a fuse. For the first ten operations the device is to make and break the load as quickly as possible, then for the next 990 operations the device is to be operated at a rate of one second ″on″ and one second ″off″ followed by the remaining operations at a rate not higher than 10 cycles per minute.

49 Temperature Rise Test

49.1 Tests are to be conducted at an ambient temperature between 10 – 40°C (50 – 104°F). If the tests are conducted at an ambient temperature of other than 25°C (77°F), the results are to be adjusted to an ambient temperature of 25°C (77°F) by adding or subtracting the appropriate variation between 25°C (77°F) and the ambient.

49.2 The temperature rise of each of three devices measured at the points described in 49.3 shall not exceed 50°C (122°F) when the device is carrying its maximum rated current. This temperature rise is based on devices intended to be wired with conductors rated 105°C (221°F).

49.3 The temperature measurement is to be made on the wiring terminals and at the contacts of the equipment, if they are accessible for mounting thermocouples. If the equipment has no wiring terminals or they or the contacts are inaccessible, temperatures shall be measured as close as possible to the face of the equipment on the male contacts inserted in the mating device.

49.4 The temperature test is to be made following the overload test on the equipment, and is to continue, in accordance with 49.5, until stabilized temperatures are attained. A temperature is considered to be stabilized when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test indicate no increase greater than 2°C (4°F). Generation of heat from sources other than contacts is to be minimized as much as possible. For example, each connection to the equipment under test is to be made by means of a length of at least 150 mm (6 inches) of the intended type and size of wire or cord, see 16.1 and 60.1.2. In the case of a connector body, wires of the indicated ampacity are to be used regardless of the size of the cord that is intended to be used with the device. The contacts of equipment under test are to be connected together by means of an inserted mating device. The terminals of the device are to be short circuited by means of the shortest feasible lengths of the wire as previously described.

49.5 For couplers rated less than 200 A, the load is to be applied continuously. For connectors rated 200 A or greater the load is to be applied for 20 minutes followed by a no-load period of 10 minutes. This cycle (20 minutes load, 10 minutes no-load) is to be repeated until temperatures stabilize. The connector is to be coupled to an inlet that employs the same AWG size power conductors that are utilized in the connector. For inlets rated 200 A or greater the load is to be applied for a single 20 minute period, with the AWG size of the power conductors sized as normally employed in the inlet.

50 Fuseholder Temperature Test

50.1 When tested as described in this section, the temperature rise of each of three devices incorporating a fuseholder shall not exceed the following:

a) 30°C (54°F) on the fuse clips when tested with a dummy fuse;

b) 85°C (153°F) on the fuse clips when tested with a live fuse;

c) 30°C (54°F) at the wiring terminals or cord connections at any time (see 50.7); and

d) The relative thermal index of the surrounding insulating material, minus an assumed ambient of 25°C (77°F), at any time (see 50.7).

50.2 The test is to be conducted on a set of three previously untested devices. The test can be conducted with either a live fuse or a dummy fuse (see 50.6 and 50.7).

Exception: The test is able to be conducted in conjunction with the Temperature Rise Test, Section 49, if agreeable to all concerned.

50.3 The devices are to be wired in a series circuit with the blades of the attachment plugs or vehicle inlets connected by the shortest possible length of solid copper wire soldered across the blades. For an attachment plug intended for use with flexible cord, each connection to the device being tested is to be made by means of a 150 mm (6 inches) or shorter length of the appropriate type of flexible cord that has an ampacity at least equal to that of the device. For an inlet, Type RH or Type TW lead-in wires no more than 150 mm (6 inches) long are to be connected to the wiring terminals. Wire of the intended ampacity is to be used regardless of the size of the cord which is intended to be used with the device.

50.4 Temperatures are to be measured by means of thermocouples attached to the fuse clips, the insulating material of the device body in proximity to the fuseholder, and the wiring terminals or cord connections.

Exception: If the wiring terminals or cord connections are not accessible for mounting thermocouples, the thermocouples are to be attached to the blades as close as possible to the face of the device.

50.5 The test is to continue for at least 4 hours even when stabilized temperatures have been attained in a somewhat shorter interval of time. A temperature is considered to be stabilized when three consecutive readings, taken at 5 minute intervals, indicate no further rise above the ambient temperature.

50.6 If the test is to be conducted with a live fuse, the devices are to be tested with the largest ampere-rated fuse intended for use with the device installed and subjected to a test current equal to the maximum fuse ampere rating.

50.7 If the test is to be conducted with a dummy fuse, the devices are to be subjected to a test current equal to the maximum ampere rating of the intended fuse. The dummy fuse size for devices incorporating Class CC, G, H, J, K, or R is to be as specified in the Standard for Fuseholders, UL 512. The dummy fuse size for devices employing miscellaneous, miniature and micro fuses is to be as indicated in Table 50.1. To represent the heating of a live fuse, 20°C (36°F) is to be added to the recorded temperature rise on the wiring terminals, cord connections, and surrounding insulating materials.

Table 50.1
Nominal dimensions of dummy fuses for miscellaneous, miniature and micro fuses

Size of fuse	Dimensions		
	Outside diameter	Wall thickness	Length
5 x 20 mm (0.2 x 0.8 inch)	5 mm (0.2 inch)	1.2 mm (0.047 inch)	20 mm (0.8 inch)
6.4 x 31.8 mm (1/4 x 1-1/4 inches)	6.4 mm (0.25 inch)	1.2 mm (0.047 inch)	31.8 mm (1-1/4 inches)

50.8 The thermocouples are to consist of Nos. 28 – 32 AWG (0.08 – 0.032 mm^2) iron and constantan wires. It is a common practice to employ thermocouples consisting of No. 30 AWG (0.05 mm^2) iron and constantan wires with a potentiometer type of indicating instrument. This equipment will be used if a referee measurement of temperature is necessary.

51 Surface Temperatures

51.1 During the Temperature Rise Test, Section 49, the temperature of a surface on each of three devices that is able to be contacted by the user shall not be more than the value specified in Table 51.1. If the test is conducted at a room temperature of other than 25°C (77°F), the results are to be corrected to that temperature. For units intended for installation outdoors or on-board an EV, the results are to be corrected to 40°C (104°F).

Table 51.1
Maximum surface temperatures

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

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

52 Resistance to Arcing Test

52.1 If a material, other than porcelain or ceramic, is used in the construction of the face of a device having female contacts in a way that the material is likely to be exposed to arcing (that is, making and/or breaking under load) while in service, each of the three devices that were subjected to 50 cycles of operation described in the Overload Test, Section 46, shall perform acceptably when subjected to an additional 200 cycles of operation under the overload-test conditions following the temperature test. There shall not be any electrical tracking, formation of a permanent carbon conductive path, or ignition of the material. The attachment plug used for this test can be changed after every 50 operations. If a contact failure occurs after the first 50 operations, the contact can be replaced to permit the remainder of the test operations to be completed.

Exception: An interlocked device identified as not intended for interrupting current need not be subjected to this test. See 60.4.1.

52.2 Alternatively one set of devices can be subjected to the 50 cycles of operation described in the Overload Test, Section 46, followed by the temperature test on the devices and then, to determine resistance to arcing, a second, previously untested set of devices can be subjected to 250 cycles of operation under the overload-test conditions.

53 Polarization Integrity Test

53.1 Compliance with the requirements specified in 14.8 shall be determined by using each of three devices assembled in its intended housing with the polarization feature removed. The devices shall not be able to mate in any manner that would energize the grounding feature of the device. The force required to mate the devices shall not exceed 180 N (40 lbf).

54 Resistance to Corrosion Test

54.1 After being tested as described in this section, ferrous parts, including enclosures, of three devices, shall not show evidence of corrosion.

54.2 All grease is to be removed from the parts to be tested, by immersion in either ethyl acetate, acetone, or methylethyl ketone for 10 minutes. The parts are then to be immersed for 10 minutes in a 10 percent solution of ammonium chloride in water at a temperature of 20 ±5°C (68 ±9°F).

54.3 Without drying, but after shaking off any excess drops by hand, the parts are then to be placed for 10 minutes in a chamber containing moisture-saturated air at a temperature of 20 ±5 °C (68 ±9°F).

54.4 The parts are then to be dried for 10 minutes in a heating cabinet at a temperature of 100 ±5°C (212 ±9°F), and their surfaces shall not show any signs of rust.

