UL 467

STANDARD FOR GROUNDING AND BONDING EQUIPMENT

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TABLE OF CONTENTS

FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

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

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

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

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

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

GENERAL

1. Scope

1.1 These requirements cover grounding and bonding equipment for use in connection with interior wiring systems in accordance with the National Electrical Code. These requirements also cover hospital grounding jacks and the mating grounding cord assemblies.

1.2 These requirements cover ground clamps, bonding devices, grounding and bonding bushings, water-meter shunts, armored grounding wire, ground rods, and the like.

2. Units of Measurement

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

3. Components

3.1 A component of a product covered by this standard shall comply with the requirements for that component, and shall be used in accordance with its recognized rating and other limitations of use. A component need not comply with a specific requirement that:

A. Involves a feature or characteristic not needed in the application of the component in the product covered by this standard, or

B. Is superseded by a requirement in this standard.

CONSTRUCTION

4. General

4.1 The general purpose of grounding and bonding devices is to provide means for grounding circuits and equipment. Accordingly, any grounding or bonding device shall be suitable for the application for which it is designed and, when installed in the intended manner, shall provide a permanent, reliable electrical bond.

4.2 The minimum electrical resistance of a bond is not specified and, in general, a grounding or bonding device that provides a substantial and reliable mechanical connection is considered to have adequate electrical conductivity. If, however, a bond has any doubtful or unusual features, it shall be investigated to determine if its design and construction are such that it will carry the current that it may be called upon to handle under actual service conditions, without over-heating or being otherwise adversely affected.

4.3 A grounding or bonding device shall be constructed of a metal or metals that, when the device is installed under conditions of actual service and exposed to moisture, will not be likely to be adversely affected by electrolysis. The device shall have adequate strength and rigidity to permit its installation in the intended manner without rupture or distortion that would adversely affect the service of the device or damage the ground electrode or equipment to which it is attached.

4.4 Pressure wire connectors are judged under the requirements for wire connectors and soldering lugs, except that a pressure wire connector that is provided as part of a grounding or bonding device may be of iron or steel with a steel terminal screw. The secureness test is not required for a connector that has provision for attachment to rigid metal conduit, electrical metallic tubing, or armor, unless the connector is of the setscrew type; neither the secureness nor the pull-out test is required for a binding-screw-type connector employed in a grounding device; and the heating test is not required in any case. If a connector that is intended for use with a No. 6 AWG (13.3 mm^2) or larger wire will not accommodate a stranded conductor of the size for which it is intended, the tests are to be performed with a solid conductor of that particular size but, the duration of the secureness test is to be only 1 hour.

4.5 Means for the attachment of a grounding conductor, if provided, shall be such that the conductor will be securely and reliably held, and shall not depend upon solder. If a pressure wire connector is not used and if the grounding conductor is attached by means of a single screw, the size of the screw shall not be smaller than specified in Table 4.1. A terminal employing a wire-binding screw shall be provided with upturned lugs or the equivalent capable of holding a wire under the head of the screw.

TABLE 4.1
SIZES OF TERMINAL SCREWS

Size of Conductor, AWG (mm^2)	Minimum Size of Screw
14—8 (2.1—8.4)[a]	No. 10
6 (13.3)	1/4 inch
4 (21.2)	5/16 inch

a The common form of wire-binding screw is not suitable for securing a wire larger than No. 8 AWG solid or No. 10 AWG (5.3 mm^2) stranded.

4.6 A cast-iron part, other than a malleable-iron part, shall not be less than 1/8 inch (3.2 mm) thick. A malleable-iron part, and a nonferrous cast-metal part other than a die-cast part, shall not be less than 3/32 inch (2.4 mm) thick. A die-cast part shall not be less than 3/32 inch thick.

Exception: A die-cast part may be not less than 1/16 inch (1.6 mm) thick if it is ribbed or otherwise reinforced so that adequate mechanical strength is provided.

5. Grounding Devices

Construction

5.1 A device intended for the connection of rigid metal conduit, electrical metallic tubing, or flexible armor shall be provided with an end stop or the equivalent and, if intended for the connection of rigid metal conduit, shall be provided with not less than five full threads in the metal.

5.2 A clamp intended to be threaded onto or otherwise rigidly attached to any form of metal raceway or flexible armor enclosing a grounding wire shall be of the protective type. The design of the clamp shall be such that the grounding wire and its connection will be effectively protected against mechanical damage, except that a grounding-wire connection having inherent protection against mechanical damage — because of its size, shape, and the like — is not required to be otherwise protected.

5.3 A ground clamp in which the grounding wire and its connection to the clamp is recessed between substantial, protective side walls will be considered to be acceptable, provided that such protective walls are not formed by removable parts that are not essential for the assembly of the device.

