



UL 467

STANDARD FOR SAFETY

Grounding and Bonding Equipment

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UL Standard for Safety for Grounding and Bonding Equipment, UL 467

Tenth Edition, Dated March 22, 2013

Summary of Topics

This trinational Standard for Grounding and Bonding Equipment, UL 467, covers grounding and bonding equipment and harmonizes ANCE, CSA Group, and UL requirements.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated January 6, 2012 and October 26, 2012.

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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 preface. 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that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

The following table lists the future effective dates with the corresponding reference.

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| Future Effective Date | Reference |
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| March 22, 2016 | Annex C and D |

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Association of Standardization and Certification
NMX-J-590-ANCE
First Edition



CSA Group
CSA C22.2 No. 41-13
Sixth Edition



Underwriters Laboratories Inc.
UL 467
Tenth Edition

Grounding and Bonding Equipment

March 22, 2013



ANSI/UL 467-2013

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

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This ANSI/UL Standard for Safety consists of the Tenth edition. The most recent designation of ANSI/UL 467 as an American National Standard (ANSI) occurred on March 22, 2013. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information.

The Department of Defense (DoD) has adopted UL 467 on June 12, 1987. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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>.

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Preface

This is the harmonized ANCE, CSA Group, and UL standard for grounding and bonding equipment. It is the first edition of NMX-J-590-ANCE, the sixth edition of CSA C22.2 No. 41, and the tenth edition of UL 467. This edition of CSA C22.2 No. 41 supersedes the previous edition published in 2007. This edition of UL 467 supersedes the previous edition published in 2007.

This harmonized standard was prepared by the Association of Standardization and Certification (ANCE), the CSA Group, and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Connectors, of the Council on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

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

This standard was reviewed by the CSA Integrated Committee on Electrical Connectors, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

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

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

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

Level of harmonization

This standard uses the IEC format but is not based on, nor is it considered equivalent to, an IEC standard. This standard is published as an equivalent standard for ANCE, CSA Group and UL.

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

Reasons for differences from IEC

The Technical Harmonization Committee identified one IEC standard, IEC 60364-5-54, that addresses grounding and bonding equipment included in the scope of this Standard, Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors. This standard addresses the earthing arrangements, protective conductors, and protective bonding conductors in order to satisfy the safety requirements of the electrical installation. It has the status of a basic safety publication in accordance with IEC Guide 104.

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The IEC standards for grounding and bonding equipment are recognized as being generally system specific. The THC determined that the safe use of grounding and bonding equipment is dependent on the design and performance of the grounding and bonding equipment in relation to the North American electrical codes with which they are intended to be installed.

Interpretations

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

ANCE effective date

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

CSA Group effective date

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

UL effective date

As of March 22, 2013, all products Listed or Recognized by UL must comply with the requirements in this standard except for annexes in the following list, which are effective March 22, 2016.

Annex C and Annex D

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

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1 Scope

1.1 This Standard applies to grounding and bonding equipment for use in accordance with the *Canadian Electrical Code, Part I, CSA C22.1*, in Canada, the *National Electrical Code, NFPA 70*, in the United States, or the *Standard for Electrical Installations, NOM-001-SEDE*, in Mexico.

1.2 This Standard applies to the following grounding and bonding equipment:

- a) ground clamps, bonding devices, grounding bushings, water-meter shunts, grounding electrodes, and the like used in a grounding system;
- b) equipment for making electrical connections between
 - i) the grounding conductors used in electrical power systems, non-current-carrying metal parts of electrical equipment, armored grounding wires, metal raceways, and the like; and
 - ii) grounding electrodes;
- c) equipment for making electrical connections between
 - i) the grounding conductors used in telecommunications systems such as telephone, radio, CATV, network power broadband, and the like; and
 - ii) grounding electrodes;
- d) hospital grounding jacks and mating grounding cord assemblies (for Mexico and the United States, see Annex A);
- e) bonding devices for making electrical connections between
 - i) the hex head of a brass fitting used in a piping system in accordance with 250.104 of NFPA 70; and
 - ii) the grounding electrodes; and
- f) intersystem bonding terminations for connecting intersystem bonding and grounding conductors for other systems in accordance with NFPA 70.

Notes:

1) In Canada, "hospital grounding jacks" are not defined in CSA C22.1, *Canadian Electrical Code, Part I*.