54.5 Traces of rust on sharp edges and yellowish film removable by rubbing are to be ignored.

54.6 Small helical springs and the like, and inaccessible parts exposed to abrasion, are to be considered protected against corrosion by a coating of grease. Such parts are to be tested only when the effectiveness of the grease film is in doubt, and the test is then made without previous removal of the grease.

55 Vibration Test

55.1 Each of three inlets or other devices intended to be permanently mounted in an EV or transported on an EV shall not emit flame or molten metal or result in a risk of fire, electric shock, or injury to persons (see 54.2) when subjected to the tests specified in 55.3 and 55.4. Separate representative devices can be used for conducting these tests.

55.2 A risk of fire, electric shock, or injury to persons is considered to exist if:

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

b) The insulation breaks down when tested in accordance with the Dielectric Withstand Test, Section 33, or live parts are made accessible (see Accessibility of Live Parts, Section 13).

55.3 An inlet or other device intended to be permanently mounted in an EV shall be mounted to the vibration fixture in accordance with the manufacturer's mounting instructions and shall be subjected to a vibration test. A device intended to be transported on an EV shall be placed in a metal container mounted to the vibration fixture and shall be subjected to a vibration test. After the unit is subjected to the vibration test described in 55.4:

a) The unit shall comply with the requirement in 55.1,

b) There shall be no loosening of parts, and

c) The unit shall operate normally.

55.4 The vibration test shall consist of vibration for one hour at a frequency of 10 to 55 Hz and back to 10 Hz, with a linear sweep having a sweep time of two minutes per sweep cycle. The amplitude is to be 1.0 +0.1, −0 mm (0.040 +0.004, −0 inch) p-p displacement limit in a vertical plane.

56 Accelerated Aging Gasket Test

56.1 Gaskets depended upon for protection from rain made of neoprene or rubber compounds and solid polyvinyl-chloride materials, except foamed materials, shall have physical properties as indicated in Table 56.1 before and after the conditioning indicated in Table 56.2.

Table 56.1
Physical properties for gaskets

Physical property[a]	Neoprene or rubber compound		Polyvinyl-chloride materials	
	Before conditioning	After conditioning	Before conditioning	After conditioning
Tensile Set Maximum set when 25.4 mm (1 inch) gage marks are stretched to 63.5 mm (2-1/2 inches), held for 2 minutes and measured 2 minutes after release.	6.4 mm (1/4 inch)	–	Not Specified	
Elongation Minimum increase in distance between 25.4 mm (1 inch) gage marks at break.	250 percent [to 88.9 mm (3-1/2 inches)]	65 percent of original	250 percent [to 88.9 mm (3-1/2 inches)]	75 percent of original
Tensile Strength Minimum force at breaking point.	5.86 MPa (850 psi)	75 percent of original	8.27 MPa (1200 psi)	90 percent of original

[a] To be determined using the test methods and apparatus described in Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension, ASTM D412-98, except the method for tensile set is to be as specified in this table.

Table 56.2
Conditioning parameters

Minimum material temperature rise[a] °C (°F)	Conditioning	
	Rubber or neoprene	Thermoplastic
35 (63)	70 hours in a circulating-air over at 100°C (212°F)	7 days in a circulating-air oven at 87°C (189°F)
50 (90)	7 days in a circulating-air oven at 100°C (212°F)	10 days in a circulating-air oven at 100°C (212°F)
55 (99)	7 days in a circulating-air oven at 113°C (235.4°F)	10 days in a circulating-air oven at 113°C (235.4°F)
65 (117)	10 days in a circulating-air oven at 121°C (249.8°F)	7 days at 121°C (249.8°F) or 60 days at 97°C (206°F) in a circulating-air oven

[a] Measured during the Temperature Rise Test, Section 49.

56.2 Gaskets of foamed materials are to be placed in a circulating air oven maintained at a temperature of at least 10°C (18°F) higher than the maximum temperature of the gasket measured during the temperature test described in the Temperature Rise Test, Section49, but not less than 70°C (158°F) for 168 hours. After conditioning the material shall have a tensile strength of not less than 75 percent and an elongation of not less than 60 percent of the values determined for unaged samples. 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.

57 Moisture Resistance Test

57.1 Plugs, receptacles, inlets and connectors requiring a degree of moisture protection shall not permit the entrance of water when subjected to the tests associated with their classifications, as described in this section. Water shall not enter the devices to any appreciable extent, shall not interfere with the intended performance of the device, and shall not reach live parts.

Exception: Enclosures for mounting devices can be evaluated as a specific enclosure type in accordance with the requirements for enclosures in the Standard for Enclosures for Electrical Equipment, UL 50.

57.2 When tested as described in 57.4 and 57.5, a device or assembly of parts, as mentioned in 57.3, (hereinafter referred to as the test assembly) shall comply with 57.1. If the construction of the devices are such that the examination of live parts following the rain exposure is impractical, it is possible to determine compliance by the application of a dielectric withstand potential as described in 57.6.

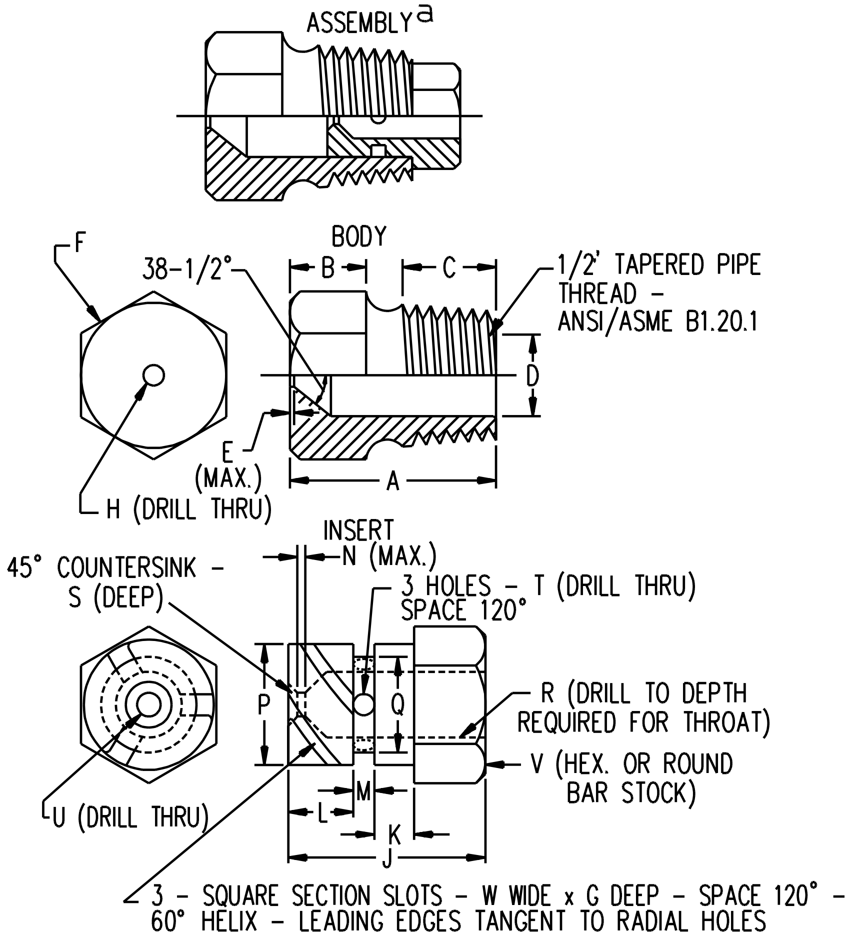
57.3 The test assembly is to be fitted with cable or conduit and installed as intended in actual service, in accordance with the assembly and installation instructions. Receptacles are to be mounted on a vertical surface, with any drains present in the lowest position. Inlets are to be mounted on a vertical surface, with any drains present in the lowest position. The test is to be conducted on two receptacles, one mated and one unmated and on two inlets, one mated and one unmated.

57.4 The test assembly is to be located under a water spray apparatus, consisting of three spray heads constructed in accordance with the details illustrated in Figure 57.1 and mounted in a water supply pipe rack as illustrated in Figure 57.2. The water pressure at each spray head is to be maintained at approximately 35 kPa (5 lb/in^2). The distance between the center nozzle and the test assembly is to be approximately 1.5 m (5 feet), with the test assembly positioned in the focal area of the three spray heads and in such a position and under such conditions that water will be most likely to enter, except that consideration shall be given to the normal mounting position. A flat surface is to be positioned so that the surface is horizontal and 0.3 m (1 ft) below the centerline of the test sample. The water spray is to be applied for one hour.