5.4 A protective-type clamp shall provide an electrical and mechanical connection between the grounding electrode and a grounding wire protected by armor or metal raceway. The mechanical connection shall be rigid.

5.5 A protective-type clamp of the strap type shall have a rigid metal base to be seated on the grounding electrode and, if the clamp is designed for use with rigid metal conduit, it shall be provided with not less than the applicable number of straps specified in Table 5.1, depending upon the trade size of rigid metal conduit with which it is intended to be used.

TABLE 5.1
STRAPS FOR PROTECTIVE-TYPE CLAMPS

Trade Size of Rigid Metal Conduit, Inch	Minimum Number of Straps
1/2	1
3/4	2
1	3

5.6 A strap-type clamp shall not be less than 3/4 inch (19.1 mm) wide, shall not be less than 0.053 inch (1.35 mm) thick before galvanizing if of sheet steel, and shall not be less than 0.048 inch (1.22 mm) thick if of copper.

6. Protection Against Corrosion

6.1 Unless the metal employed is inherently resistant to corrosion — nonferrous — a grounding device shall be protected by galvanizing, sherardizing, or an equivalent metallic plated coating. A strap-type clamp of sheet steel shall be zinc coated by the hot-dip process after fabrication.

6.2 A plating or a coating that is required or otherwise provided on a grounding or bonding device shall not be of a material or color that would tend to indicate that the device is of a material other than that of which it is actually made.

7. Bushings

7.1 A bonding bushing for use with rigid metal conduit shall provide means for reliably bonding the bushing to the enclosure with which it is used. Only surface contact of the bushing with the enclosure wall is not acceptable.

7.2 A grounding bushing has provision for the connection of a bonding or grounding conductor; whereas a bonding bushing has no such provision, although it may be provided with a screw that serves as a part of the bonding function. If, however, a bushing can be used as either a grounding bushing or a bonding bushing — that is, either with or without a bonding or grounding conductor — it is considered to be a grounding bushing.

7.3 A bonding screw intended to bond a bushing to an enclosure shall be adjustable to extend not less than 1/8 inch (3.2 mm) beyond the surface of the bushing, except that if two or more such screws or the equivalent are evenly spaced around the bushing this adjustment may be less than 1/8 inch, but not less than 1/16 inch (1.6 mm). When adjusted in any position to provide a bond, a bonding screw shall engage not less than two threads in the bushing.

7.4 A bushing intended for use with a grounding or bonding conductor shall have provision for the connection of a wire — solid or stranded for No. 4 AWG (21.2 mm^2) or smaller, stranded for No. 2 AWG (33.6 mm^2) or larger — of the size specified in Table 7.1 or a larger conductor.

TABLE 7.1
SIZES OF CONNECTED CONDUCTORS

Trade Size of Bushing, Inches	Size of Bonding Conductor, AWG (mm^2)
1-1/4 and smaller	8 (8.4)
1-1/2	6 (13.3)
2	4 (21.2)
2-1/2	2 (33.6)
3	1/0 (53.5)
3-1/2, 4	2/0 (67.4)
4-1/2, 5, 6	3/0 (85.0)

7.5 In an insulated metal bushing, all surfaces of the throat that may be contacted by a conductor shall be lined with the insulating material.

7.6 A bushing intended for use with separable wire connectors shall have provision for the mounting of a wire connector of the proper size in accordance with paragraph 7.4.

7.7 A bushing may be shipped without a wire connector or with a wire connector of any size provided a connector of the required size is also made available by the manufacturer. See paragraph 16.2.

8. Water-Meter Shunts

8.1 A water-meter shunt shall consist of two clamps connected by means of a No. 4 AWG (21.2 mm^2) or larger solid copper wire. The clamps shall comply with the requirements for clamps given in this standard.

9. Armored Grounding Wire

General

9.1 Armored grounding wire shall consist of a single corrosion-resistant conductor complying with the requirement in paragraph 4.3, within a flexible, helically formed, steel armor similar in general design to that employed in armored cable.

Conductor

9.2 The copper conductor shall be one that has been investigated and found to be acceptable. The conductor need not be tinned.

Armor

9.3 Splices made in the steel strip forming the armor shall be made in a workmanlike manner, and shall not increase materially the thickness or diameter of the armor nor lessen its mechanical strength.

9.4 The strip used in the armor shall not be less than 0.025 inch (0.64 mm) thick. It is usually necessary to use a strip made with a tolerance such that the minimum thickness will be maintained in the finished product.

9.5 In an armored grounding wire employing an uninsulated (bare) conductor, the weight of single-strip armor shall not be less than specified in Table 9.1.