2) In Canada, "mating ground cord assemblies" are covered in CSA C22.2 No. 21 and CSA C22.2 No. 42.

2 Reference publications

For undated references to Standards, such reference shall be considered to refer to the latest edition and all revisions to that edition up to the time when this Standard was approved. For dated references to Standards, such reference shall be considered to refer to the dated edition and all revisions published to that edition up to the time the Standard was approved.

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NOM-001-SEDE
Standard for Electrical Installations

NMX-J-010-ANCE
Thermoplastic-Insulated Wires and Cables

NMX-J-017-ANCE
Conduit, Tubing and Cable Fittings

NMX-J-451-ANCE
Thermoset-Insulated Wires and Cables

NMX-J-543-ANCE
Wire Connectors

NMX-J-548-ANCE
Splicing Wire Connectors

CSA (Canadian Standards Association)

Note: For products intended for use in Canada, general requirements are given in CAN/CSA-C22.2 No. 0 and grounding and bonding requirements are given in CSA C22.2 No. 0.4.

C22.1-12
Canadian Electrical Code, Part I

CAN/CSA-C22.2 No. 0-10
General requirements – Canadian Electrical Code, Part II

C22.2 No. 0.4-04,
Bonding and grounding of electrical equipment

C22.2 No. 18.3
Conduit, tubing, and cable fittings

C22.2 No. 21-95 (R2004)
Cord sets and power supply cords

C22.2 No. 42-99 (R2004)
General use receptacles, attachment plugs, and similar wiring devices

C22.2 No. 51-09
Armoured cables

C22.2 No. 65-03
Wire connectors

C22.2 No. 188-04
Splicing wire connectors

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UL 4
Standard for Armored Cable

UL 44
Thermoset-Insulated Wires and Cables

UL 83
Thermoplastic-Insulated Wires and Cables

UL 486A-486B
Wire Connectors

UL 486C
Splicing Wire Connectors

UL 514B
Conduit, Tubing, and Cable Fittings

ASTM (American Society for Testing and Materials)

A 90/A 90M-01
Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A 653/A 653M-04a
Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by Hot-Dip Process

IEEE (Institute of Electrical and Electronics Engineers)

IEEE 837-2002
Standard for Qualifying Permanent Connections Used in Substation Grounding

NFPA (National Fire Protection Association)

NFPA 70-2011
National Electrical Code (NEC)

3 Units of measurement

The values given in SI (metric) units shall be normative, except for AWG/kcmil conductor sizes and other trade sizes. Any other values given shall be for information only.

4 Definitions

The following definitions apply in this Standard:

Bonding bushing – a bushing having one or more screws intended to provide the bonding function between the bushing and the enclosure (see Figure 1(c)).

Ground clamp – a device used for connection of a grounding conductor to a grounding electrode (see Figure 1(a)).

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Grounding bushing – a bushing having provision for the connection of a bonding or grounding conductor (see Figure 1(b)).

Note: A grounding bushing may also be provided with one or more screws intended to supplement the bonding function between the bushing and the enclosure.

Ground mesh – a copper wire mesh that is intended to be installed in ground or embedded in concrete and bonded to a grounding electrode system for the purpose of improving ground planes.

Intersystem bonding termination – a device that provides a means for connecting bonding conductor(s) for communications systems to the grounding electrode system.

Plate electrode – a metal plate, having a defined surface area, with a means for attachment to the system-grounding conductor.

Protective-type clamp – a ground clamp designed so that the grounding conductor and its connection will be effectively protected against mechanical damage.

Separable connector – a wire connector that is removable from the bushing with which it is used.

Strap-type clamp – a clamp constructed of perforated or expanded flexible metal suitable for assembly on pipe.

5 Components

A component shall comply with the ANCE, CSA Group or UL standards as appropriate for the country where the product is to be used.

6 Construction

6.1 General

6.1.1 A grounding or bonding device shall be constructed of metals or metal alloys that provide sufficient strength and rigidity to permit installation and use in the intended manner without either:

- a) adversely affecting the function of the device; or
- b) damaging the grounding or bonding conductor, the grounding electrode, or equipment to which the device is attached.

6.1.2 A grounding or bonding device marked for direct burial shall be provided with all screws necessary for assembly or connection of the device, and all components shall be constructed of:

- a) copper or a copper alloy containing not less than 80% copper;
- b) stainless steel; or
- c) materials other than aluminum and aluminum alloys, if investigated and found to be acceptable for the application.