57.5 Following the exposure to rain, a cover that requires positioning or movement in normal use shall remain functional after 10,000 cycles of operation.

57.6 Immediately following the completion of this test, the devices are to be subjected to a repeated dielectric voltage withstand test as described in the Dielectric Withstand Test, Section 33.

Figure 57.1
Rain-test spray head



Item	mm	inch	Item	mm	inch
A	31.0	1-7/32	N	0.80	1/32
B	11.0	7/16	P	14.61	.575
C	14.0	9/16		14.63	.576
D	14.68	.578	Q	11.51	.453
	14.73	.580		11.53	.454
E	0.40	1/64	R	6.35	1/4
F	c	c	S	0.80	1/32
G	1.52	.06	T	2.80	(No. 35)[b]
H	5.0	(No.9)[b]	U	2.50	(No. 40)[b]
J	18.3	23/32	V	16.0	5/8
K	3.97	5/32	W	1.52	0.06
L	6.35	1/4			
M	2.38	3/32			

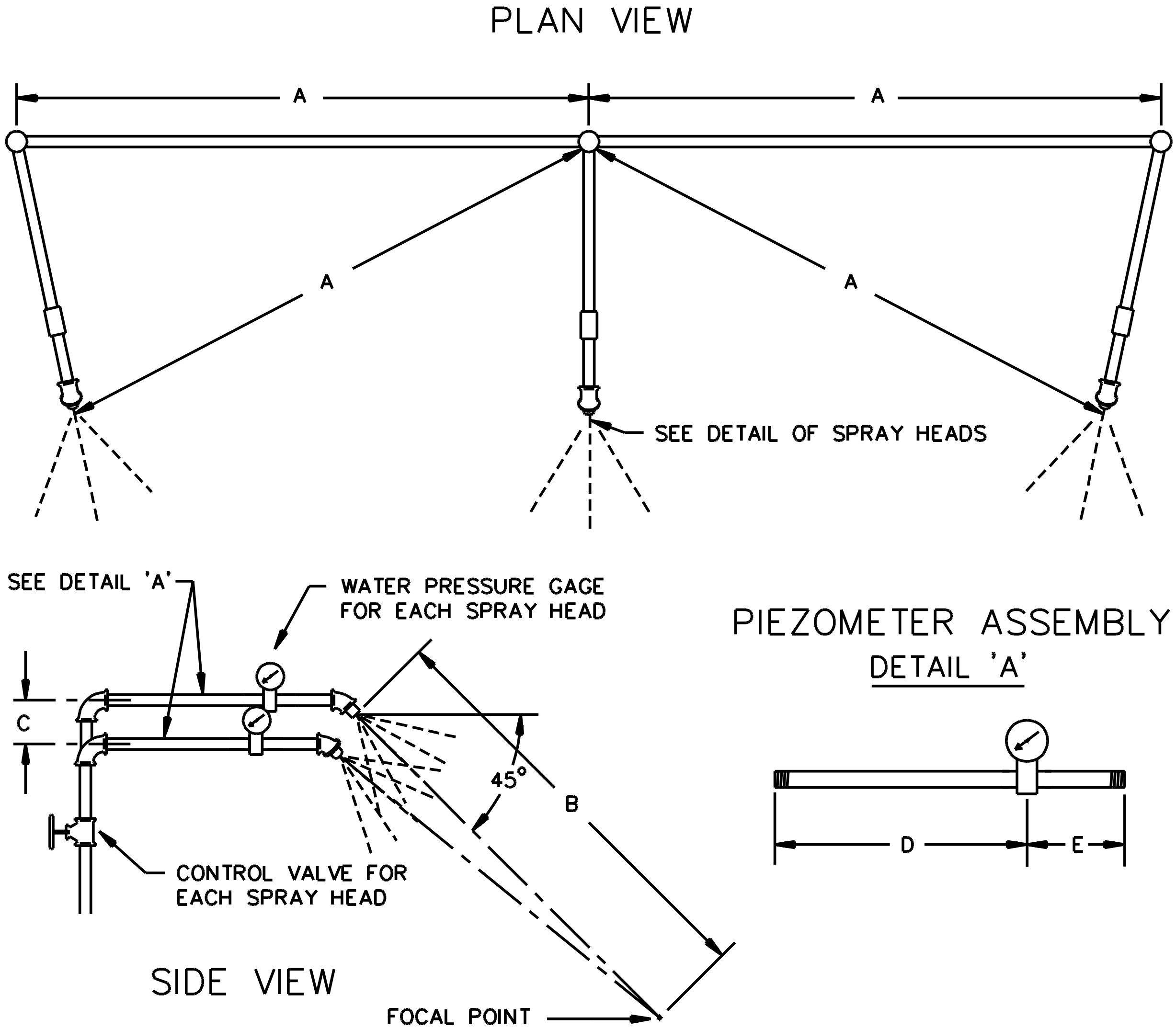
[a] Nylon Rain-Test Spray Heads are available from Underwriters Laboratories

[b] ANSI B94.11M Drill Size

[c] Optional – To serve as a wrench grip.

RT100F

Figure 57.2
Rain-test spray-head piping



Item	mm	inch
A	710	28
B	1400	55
C	55	2-1/4
D	230	9
E	75	3

RT101F

57A Permanence of Marking Tests

57A.1 Following the test described in 57A.2 - 57A.5, the marking shall be considered permanently affixed when there is no indication of the results shown in (a) – (d). Manipulation of the hang tag, such as straightening by hand, is allowed when determining compliance with these requirements.

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 cable,

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.

57A.1 added December 22, 2009

57A.2 Nine samples of a hang tag are to be tested as described in 57A.5. Each sample is to consist of a length of cable to which the hang tag has been attached in the intended manner. If the hang tag is secured by an adhesive, the test is to be conducted no sooner than 24 h after application of the hang tag. Three samples are to be tested as received; the additional samples are to be conditioned as described in 57A.3 and 57A.4 prior to testing.

57A.2 added December 22, 2009

57A.3 Three samples are to be conditioned for 240 h in an air-circulating oven maintained at a uniform temperature of 87.0 ±1.0°C (188.6 ±1.8°F). Following removal from the oven, the samples are to remain at a temperature of 23.0 ±2.0°C (73.4 ±3.6°F) and a relative humidity of 50 ±5 percent for 30 min before testing.

57A.3 added December 22, 2009

57A.4 Three additional samples are to be conditioned for 72 h at a temperature of 32.0 ±2.0°C (89.6 ±3.6°F) and a relative humidity of 85 ±5 percent. The samples are to be tested within 1 min after exposure.

57A.4 added December 22, 2009

57A.5 Each sample cable with attached hang tag is to be tightly suspended and clamped at each end in a vertical plane with the attachment plug on a cord pointing upward. A 5-lb (22.2-N) force is to be applied for 1 min at the uppermost corner of the tag farthest from the cable and within 1/4 in (6.4 mm) of the vertical edge of the hang tag. The force is to be applied vertically downward in a direction parallel to the major axis of the cable.

57A.5 added December 22, 2009

58 Enclosure Tests for Environmental Protection

58.1 A device and its enclosure are to be subjected to the tests specified in Table 58.1 for a Type 3S or higher rating (see the Standard for Enclosures for Electrical Equipment, UL 50, for test descriptions), and shall comply with the construction requirements applicable to a Type 3S device or the type number or numbers with which it is marked. See 60.13.1 – 60.13.6.

58.2 When a panel mounted device is tested, it is to be mounted on a panel of the appropriate enclosure type, in accordance with the manufacturer's instructions.

58.3 Each of two devices is to be tested. One device is to be tested when coupled to its mating device (that is, a plug with a receptacle and a connector with an inlet). The second device is to be tested uncoupled, in its stored position, with all self-closing covers, doors, caps, and the like, in the closed position.