TABLE 9.1
WEIGHTS OF SINGLE-STRIP ARMOR

Size of Conductor, AWG (mm^2)	Minimum Weight, Pounds per 100 feet (Kg/30.5 m)	
	Solid Conductor	Stranded Conductor
8 (8.4)	7.25 (3.2)	7.97 (3.6)
6 (13.3)	8.60 (3.9)	9.53 (4.3)
4 (21.2)	10.30 (4.7)	11.48 (5.2)

9.6 The steel armor of an armored grounding wire shall comply with the requirements for zinc coating, tension — 150 pounds, and flexibility applicable to armored cable.

10. Grounding Electrodes

General

10.1 A grounding electrode shall not be less than 8 feet (2.4 m) long and shall be capable of being driven to a depth of 8 feet.

Pipe Electrodes

10.2 A pipe electrode shall have an internal diameter not less than 3/4 inch (19.1 mm) and shall have a wall thickness not less than that of the corresponding trade size of rigid ferrous-metal conduit.

10.3 A pipe electrode of iron or steel shall be protected against corrosion on the outer surface by means of galvanizing, sherardizing, or an equivalent metallic-plated coating. A protective coating of zinc shall comply with the requirements in paragraph 15.1.

Rod Electrodes

10.4 A solid-rod electrode of copper or other suitable nonferrous metal, or a solid-rod electrode of iron or steel with a copper or other suitable nonferrous metal or stainless steel jacket shall have a diameter not less than 1/2 inch (12.7 mm) or, if other than circular, shall have a periphery not less than 1.6 inches (40.6 mm) and a minimum thickness of not less than 3/8 inch (9.5 mm).

10.5 The stainless steel jacket mentioned in paragraph 10.4 shall not be less than 0.015 inch (0.38 mm) thick at any point.

10.6 The copper jacket mentioned in paragraph 10.4 shall not be less than 0.010 inch (0.25 mm) thick at any point and shall comply with the adherence requirement in paragraph 10.7 and the bending requirement in paragraph 10.8.

10.7 With reference to the requirement in paragraph 10.6 concerning adherence of the jacket, an 18 inch (457 mm) length of the rod with one end cut to a 45 degree point shall be driven between two steel clamping plates or the jaws of a vise set 0.04 inch (1.02 mm) less than the diameter of the rod, so as to shear off sufficient metal to expose the bond between the jacket and rod. Peeling of the jacket by the steel plates or the jaws of the vise is acceptable, but there shall be no other evidence of separation of the jacket from the steel core.

10.8 With reference to the requirement in paragraph 10.6 concerning bending of the rod, there shall be no evidence of cracking of the jacket if at room temperature a length of the rod is rigidly held in a clamp or vise and the free end bent by applying a force normal to the rod at a distance from the clamping device equal to 40 times the rod diameter. The magnitude of the force and the direction of application shall be such that the rod is permanently bent through a 30-degree angle.

10.9 The stainless steel jacket mentioned in paragraphs 10.4 and 10.11 or a stainless steel rod shall be formed of an austenitic stainless steel of the 18 percent chromium, 8 percent nickel type.

10.10 A solid-rod electrode of iron or steel shall have a diameter not less than 5/8 inch (15.9 mm) or, if other than circular, shall have a periphery not less than 2 inches and a minimum thickness of not less than 3/8 inch (9.5 mm).

10.11 A plastic-filled hollow-type rod electrode of stainless steel or copper or other suitable nonferrous metal with a stainless steel jacket shall have a circular cross section with an external diameter of not less than 5/8 inch (15.9 mm). The wall of the rod shall have a total thickness not less than 0.056 inch (1.4 mm) with the thickness of the stainless steel jacket not less than 0.028 inch (0.7 mm).

10.12 A hollow-tube, chemically-charged-rod electrode shall:

A. Be constructed of copper or an equivalent material resistant to the corrosive effects of moist soil;

B. Have an internal diameter not less than 2 inches (50.8 mm), and a wall thickness not less than 0.080 inch (2.03 mm); and

C. If the means of installation is not obvious, be accompanied by adequate installation instructions.

10.13 The chemical charge within the rod electrode described in paragraph 10.12 shall be a substance that does not cause the electrode to corrode at a faster rate than a pipe electrode constructed in accordance with paragraphs 10.2 and 10.3.

10.14 With reference to paragraph 10.13, a chemical charge of 60 percent sodium chloride and 40 percent calcium chloride may be used if the total weight of the charge is less than 11 pounds (5 kg).

11. Miscellaneous Devices

11.1 Grounding and bonding devices not specifically covered in paragraphs 1.1—10.14, for example, bonding locknuts, gaskets, grounding wedge lugs, adapters, and the like, shall be judged under the intent of these requirements. Particular attention shall be given to the reliability of the bonding afforded, the protection of iron and steel parts against corrosion, and the provision of means for the connection of grounding or bonding conductors if such conductors are used. Unusual features and those not contemplated by these requirements shall be investigated to determine if they are suitable for the purpose.