Note: Among the factors to be taken into consideration when judging the acceptability of such materials are the

- a) *change of resistance across the bonding-grounding joint; and*

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b) *amount and degree of corrosion.*

6.1.3 Connectors provided as part of a grounding or bonding device shall comply with the construction requirements of

a) NMX-J-543-ANCE, CSA C22.2 No. 65 or UL 486A-486B; or

b) NMX-J-548-ANCE, CSA C22.2 No. 188 or UL 486C

and may be made of iron or steel with a steel terminal screw.

6.1.4 Means for the attachment of a grounding or bonding conductor shall be so designed that the conductor is securely and reliably held without depending on solder.

6.1.5 For connectors not covered in Clause 6.1.3, and where the conductor is attached by means of a single screw, the size of the screw shall not be smaller than as specified in Table 1.

6.1.6 A wire-binding screw shall be provided with upturned lugs or the equivalent capable of holding a wire under the head of the screw.

6.1.7 A cast iron part, other than malleable iron, shall be not less than 3.2 mm (1/8 in) thick. A malleable iron part, a nonferrous cast-metal part, and a die-cast or extruded part shall be not less than 2.4 mm (3/32 in) thick, except that a die-cast part may be not less than 1.6 mm (1/16 in) thick if it is ribbed or otherwise reinforced and not marked for direct burial.

6.1.8 A fitting, such as a hub, a bushing, or a locknut to be used for grounding and intended to provide a rain-tight or liquid-tight connection between threaded metal conduit and a sheet metal enclosure shall comply with the requirements in this Standard and with the requirements for such a fitting in NMX-J-017-ANCE, CSA C22.2 No. 18.3, or UL 514B. See Clause 10.4.

6.1.9 A device intended for the connection of 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 metal conduit, it shall be provided with not less than three full threads in the metal.

6.2 Protective-type ground clamps

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

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

6.2.3 A protective-type clamp shall provide an electrical and mechanical connection between the grounding electrode and a grounding conductor protected by armor or metal raceway. The mechanical connection shall be rigid if the clamp is designed for use with metal conduit.

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6.2.4 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 metal conduit, it shall be provided with not less than the applicable number of straps specified in Table 2, depending upon the trade size of metal conduit with which it is intended to be used.

6.3 Strap-type clamps

6.3.1 A strap-type clamp shall not be less than 12.7 mm (1/2 in) wide and 0.64 mm (0.025 in) thick.

6.3.2 A communications strap-type clamp shall not be less than 12.7 mm (1/2 in) in width and not be less than 0.64 mm (0.025 in) in thickness. Strap-type clamps intended for outdoor use shall satisfy the temperature conditioning test described in Clause 9.9.

6.3.3 Communication ground clamps may be in the form of straps of copper or other suitable metal.

6.3.4 Communication ground straps shall be fitted either with brass or galvanized steel screws.

6.4 Protection against corrosion

6.4.1 A grounding or bonding device shall be protected by a zinc coating at least 0.025 mm (0.001 in) thick, except as follows:

- a) if the metal is inherently resistant to corrosion such as nonferrous or stainless steel;
- b) a device that is used in conjunction with an electrical metallic raceway or metallic cable system and complies with the corrosion protection requirements for fittings in CSA C22.2 No. 18.3 or UL 514B;
- c) the thickness of the coating shall be at least 0.013 mm (0.0005 in) if the device provides for a direct pressure connection between the grounding or bonding conductor and the surface of an outlet box;
- d) the thickness of the coating shall be at least 0.0038 mm (0.00015 in) if the device is intended for use completely inside an outlet box.

Also see Clause 6.4.6.

6.4.2 In regards to Clause 6.4.1, corrosion protection on small parts of the grounding and bonding device, such as screws, is not specified. Evidence of corrosion protection shall be verified by visual inspection.

6.4.3 Unless a grounding or bonding device is made of a material specified in Clause 6.1.2, a plating or a coating provided on the 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.

6.4.4 Except as specified in Clause 6.4.3, colored chromate shall be permitted.

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6.4.5 Die-cast zinc or another metal shall be one or more of the following:

- a) a grade or alloy known to be resistant to atmospheric corrosion;
- b) subjected to appropriate tests; or
- c) additionally protected against corrosion.