Table 58.1
Enclosure types and tests

Designation	Intended use and description	Requirement or qualification tests[a]
1	Indoor use primarily to provide a degree of protection against a limited amount of falling dirt.	Corrosion protection or rust resistance.
2	Indoor use primarily to provide a degree of protection against limited amounts of falling water and dirt.	Drip, gasket aging and rust resistance or corrosion protection.
3	Outdoor use primarily to provide a degree of protection against rain, sleet, windblown dust and damage from external ice formation.	Rain, icing, protective coating, gasket aging, and outdoor dust or hose.
3R	Outdoor use primarily to provide a degree of protection against rain, sleet and damage from external ice formation.	Rain, icing, protective coating, and gasket aging.
3S	Outdoor use primarily to provide a degree of protection against rain, sleet, windblown dust and to provide for operation of external mechanisms when ice laden.	Rain, icing, protective coating, gasket aging and outdoor dust or hose.
4	Indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, hose-directed water and damaged from external ice formation.	Hosedown, icing, protective coating and gasket aging.
4X	Indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, hose-directed water and damage from external ice formation.	Hosedown, icing, protective coating, corrosion resistance, and gasket aging.
5	Indoor use primarily to provide a degree of protection against settling airborne dust, falling dirt, and dripping noncorrosive liquids.	Corrosion protection or rust resistance, drip, indoor settling airborne dust or atomized water Method B, and gasket aging.

Table 58.1 Continued on Next Page

Table 58.1 Continued

Designation	Intended use and description	Requirement or qualification tests[a]
6	Indoor or outdoor use primarily to provide a degree of protection against hose-directed water, and the entry of water during occasional temporary submersion at a limited depth and damage from external ice formation.	Hosedown, icing, submersion, protective coating, and gasket aging.

Table 58.1 Continued on Next Page

Table 58.1 Continued

Designation	Intended use and description	Requirement or qualification tests[a]
6P	Indoor or outdoor use primarily to provide a degree of protection against hose-directed water, the entry of water during prolonged submersion at a limited depth and damage from external ice formation.	Hosedown, icing, air pressure, protective coating, and gasket aging.
12, 12K	Indoor use primarily to provide a degree of protection against circulating dust, falling dirt, and dripping noncorrosive liquids.	Corrosion protection or drip, indoor circulating airborne dust or atomized water Method A, and gasket aging and oil immersion.
13	Indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and noncorrosive liquids.	Corrosion protection or rust resistance, oil, and gasket aging and oil immersion.

[a] For a description of tests, see the Standard for Enclosures for Electrical Equipment, UL 50.

RATINGS

59 General

59.1 Devices shall be rated in amperes and in volts, ac or dc, or both. A device is permitted have multiple voltage and current ratings unless designed for a single voltage and current rating.

59.2 An outlet device shall be rated in amperes and volts (see 59.4). If the contact configuration of the device is one of the configurations illustrated in Figures 63.1 – 63.6, the device shall be given only the ratings shown in the figure. See 7.1.

59.3 The electrical rating of an attachment plug and connector shall correspond to the rating of the receptacle and inlet, respectively, that is intended for use with the plug or connector.

59.4 If a device includes a snap switch that controls an outlet, the overall rating of the device shall not be higher that the rating of the switch.

59.5 A device shall be rated for disconnecting use only, not for current interrupting, if the potential rating is higher than 250 V dc. A device can be rated for disconnecting use only, not for current interrupting, if current rating is greater than 60 A ac, dc, or ac-dc. See 46.3.

MARKINGS

60 Details

60.1 Company name, catalog designation, electrical rating

60.1.1 A device shall be legibly and permanently marked, where readily visible after installation, 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. The manufacturer's identification is permitted to be in a traceable code if the device is identified by the brand or trademark owned by a private labeler.

b) The catalog number or an equivalent designation, where practicable. See 60.8.1.

c) The electrical rating in both volts and amperes;

d) The horsepower rating and associated electrical rating (voltage, no. of phases, and the like), if so rated;

e) Whether ac or dc or both, see 60.5;

f) For devices incorporating either fuses or circuit breakers, the interrupting rating in amperes;

g) Ambient temperature rating, if higher than 40°C (104°F); and

h) If intended for a specific location, the type of location in which the device is intended to be used.

60.1.2 A device intended for use with flexible cord or cable shall be marked with the intended flexible cord or cable types, conductor size or sizes, total number of conductors, and the overall cord diameter if the device is intended to be utilized with a limited range of cord diameters available for a cord, on the smallest unit shipping carton, on an instruction sheet provided in the carton, or on the device.

60.1.3 If the device is rated 100 A or less and is intended for use with conductors having 75°C (167°F) insulation, the device shall be marked with the temperature rating of the insulation

60.1.4 If a device is intended for use with conductors having a temperature rating higher than 60°C (140°F) but is intended to be used based on 60°C (140°F) ampacities, the minimum conductor size shall be indicated on the device and, on the smallest unit shipping carton, or on an instruction sheet provided in the carton.

60.1.5 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 stamped lettering on a pressure-sensitive label that complies with the requirements in the Standard for Marking and Labeling Systems, UL 969. Expected usage, handling, storage, and the like, of a product are considered in the determination of the permanence of marking.

60.1.5 added December 22, 2009

60.1.6 In addition to complying with the requirement in 60.1.5, a hang tag shall also meet the requirements in 57A.1 - 57A.5.

60.1.6 added December 22, 2009

No Text on This Page

60.2 Multiple factories

60.2.1 If a manufacturer produces or assembles attachment plugs, receptacles, cord connectors, and the like at more than one factory, each finished device shall have a distinctive marking on the device, that can be in code, by which the device is capable of being identified as the product of a particular factory.

60.3 Nonconductive mounting means

60.3.1 The receptacle or a flanged inlet described in 14.2 (Exception No. 2) shall be plainly marked on the device where visible during installation as follows: ″CAUTION - Mounting means not grounded. Grounding wire connection required″ or an equivalent wording following the word ″CAUTION″.

60.4 Disconnecting use only

60.4.1 A device intended exclusively for disconnecting use shall be marked ″CAUTION - Risk of Electric Shock, Do Not Disconnect Under Load″, or ″Not for current interrupting,″ or an equivalent statement following the word ″CAUTION″.

60.5 AC only devices

60.5.1 A wiring device that is intended for use on alternating current circuits only shall be identified as such by means of the letters ″AC″, or ″AC Only″, or an acceptable frequency marking (for example, ″60 Hz″), or a phase marking, which shall be a part of the electrical rating. For multiphase devices that are intended for use only on a Wye system, the marking shall include the word ″Wye,″ or the equivalent.

60.6 Cover grounded devices

60.6.1 An armored attachment plug or cord connector in which the armor is conductively connected to the grounding pin, blade, or contact shall be marked on the device ″cover grounded″ or with an equivalent statement unless the grounding connection is readily visible.

60.7 Catalog designation

60.7.1 If the product is too small, or where the legibility would be difficult to attain to include the complete catalog designation or an equivalent designation, or where several catalog numbers use common parts, the complete designation shall appear on the unit container.

60.8 Fused devices

60.8.1 A device intended to accommodate fuses, other than a plug or cartridge fuse acceptable for branch circuit protection, shall be marked ″Use only with a ___ volt fuse.″ The potential to be used in the marking shall be the potential rating of the fuse for which the device is intended.

60.8.2 An attachment plug that is intended to accommodate fuses that are capable of being removed after the attachment plug has been inserted in a receptacle shall be marked ″Disconnect power before replacing fuses″ or an equivalent wording. See 20.1 and 20.4.

60.9 Locking-type devices

60.9.1 An attachment plug or connector that is required to be given a twisting or turning motion to lock or unlock it after the contacts have been inserted into the mating device, and the mating device intended to accommodate such an attachment plug or connector, shall be marked on the device ″Turn and pull″ or an equivalent wording. The marking shall be visible while the device is in use.

60.10 Receptacle marking location

60.10.1 The markings required in 60.1.1, and 60.5.1 shall appear on the front of the body of a receptacle intended for use with a separate flush plate, and shall be readily visible on the outside of a receptacle mounted on a metal outlet-box cover.

60.11 Wiring information – field wiring terminals

60.11.1 A device intended for field wiring shall be marked with the value of tightening torque assigned in accordance with 16.9. The value of tightening torque assigned shall be marked where readily visible:

a) On the device,

b) On the smallest unit container, or

c) On an information sheet packed in the smallest unit container.

60.11.2 If field wiring terminals employing solder connections are intended for solid or tinned stranded conductors only, instructions regarding the use of solid wire, pretinned stranded wire or the tinning of stranded wire shall be marked where readily visible:

a) On the device,

b) On the smallest unit container, or

c) On an information sheet packed in the smallest unit container.

60.11.3 Except when a device is so constructed that the factory installed bond between the terminal and exposed non-current-carrying metal parts is readily visible and the terminal for the connection of the grounding conductor is obvious, the terminal for the connection of an equipment grounding conductor shall have a permanent identification that is readily recognizable during installation.