PERFORMANCE

12. Mechanical Strength Test

Tightening Force

12.1 A ground clamp shall withstand, without damage, a tightening force applied to each clamping bolt or screw when assembled on each size of grounding electrode with which it is intended to be used. The tightening torque is to be 150 pound-inches (16.9 N·m) applied to each clamping bolt or screw.

Exception: A torque of 50 pound-inches (5.6 N·m) is to be applied to a clamping screw intended to be tightened only with a screwdriver.

12.2 To determine if a ground clamp complies with the requirement in paragraph 12.1, two samples of a representative size of each design are to be tested. If the clamp is designed for use with a range of electrode sizes, two samples are to be tested for both the largest and smallest sizes specified. If a reversible part is employed, two samples are to be tested in both the normal and reversed positions.

Pull

12.3 A protective-type ground clamp having provision for the connection of cable armor or an armored grounding wire shall withstand for 5 minutes a pull of 150 pounds.(667 N) applied between the device and the armor of an armored grounding wire of the proper size.

12.4 During the test described in paragraph 12.3, the complete armored grounding wire is to be connected to the device in the intended manner, but the conductor itself is not to be stressed by the application of the 150-pound (667-N) force to the armor — that is, the pull on the armor is to affect only the means for holding the armor in the ground clamp. Bolts and screws are to be tightened with the torque specified in paragraph 12.1.

13. Combustion Test

13.1 If the throat of a bushing is made of thermoplastic or thermosetting insulating material:

A. The throat shall not support combustion for more than 1 minute after the last application of the flame when tested as described in paragraphs 13.8—13.13.

B. The throat shall not be completely consumed when subjected to the test described in paragraphs 13.8—13.13.

Exception: A throat of a bushing that is made of a material that has been investigated and found to comply with the requirements for material designated as 94V-0, 94V-1, or 94V-2, in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, may be consumed during the test.

C. The complete bushing assembly shall perform acceptably in the tests described in paragraphs 13.4—13.6.

13.2 The throat of a bushing made of an insulating material mentioned in the exception to item B of paragraph 13.1 shall have a thickness not less than the thickness used to determine the vertical burning rate.

13.3 Not less than six samples of each trade size are to be subjected to each test, except that if a line of at least four trade sizes of a particular design is being investigated, not less than three samples of each trade size are to be tested.

13.4 A metal bushing with a throat insulator made of a material mentioned in paragraph 13.1 is to be conditioned for 168 hours in an air-circulating oven at the temperature specified in paragraph 13.7 and Table 13.2. If the inside diameter of the throat is reduced to a dimension less than 90 percent of the value specified as a minimum in Table 13.1, the distortion of the throat is unacceptable.

TABLE 13.1
DIAMETER OF BUSHINGS

Trade Size of Fitting, Inches	Throat Diameter of Bushing, Inches (mm) Minimum	Maximum
3/8	0.444 (11.27)	0.493 (12.5)
1/2	0.560 (14.2)	0.622 (15.8)
3/4	0.742 (18.8)	0.824 (20.9)
1	0.944 (24.0)	1.049 (26.6)
1-1/4	1.242 (31.5)	1.380 (35.1)
1-1/2	1.449 (36.8)	1.610 (40.9)
2	1.860 (47.2)	2.067 (52.5)
2-1/2	2.222 (56.4)	2.469 (62.7)
3	2.761 (70.1)	3.068 (77.9)
3-1/2	3.193 (81.1)	3.548 (90.1)
4	3.623 (92.0)	4.026 (102.2)
4-1/2	4.055 (103.0)	4.506 (114.5)
5	4.542 (115.4)	5.047 (128.2)
6	5.458 (138.6)	6.065 (154.0)

13.5 A metal bushing with a throat insulator made of a material mentioned in paragraph 13.1 is to be mounted on tubing or conduit in a normal manner. Each tubing or conduit section is to be mounted horizontally in an air-circulating oven at the temperature specified in paragraph 13.7 and Table 13.2. A loop of No. 12 AWG (3.3 mm^2) bare, solid copper conductor is to be brought through the open end of each test section of tubing or conduit, and a 10 pound (4.5 kg) weight is to be suspended from each loop. The test is to be continued for 72 hours. If the insulating material cracks or melts so as to expose metal or form an incomplete insulating throat, the test results are unacceptable.

13.6 The samples conditioned as described in paragraph 13.5 are to be allowed to return to room temperature. Each sample is then to be dropped on a hardwood surface from a height of 1 foot (0.305 m). The bushing is not acceptable if a throat insulator is dislodged by the impact.