6.4.6 In accordance with Clause 6.4.1, a device constructed of ferrous metal shall be protected against corrosion by one of the following means or by other metallic coatings that have been found to give equivalent protection, as described in Clause 6.4.7:

- a) hot-dipped, mill-galvanized sheet steel conforming with the coating designation G90 in Table I of ASTM A 653/A 653M, with not less than 40% of the zinc on any side, based on the minimum single-spot-test requirement in ASTM A 653/A 653M. The weight of zinc coating may be determined by any acceptable method; however, in case of question, the weight of coating shall be established in accordance with ASTM A 90/A 90M; and
- b) a zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to a thickness of not less than 0.025 mm (0.001 in) on each surface. The thickness of the coating shall be established by the thickness of protective coating test described in Clause 9.6.

6.4.7 With reference to Clause 6.4.6, other finishes, including special metallic finishes, may be used when comparative tests with galvanized sheet steel having no annealing, wiping, or other surface treatment that conform to Clause 6.4.6, Item (a), indicate they provide equivalent protection.

Note: *Among the factors that are taken into consideration when judging the acceptability of such coating systems are exposure to salt spray, moist carbon dioxide-sulphur dioxide-air mixtures, moist hydrogen sulphide-air mixtures, ultraviolet light, and water.*

6.5 Ground clamps

6.5.1 Clamps and electrode connections shall be any one of the following:

- a) rigid bolted clamps of cast, formed, or extruded metal;
- b) plug-type grounding fittings (pipe fittings, plugs, or other approved forms for threading into pipes or pipe fittings); or
- c) exothermically welded connections.

6.5.2 A clamp for use in damp or dry locations shall be made of copper alloy, malleable iron, aluminum, or die-cast zinc.

6.5.3 In Canada, a clamp used for a wet location shall be of copper, bronze, or brass, and the bolts shall be of similar material or of stainless steel.

In Mexico and the United States, a clamp used for a wet location shall be of copper, bronze, brass, zinc alloys, or aluminum, and the bolts shall be of similar material or of stainless steel.

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6.6 Bushings

6.6.1 Bushings shall meet the requirements of CSA C22.2 No. 18.3, UL 514B, or NMX-J-017-ANCE. For an insulated metal bushing, all surfaces of the throat that can be contacted by a conductor shall be lined with the insulating material.

6.6.2 Bonding bushings shall be provided with a means (usually one or more set screws) for reliably bonding the bushing (and the conduit or fittings on which it is attached) to the metal equipment enclosure or box. A means for connecting a grounding or bonding conductor shall not be provided.

Note: *If there is need for a grounding or bonding conductor, a grounding bushing should be used.*

6.6.3 A bonding screw intended to bond a bushing to an enclosure shall be adjustable to extend not less than 3.2 mm (1/8 in) 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 3.2 mm (1/8 in), but not less than 1.6 mm (1/16 in). When adjusted in any position, a bonding screw shall engage not less than two threads in the bushing.

6.6.4 Grounding bushings shall have provision for the connection of the minimum size bonding or grounding conductor in accordance with Table 3 or have provisions for mounting a separable wire connector accepting the minimum size conductor in accordance with Table 3. A grounding bushing shall also have means (usually one or more set screws) for reliably bonding the bushing to the metal equipment enclosure or box in the same manner that is accomplished by a bonding bushing, see Clauses 6.6.2 and 6.6.3.

Note: *Grounding bushings may be used with or without a bonding or grounding conductor as determined by the bonding or grounding function that is intended to be accomplished.*

6.6.5 With reference to the requirement in Clause 6.6.4, an integral wire connector is considered to be nonremovable from the grounding bushing. A separable wire connector may be either factory assembled to the grounding bushing or be separately available from the manufacturer.

6.7 Fittings

A grounding fitting or bonding fitting shall meet the requirements of Clauses 6.2, 6.4, 6.5, and 6.6, as applicable.

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6.8 Water-meter shunts

A water-meter shunt shall consist of two clamps connected by means of a 4 AWG (21.2 mm²) or larger solid copper wire. The clamps shall comply with the requirements for clamps given in this Standard.

6.9 Armored grounding wire

6.9.1 General

Armored grounding wire shall consist of a single corrosion-resistant copper, aluminum, or copper-clad aluminum conductor, within a flexible, helically formed steel armor similar in general design to that employed in armored cable.