60.11.4 The wire entrance hole for a grounding terminal shall be identified by a distinct green colored area immediately adjacent to the entrance hole. Additionally, the marking ″G″, ″GR″, or ″GROUND″ or the symbol ⏚ is permitted to appear adjacent to the wire entrance hole.

60.11.5 A readily removable part of an equipment grounding terminal, such as a set screw or a clamp, shall not be colored green or otherwise identified as part of the grounding terminal, if such a part is able to be interchanged with a similar part of another terminal on the device.

60.11.6 An equipment grounding conductor shall be green or green with one or more yellow stripes, and no other lead shall be so coded.

60.12 Overcurrent protection

60.12.1 A device contactor rated over 1.12 kW shall be marked ″Suitable For Use On A Circuit Capable Of Delivering Not More Than _______ rms Symmetrical Amperes, _______ Volts Maximum.″ The ampere rating is not to be more than the value for which the device was tested in accordance with Table 42.2.

a) If tested with a time delay fuse in accordance with Table 42.1, the marking shall also include the following or the equivalent:

″When Protected by Time Delay _______ Class Fuses″

b) If tested in accordance with 42.2.2, part A, the marking shall also include the following or the equivalent:

″When Protected by a Circuit Breaker Having an Interrupting Rating Not Less Than _______ rms Symmetrical Amperes, _______ Volts Maximum″.

60.13 Environmental enclosures

60.13.1 A device enclosure type designation marking shall be one of those specified in Table 58.1. The marking shall be visible after installation and shall be permanent. See 60.13.7 and 60.13.8.

60.13.2 If a device enclosure has been evaluated as a specific enclosure type in accordance with the requirements for enclosures in the IEC Standard for Degrees of Protection Provided By Enclosures, IEC 529-1989, the enclosure shall be marked with the appropriate IP code designation. The marking shall be visible after installation and shall be permanent. See 60.13.7 and 60.13.8.

60.13.3 An enclosure that complies with the requirements for more than one type of enclosure is permitted to be marked with multiple designations.

60.13.4 Device enclosures are permitted to be provided with the following additional markings:

a) A Type 4, 4X, 6 or 6P enclosure is permitted to be marked ″Watertight″, or

b) A Type 4X or 6P enclosure is permitted to be marked ″Corrosion Resistant″.

60.13.5 If the acceptability of a rating for a device is dependent upon a particular mounting orientation, the device shall be marked to indicate the required orientation.

60.13.6 A plug, receptacle, or connector that provides enclosure protection shall be legibly marked where visible during intended use, ″To maintain enclosure rating, use only with a device with identical marking (specific identification) _________″ or the equivalent.

60.13.7 A marking identifying an environmental enclosure type or types 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 acceptable 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.

60.13.8 A pressure-sensitive label or a label secured by cement or adhesive shall comply with the applicable requirements for indoor or outdoor use labels in the Standard for Marking and Labeling Systems, UL 969.

61 Identification and Marking of Terminals

61.1 General

61.1.1 Wiring terminals are to be marked to indicate the proper connections for the power supply, load, control circuit, and the like, or a wiring diagram coded to the terminal marking shall be provided with the product.

61.2 Grounded and grounding

61.2.1 Device wiring terminals designated ″W″ (white) intended for connection to grounded circuit conductors, or designated ″G″ (green) for grounding conductors, shall be clearly and permanently identified on the device in accordance with Table 61.1 or 61.2. The colors or markings specified for this terminal identification shall not be applied to other than the designated terminals. The identifications shall be readily recognizable during wiring and relate directly to the appropriate terminals.

61.2.2 A part relied upon to provide the terminal identification required in 61.2.1 shall not be readily removable if it is capable of being replaced with a similar part of another wiring terminal of the device. A suitably staked terminal screw is considered to be not readily removable for this purpose. A surface of a permanent appendage to a wiring terminal can be used to mark the terminal identification.

61.3 Other terminals

61.3.1 Device wiring terminals other than the grounded and grounding terminals described in 61.2.1 need not be identified, but if they are, the letters ″X″, ″Y″, and ″Z″ or other recognized marking conventions shall be used for identification according to the following convention:

a) Viewing the pin end of the plug and proceeding counter-clockwise starting from the grounding pin (G), or in the absence of a grounding pin, the grounded pin (W), the terminals shall be marked in sequence ″X″, ″Y″ and ″Z″. Other recognized marking conventions can be used provided they are identical to the convention used on the mating device.

b) Viewing the face end of the receptacle and proceeding clockwise, starting from the grounding contact slot (G), or in the absence of a grounding contact slot, the grounded contact slot (W), the terminals shall be marked in sequence ″X″, ″Y″ and ″Z″. Other recognized marking conventions can be used provided they are identical to the convention used on the mating device.

Table 61.1
Identification of wiring terminals

Identification by:	Grounded terminal	Grounding terminal	All other terminals
Wire-binding screw	White metal or plating	Hexagonal, green-colored nut[b] or slotted screw head[b]b	Other than white or green circular screw head
Pressure wire terminal-visible	White metal or plating on terminal	Green-colored terminal or appendage[b]	Other than white or green-colored terminal
Pressure wire terminal-concealed	Distinct white-colored area adjacent to wire entrance hole, or the word ″white″ distinctively marked adjacent to wire entrance hole	Distinct green-colored area adjacent to wire entrance hole, or the word ″green″ or ″ground″, the letters ″G″ or ″GR″[c] or the grounding symbol shown in Figure 61.1 distinctively marked adjacent to wire entrance hole	Other than white or green area adjacent to wire entrance hole
Set screw	Distinct white-colored area adjacent to wire entrance hole, or the word ″white″ distinctively marked adjacent to wire entrance hole	Distinct green-colored area adjacent to wire entrance hole, or the word ″green″ or ″ground″, the letters ″G″ or ″GR″,[c] or the grounding symbol shown in Figure 61.1 distinctively marked adjacent to wire entrance hole	Other than white or green area adjacent to wire entrance hole
Terminal plate[a]	White metal or plating	–	Other than white or green metal or plating
Insulating enclosure or terminal	The word ″white″ marked on or directly adjacent to terminal, or white metal or plating on terminal	The word ″green″ or ″ground″, the letters ″G″ or ″GR″, or the grounding symbol shown in Figure 61.1 marked on or directly adjacent to terminal, or green colored terminal	Other than white or green-colored terminal

Table 61.1 Continued on Next Page

Table 61.1 Continued

Identification by:	Grounded terminal	Grounding terminal	All other terminals
[a] Only if all line-terminal binding screws are of the same color.			
[b] Not readily removable. See 60.11.5.			
[c] In letters at least 1.6 mm (1/16 inch) high.			

Table 61.2
Identification of leads

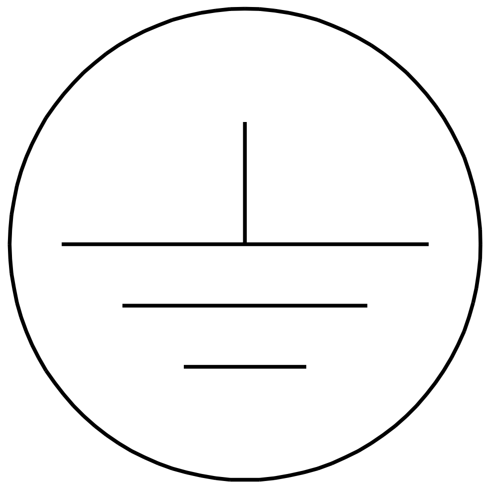
Identification by:	Grounded conductor	Grounding conductor	All other conductors
Color of braid[b]	Solid white or natural grey (without trace)	Not applicable	White or natural grey with tracer in braid or solid color other than white, natural grey, or green[a] (without tracer)
	Color other than white, natural grey or green, with tracer in braid	Not applicable	Solid color other than white, natural grey, or green[a] (without tracer)
Color of insulation[b]	Solid white or natural grey; stripe, white or natural grey, on contrasting color other than greena	Green with or without one or more yellow stripes	Solid color other than white, natural grey, or green[a]
Colorof separator[b]	Solid white or natural grey	Not applicable	Solid color other than white, natural grey or green[a]
Conductor tinning[c]	Tin or other acceptable metal on all strands of the conductor	Not applicable	No tin or other white metal on the strands of the conductor

[a] A green wire, with or without one or more yellow stripes, is to be used only as an equipment grounding conductor.

[b] If color of braid, insulation, or separator is used for identification, all conductors are to be either tinned or not tinned.