13.7 The oven temperature mentioned in paragraphs 13.4 and 13.5 is to equal the rated temperature of the insulator plus 15°C (27°F) plus 2 percent of the rated temperature on the absolute scale, as specified in Table 13.2.

TABLE 13.2
TEMPERATURES FOR CONDITIONING BUSHINGS AND PARTS

Temperature Rating of Device, Degrees		Conditioning Temperature, Degrees	
C	F	C	F
90	194	112	234
105	221	128	261
150	302	173	343

13.8 To determine whether a bushing complies with the requirements in items A and B of paragraph 13.1, the samples are to be tested as described in paragraphs 13.9—13.13.

13.9 The test is to be conducted in a 3-sided enclosure that is 12 inches (305 mm) wide, 14 inches (356 mm) deep, and 24 inches (610 mm) high. The top and front of the enclosure are to be open. The room or hood in which the enclosure is located for the test is to be adequately ventilated, but drafts are to be prevented from affecting the test flame. A sample of the bushing mentioned in paragraph 13.1 is to be mounted on a 1 foot (0.305 m) length of conduit and suspended at an angle of 45 degrees to the axis of the test flame described in paragraph 13.10. The tip of the inner blue cone of the flame is to be applied to the upper edge of the inner diameter of the bushing.

13.10 A Tirrill gas burner to which a gas pilot light is attached is to supply the test flame. The barrel of the burner is to extend 4 inches (102 mm) above the air inlets and its inside diameter is to be 3/8 inch (9.5 mm). While the barrel is vertical, the over-all height of the flame is to be adjusted to 5 inches (127 mm). The blue inner cone is to be 1-1/2 inches (38 mm) high. Without disturbing the adjustments for the height of the flame, the valves supplying gas to the burner and pilot flames are to be closed.

13.11 A wedge to which the base of the burner can be secured is to be provided for tilting the barrel 20 degrees from the vertical while the longitudinal axis of the barrel remains in a vertical plane. The burner is to be secured to the wedge and the assembly is to be placed in an adjustable jig that is attached to the floor of the enclosure. The jig is to be adjusted laterally to place the longitudinal axis of the barrel in the same vertical plane as the vertical axis of the bushing. The plane is to be parallel to the sides of the enclosure.

13.12 The jig is also to be adjusted toward the rear or front of the enclosure to a point at which the intersection of the longitudinal axis of the barrel with the plane of the tip of the barrel is 1-1/2 inches (38 mm) from the point at which the extended longitudinal axis of the barrel meets the front surface of the specimen. The latter is the point at which the tip of the inner blue cone will touch the upper edge of the diameter of the bushing.

13.13 The valve supplying gas to the pilot is to be opened and the pilot flame lit. The valve supplying gas to the burner is to be opened to apply the flame to the specimen automatically. This valve is to be held open for 15 seconds and then closed for 15 seconds. This procedure is to be repeated four times for a total of five applications of flame to the specimen.

13.14 The throat insulator shall be assigned one of the temperature ratings specified in Table 13.2 and it shall be marked where visible after installation with its temperature rating. See paragraph 16.6.

14. Current Test

14.1 A grounding or bonding fitting shall carry the current specified in Table 14.1 for the time specified in that table. The current shall be based on either (1) the conduit size involved or (2) the largest size of wire for which the fitting is marked, whichever is less. The fitting shall not crack, break, or melt. Arcing and burning of a throat insulator is acceptable.

TABLE 14.1
SHORT-TIME TEST CURRENTS

Conduit Trade Size, Inch	Equipment Grounding and Bonding Conductor Size (Copper), AWG (mm^2)	Time, Seconds	Test Current, Amperes
—	14 AWG (2.1)	4	300
—	12 (3.3)	4	470
—	10 (5.3)	4	750
1/2	8 (8.4)	4	1180
3/4, 1	6 (13.3)	6	1530
1-1/4, 1-1/2	4 (21.2)	6	2450
—	3 (26.7)	6	3100
2	2 (33.6)	6	3900
2-1/2	1 (42.4)	6	4900
3, 3-1/2, 4	1/0 (53.5)	9	5050
4-1/2	2/0 (67.4)	9	6400
5, 6	3/0 (85.0)	9	8030
—	4/0 (107)	9	10100
—	250 MCM (127)	9	12000

14.2 A grounding or bonding fitting intended for use with a grounding conductor is to be mounted on a length of maximum size ground rod, conduit, or galvanized pipe, for which it is intended to be used; or on an enclosure or outlet box in the intended manner. A grounding conductor of the maximum intended size, not less than 2 feet (0.609 m) long, is to be installed. A pressure wire connector employed to hold the conductor is to be tightened using a torque specified in the Standard for Wire Connectors and Soldering Lugs for Use With Copper Conductors, UL 486A. The test current is to be passed through the equipment and the grounding wire in series.

14.3 A bonding device intended to bond conduit to an enclosure is to be tested by assembling the device, with the maximum intended size conduit, to a typical enclosure, such as a 4-inch (102-mm) square outlet box, and causing the test current to flow from the conduit through the joint to the enclosure. The test current is to be as specified in Table 14.1 for the conduit size used.

14.4 After having carried the current specified in paragraph 14.1, continuity shall exist on the test sample assembly when measured between a point on the rod, conduit, pipe, enclosure, or outlet box 1/4 inch (6.4 mm) from the connection of a grounding or bonding fitting and a similar point on the wire.

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

15. Metallic-Coating Thickness Test

15.1 A protective coating of zinc or cadmium shall be such that it will withstand the metallic-coating-thickness test for the number of seconds specified in Table 15.1 — see paragraph 15.8.

Exception: The time may be at least one-half the value specified in the table only if the device provides for a direct pressure connection between the grounding conductor and the surface of an outlet box.

TABLE 15.1
METALLIC COATING THICKNESS

Temperature, Degrees F (C)	Time, Seconds	
	Zinc	Cadmium
65 (16)	106	78
70 (21)	102	76
75 (24)	98	72
80 (27)	94	70
85 (29)	90	68
90 (32)	86	64
95 (35)	84	62

15.2 The method of determining the thickness of zinc or cadmium coatings by the metallic-coating-thickness test is described in paragraphs 15.3—15.9.

15.3 The solution to be used for the metallic-coating-thickness test is to be made from distilled water and is to contain 200 grams per liter of reagent grade chromic acid (CrO_3) and 50 grams per liter of reagent grade concentrated sulphuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of reagent grade concentrated sulphuric acid, specific gravity 1.84, containing 96 percent of H_2SO_4.

15.4 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube having an inside bore of 0.025 inch (0.64 mm) and a length of 5.5 inches (140 mm). The lower end of the capillary tube is tapered to form a tip, the drops from which are about 0.05 milliliters each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that, when the stopcock is open, the rate of dropping is 100 ± 5 drops per minute. An additional stopcock may be used in place of the glass tube to control the rate of dropping.

15.5 The sample and the test solution are to be kept in the test room long enough to acquire the temperature of the room, which is to be noted and recorded. The test is to be conducted at a room temperature of 70.0—90.0°F (21.1—32.2°C).

15.6 Each sample is to be thoroughly cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings are to be removed completely by means of solvents. Samples are then to be thoroughly rinsed in water and dried with clean cheesecloth. Care is to be exercised to avoid contact of the cleaned surface with the hands or any foreign material.

15.7 The sample to be tested is to be supported from 0.7—1 inch (17.8—25.4 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested should be inclined about 45 degrees from horizontal.

15.8 After cleaning, the sample to be tested is to be put in place under the orifice. The stopcock is to be opened and the time in seconds is to be measured with a stop watch until the dropping solution dissolves the protective metal coating exposing the base metal. The end point is the first appearance of the base metal recognizable by a change in color at that point.

15.9 Each sample of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface, at places where the metal coating may be expected to be the thinnest. On grounding and bonding equipment made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

MARKING

16. Details

16.1 A ground clamp shall be stamped, cast, or otherwise acceptably marked where readily visible as follows:

A. A clamp shall be marked with:

1. The manufacturer's name, trade name, or both, or any other acceptable marking whereby the organization responsible for the product can be readily identified.

2. The size of electrode and grounding wire with which the clamp is intended to be used.

B. A protective clamp shall be marked with the size of rigid metal conduit or armor, unless the size is obvious.

C. A clamp larger than 2 inches (50.8 mm) shall be marked with a distinctive catalog number or equivalent identification.

D. For a 2-inch or smaller clamp, the catalog number or an equivalent identification shall be marked on the (1) clamp, (2) carton or other clamp package, or (3) clamp and on the package.

E. A clamp that is acceptable for use with aluminum wire shall be marked (1) "AL" or (2) as specified in items A—D of this paragraph in addition to the markings specified in items A—D and "AL" marked on a tag secured to the clamp by a reliable means such as a wire through a metal eyelet in the tag.

F. A clamp that is acceptable for use with aluminum or copper wire shall be marked (1) "AL-CU" or (2) as specified in items A—D of this paragraph in addition to the markings specified in items A—D and "AL-CU" marked on a tag secured to the clamp by a reliable means such as a wire through a metal eyelet in the tag.

16.2 A grounding or bonding bushing shall be stamped, cast, or otherwise acceptably marked where readily visible as follows:

A. A bushing shall be marked with (1) the manufacturer's name, trade name, or both, or (2) any other distinctive marking whereby the organization responsible for the product can be readily identified.