[c] If conductor tinning is used for identification, all braids and/or insulation are to have the same color and shape.

Figure 61.1
Grounding symbol



GND1

CONFIGURATIONS

62 General

62.1 The information given in (a) – (f) applies to each configuration in Plugs and Receptacles, Section 63.

a) All dimensions are in inches.

b) Decimal dimensions without tolerances shall be subject to a ±0.005 inch tolerance.

c) Angular dimensions without tolerances shall be subject to a ±1/2 degree tolerance.

d) Where two values are given for the same dimension, the larger is the maximum value and the smaller the minimum value.

e) Constructions shown depict an acceptable construction; it is possible that other constructions are equivalent.

f) Terminal identification shall comply with Identification and Marking of Terminals, Section 61.

63 Plugs and Receptacles

NOTE: These configurations were obtained from SAE J1772 (10/96) and are for illustrative purposes only.

Figure 63.1
Interface layout for coupler Design A

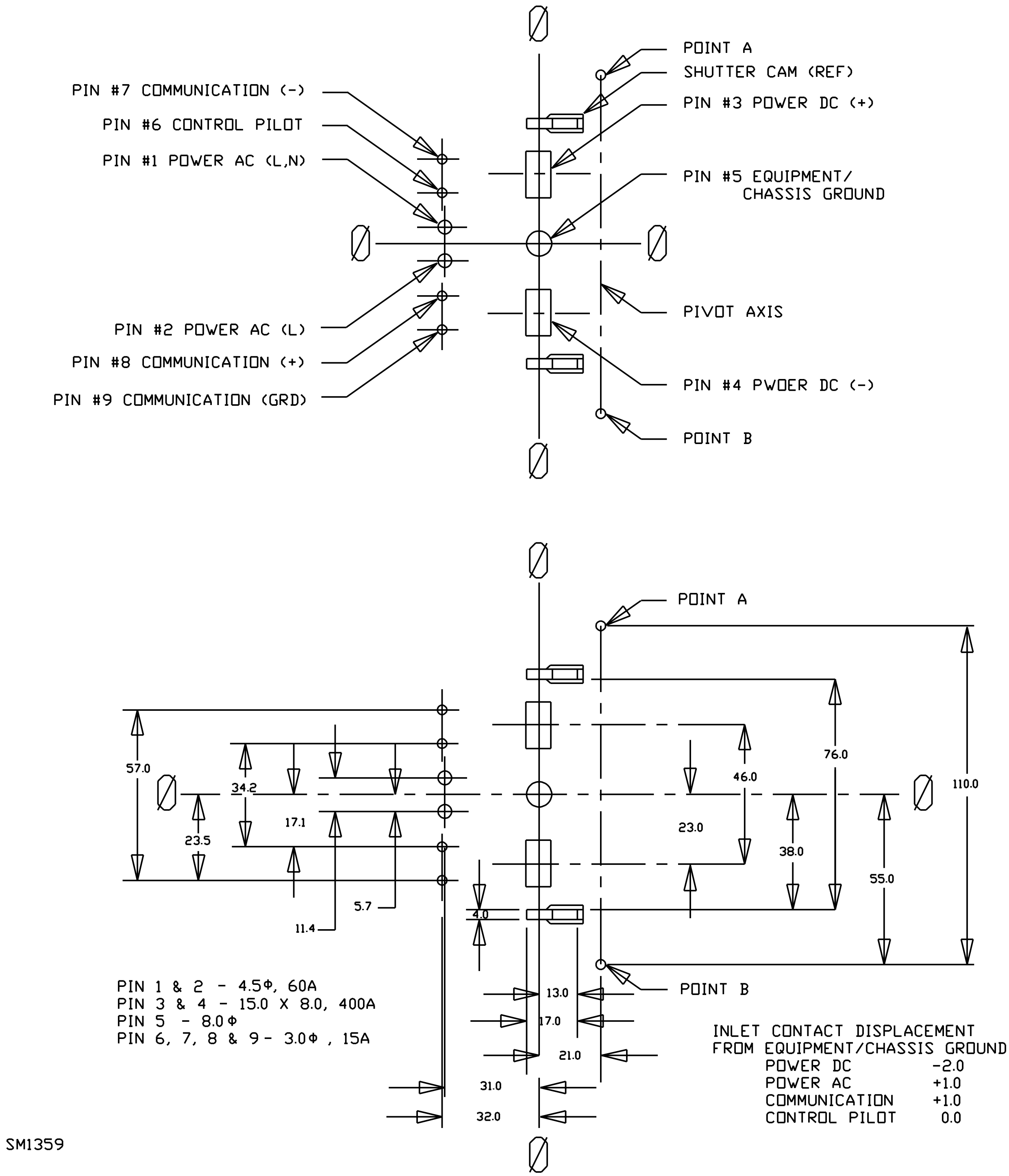


Figure 63.2
Vehicle inlet for coupler Design A

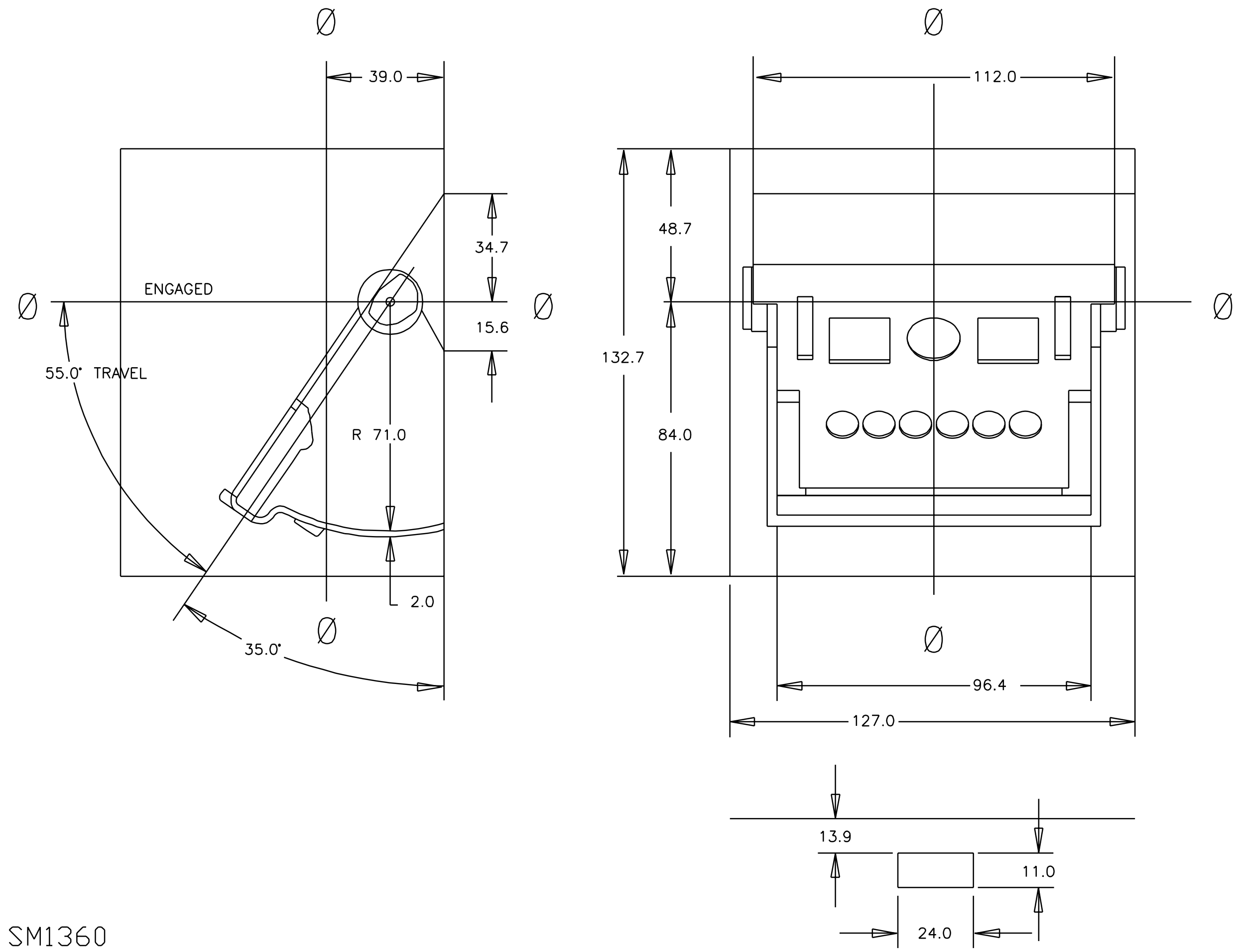
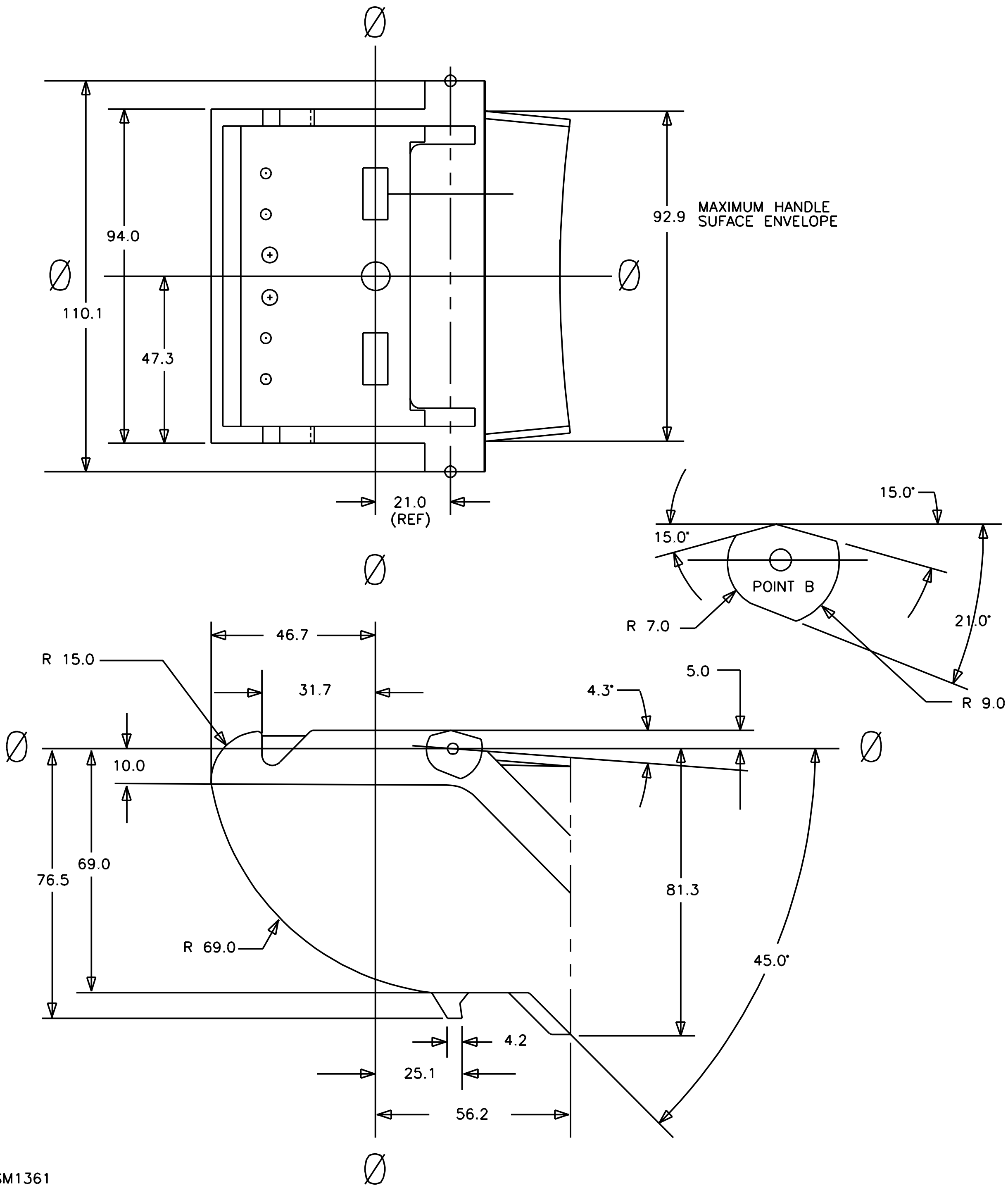
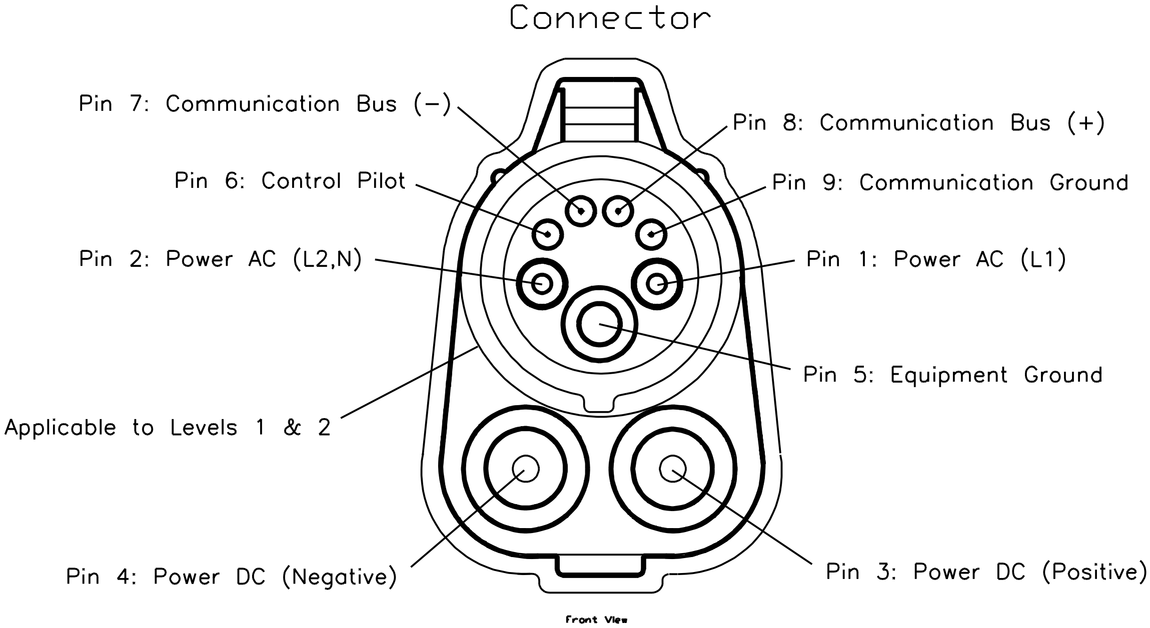


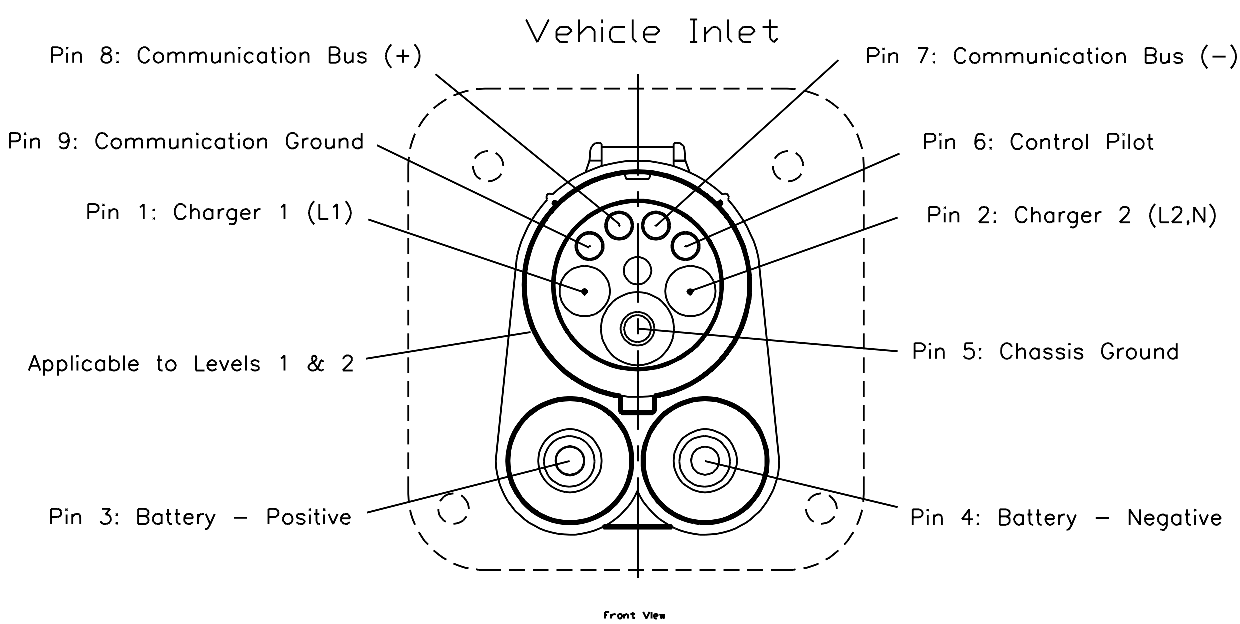
Figure 63.3
Connector for couple Design A