B. A bushing larger than 2 inches (50.8 mm) shall be marked with a distinctive catalog number or equivalent identification.

C. For a 2-inch and smaller bushing, the catalog number or equivalent identification shall be marked on the (1) bushing, (2) carton or other bushing package, or (3) bushing and the package.

D. A bushing that does not have a mounting for a separable wire connector shall be marked with the size of the grounding wire with which the bushing is intended to be used.

E. For a bushing having a mounting for a separable wire connector — see paragraph 7.6 — the size of grounding wire accommodated by each connector intended for use with the bushing shall be marked on the (1) bushing, (2) carton or other bushing package, or (3) bushing and the package.

16.3 A grounding or bonding locknut shall be stamped, cast, or otherwise marked where readily visible as follows:

A. A locknut shall be marked with (1) the manufacturer's name, trade name, or both, or (2) any other distinctive marking whereby the organization responsible for the product can be readily identified.

B. A locknut larger than 2 inches (50.8 mm) shall be marked with a distinctive catalog number or equivalent identification.

C. For a 2-inch or smaller locknut the catalog number or a distinctive equivalent identification shall be marked on the (1) locknut, (2) carton or other locknut package, or (3) locknut and the package.

16.4 In a series or complete line of products that consists of devices assembled from interchangeable parts, each part shall have a marking that, taken together with the markings on all of the other parts assembled as intended to form a complete device, results in a distinctive catalog number, type designation, or the like that definitely identifies the assembled device.

16.5 As an example of compliance of devices with the requirement in paragraph 16.4, threaded parts for the connection of rigid metal conduit might be designated and marked A for 1/2 inch (12.7 mm), B for 3/4 inch (19.1 mm), C for 1 inch (25.4 mm), D for 1-1/4 inch (31.8 mm), and the like. Clamp parts for water-pipe or rod electrodes might be designated and marked 2 for 1/2 inch, 3 for 3/4 inch, 4 for 1 inch, 5 for 1-1/4 inch, and the like. Then the complete assemblies constituting the series would be designated and identifiable as A—2, B—3, B—4, C—3, C—4, D—5, and the like.

16.6 A black or brown color may be used to identify an insulator rated 150°C (302°F), as mentioned in paragraph 13.14, and an insulator having a rating other than 150°C (302°F) shall not be black or brown. A part rated 90°C (194°F) need not be marked.

16.7 The marking of a ground rod shall be located within 12 inches (305 mm) of the top of the rod and shall include the following:

A. The manufacturer's name, trade name, or both, or any other distinctive marking whereby the organization responsible for the product can readily be identified.

B. A distinctive catalog number or an equivalent identification.

C. The length of the rod.

16.8 The following information shall be plainly marked on a tag that is to be tied to every shipping length of finished armored grounding wire. If the wire is wound on a reel or coiled in a carton, the tag may be glued, tied, stapled, or otherwise attached to the reel or carton, the information may be printed or stenciled on the reel or carton. Other information may be included if it is not confusing or misleading. The marking shall be as follows:

A. The words "Bare armored grounding wire."

B. The manufacturer's name, trade name, or both, or any other distinctive marking whereby the organization responsible for the product can readily be identified.

C. The AWG size of the grounding conductor.

HOSPITAL GROUNDING EQUIPMENT

17. General

17.1 The requirements in paragraphs 18.1—20.2 apply to grounding jacks and mating grounding cord assemblies that are intended for use in a hospital room or other health-care facility to connect equipment to a patient grounding point or other appropriate reference grounding point.

18. Construction

Cord

18.1 The cord of a grounding cord assembly shall be stranded copper wire not smaller than No. 10 AWG (5.3 mm^2) with the individual strands of wire not larger than 0.0159 inch (0.4 mm) in diameter.

18.2 The insulation on the conductors shall not be less than 3/64 inch (1.2 mm) thick, and shall comply with the requirements in paragraphs 19.5 and 19.9.

18.3 With reference to paragraph 18.2, the surface of the insulation on the conductor shall be green with or without one or more yellow stripes.

18.4 The connection between a plug and cord shall comply with the requirements for strain relief in paragraph 19.4.

Field-Wiring Terminals and Leads

18.5 A grounding jack shall have a wiring terminal for connection to a field-installed conductor or a No. 10 or larger threaded stud and nut terminal for bolted connection to a bus bar. A terminal of either configuration shall be copper or copper alloy.

Exception: The pressure screw of a wiring terminal and the nut of a stud terminal may be of other acceptable metal.

18.6 A wiring terminal shall be suitable for the connection of a No. 10 AWG (5.3 mm^2) copper conductor and may hold conductors of other sizes if the connection complies with the secureness and pull-out tests described in the Standard for Wire Connectors and Soldering Lugs for Use With Copper Conductors, UL 486A.