SM1361

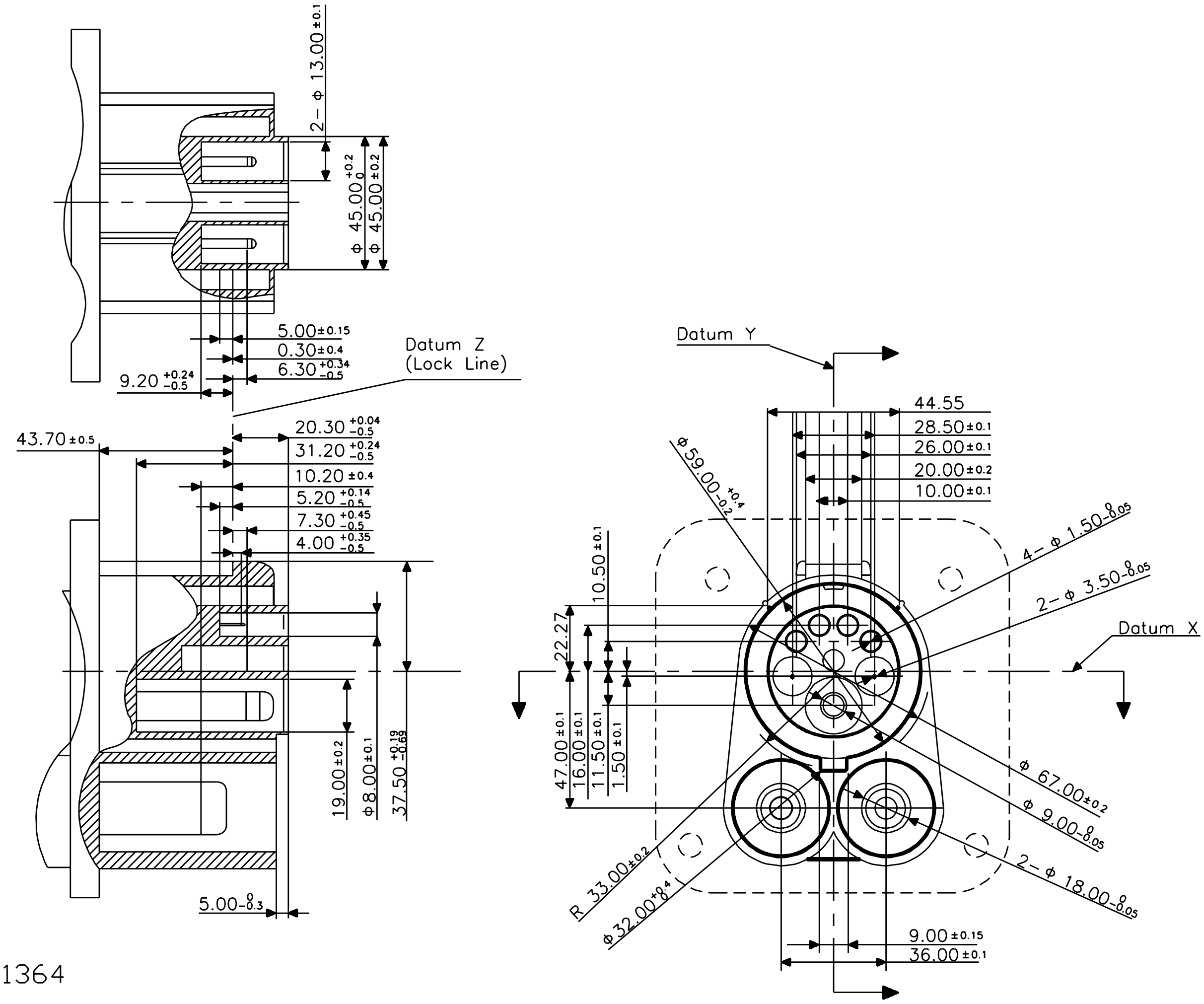
Figure 63.4
Interface layout for coupler Design B





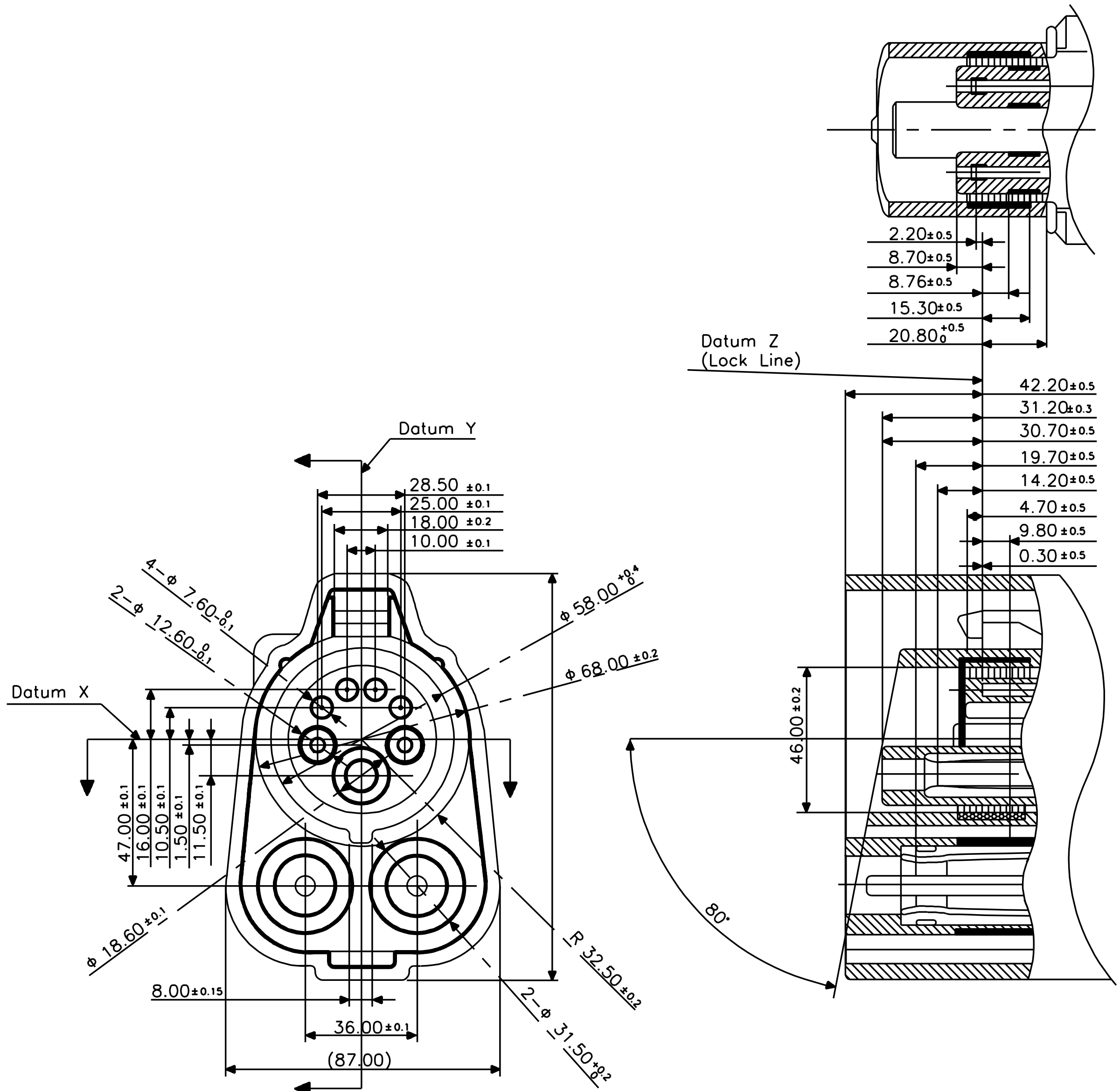
SM1362

Figure 63.5
Vehicle inlet coupler Design B



SM1364

Figure 63.6
Connector for coupler Design B



SM1363