18.7 A terminal shall be crimped to the conductor at the end of a grounding cord assembly opposite the plug, and shall have a closed-loop eyelet for bolted connection to equipment to be grounded. The connection shall comply with the secureness and pull-out tests described in the Standard for Wire Connectors and Soldering Lugs for Use With Copper Conductors, UL 486A.

Exception: A connection other than a crimp connection, such as a brazed or welded connection, may be used.

18.8 Insulation on a handle shall be green and shall comply with the flammability requirements in paragraph 19.6. Rubber and rubberlike materials shall also comply with the requirements in paragraphs 19.10 and 19.11.

18.9 A handle shall be positively secured to a grounding plug.

18.10 A pin shall be copper or copper alloy.

Grounding Jacks

18.11 The visible face of a grounding jack shall be green. A grounding jack contact shall be copper or copper alloy.

Samples

18.12 Six samples of a grounding cord assembly shall be subjected to the tests described in pargraphs 19.1—19.11.

18.13 Samples that consist of a terminal connector, cord, plug, and grounding jack are to be assembled to simulate the end-use application.

19. Performance

Contact Resistance

19.1 A direct current of 30 amperes is to be passed through the samples and the contact resistance is to be measured. The resultant voltage drop is to be measured across each assembly from the grounding jack to the terminal connector. The resistance shall not exceed 0.030 ohms nor be more than 0.005 ohms greater than the resistance of the grounding cord assembly measured from the tip of the plug to the terminal connector.

Endurance

19.2 The samples used for the contact resistance test are to be subjected to 6000 cycles of insertion, twist to lock and unlock if appropriate, and withdrawal. There shall be no mechanical damage to the plug or the grounding jack.

19.3 Following the endurance test described in paragraph 19.2, the samples are to be subjected to a repeated contact resistance test. The resistance shall not have increased by more than 0.005 ohms.

Strain Relief

19.4 Six new samples are to be assembled as intended. With the plug held by the pin in the horizontal plane, the cord shall withstand for 1 minute, without more than 1/32-inch displacement from the handle or the plug, a 35-pound vertical force applied to the grounding cord terminal. For an assembly having a plug handle molded on the pin, the force is to be applied to both molded and unmolded samples.

Flame Resistance

19.5 Insulated wire shall comply with the flammability requirements for the vertical flame test as described in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, or in the Standard for Rubber-Insulated Wires and Cables, UL 44, whichever is appropriate.

19.6 Insulation on a grounding jack shall comply with the requirements in paragraph 19.7. Rubber and rubberlike insulation on a grounding jack shall also comply with the requirements in paragraphs 19.10 and 19.11.

19.7 When tested as described in paragraph 19.8, the insulation on a grounding jack or a plug handle shall not support combustion for more than 1 minute after five 15-second applications of a test flame, with an interval of 15 seconds between applications of the flame.

19.8 The test is to be conducted as described in paragraphs 13.9—13.13, except that the grounding jack is to be mounted on 0.053 inch (1.3 mm) thick steel in the intended manner. The tip of the inner blue cone of the flame is to be applied (1) to the lower edge of the visible face of the grounding jack, (2) to the body of the plug handle with the plug installed in the jack, and (3) with the steel plate rotated 180 degrees about the vertical axis, to the body of the grounding jack.

Dielectric Voltage Withstand

19.9 Insulation on a wire shall withstand for 1 minute without breakdown the application of 1500 volts applied as described in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, or in the Standard for Rubber-Insulated Wires and Cables, UL 44, whichever is appropriate.

Accelerated Aging

19.10 A rubber-insulated cord or handle shall show no apparent deterioration and shall show no greater change in hardness than five numbers — 0.005 inch (0.13 mm) — as a result of a 96-hour exposure to oxygen at a pressure of 300 ± 10 pounds per square inch gauge (psig) and a temperature of 70.0 ± 1.0°C (158.0 ± 1.8°F).

19.11 The hardness of the rubber is to be determined as the average of five readings with a suitable gauge such as a Rex hardness gauge or a Shore durometer. The device is then to be exposed to oxygen for 96 hours in accordance with the method described in the Standard for Rubber-Insulated Wires and Cables, UL 44. The device is to be allowed to rest at room temperature for at least 4 hours after removal from the oxygen bomb. 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 oxygen is the change in hardness.

20. Marking

20.1 A plug handle or grounding jack body shall be marked with (1) the manufacturer's name, and (2) the catalog number or the equivalent.

20.2 The cover of a hospital grounding jack having a twist-to-lock configuration shall be marked "Lock — for Grounding" or "Twist to Lock — for Grounding."