6.9.2 Conductor

The conductor shall be sized in accordance with Table 4 and shall comply with the short-time current requirement in Clause 9.5. The conductor is not required to be tinned.

6.9.3 Armor

6.9.3.1 Splices made in the steel strip forming the armor shall not increase the thickness or diameter of the armor or lessen its mechanical strength.

6.9.3.2 The strip used in the armor shall not be less than 0.64 mm (0.025 in) thick.

6.9.3.3 In an armored grounding wire employing an uninsulated (bare) conductor, the weight of single-strip steel armor shall not be less than specified in Table 4.

6.9.3.4 The steel armor of an armored grounding wire shall comply with the requirements for zinc coating, be able to support a tension of 667 N (150 lbf), and have the flexibility applicable to armored cable.

Note: The steel armor of an armored grounding wire conforming to CSA C22.2 No. 51 or UL 4 is considered to be in compliance with Clauses 6.9.3.1 to 6.9.3.4.

6.10 Grounding electrodes

6.10.1 General

Grounding electrodes shall be one of the types described in Clauses 6.10.2 to 6.10.4.

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6.10.2 Rod electrodes

6.10.2.1 In Canada and Mexico, a rod electrode shall not be less than 3 m (10 ft) long.

In the United States, a rod electrode shall be not less than 2.44 m (8 ft) long.

6.10.2.2 In Mexico, a solid rod electrode of iron or steel shall have a diameter not less than 16 mm (5/8 in).

In Canada, a solid rod electrode of iron or steel shall have a diameter not less than 15.8 mm (5/8 in).

In the United States, a solid rod electrode of iron or steel shall have a diameter not less than 15.87 mm (5/8 in).

6.10.2.3 In Mexico, an uncoated solid rod electrode of stainless steel, copper, or suitable nonferrous metal shall have a diameter of not less than 14.8 mm (0.583 in).

In Canada and the United States, a solid rod electrode of stainless steel, copper, or suitable nonferrous metal shall have a diameter not less than 12.7 mm (1/2 in).

6.10.2.4 A coated solid rod electrode of iron or steel shall have a zinc, stainless steel, copper, or suitable nonferrous metal coating and shall have a diameter of not less than 12.7 mm (1/2 in).

6.10.2.5 The stainless steel coating shall not be less than 0.38 mm (0.015 in) thick at any point.

6.10.2.6 The copper coating shall not be less than 0.25 mm (0.010 in) thick at any point and shall comply with the adherence requirement in Clause 7.7.1 and the bending requirement in Clause 7.7.2.

6.10.2.7 A zinc coating shall not be less than 0.099 mm (0.0039 in) thick at any point and shall comply with the adherence requirements in Clause 7.7.1 and the bending requirements in Clause 7.7.2.

6.10.2.8 The stainless steel coating or a stainless steel rod shall be formed of an austenitic stainless steel of the 18% chromium, 8% nickel type.

6.10.3 Chemically charged rod electrodes

6.10.3.1 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 49.3 mm (1.94 in) and a wall thickness not less than 1.93 mm (0.076 in);
- c) comply with the minimum length in Clause 6.10.2.1; and
- d) be accompanied by adequate installation and maintenance instructions.

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6.10.3.2 The chemical charge within the rod electrode shall be a substance that does not cause the electrode to corrode at a faster rate than an electrode constructed of trade size 3/4 (21) ferrous metal conduit.

6.10.3.3 A chemical charge of 60% sodium chloride and 40% calcium chloride having a total weight of less than 5 kg (11 lb) may be used without further evaluation.

6.10.4 Plate electrodes

6.10.4.1 A plate electrode shall

- a) be not less than 6.4 mm (1/4 in) in thickness if of iron or steel, or 1.5 mm (0.06 in) if of nonferrous metal, other than aluminum;
- b) have a total surface area of not less than 0.186 m² (2 ft²);
- c) if provided with a means of connection to the system grounding conductor, have connections that comply with the requirements of Clauses 6.1.3, 7.1, and 7.5; and
- d) shall be marked in accordance with Clause 10.10.

6.10.4.2 In Canada, a plate electrode for concrete encasement shall

- a) be not less than 6 mm (0.24 in) in thickness if of iron or steel or 1.5 mm (0.06 in) if of nonferrous metal, other than aluminum;
- b) have a total surface area of not less than 0.4 m² (4.3 ft²);
- c) have a means of connection to the system-grounding conductor that shall be accessible. Solderless connections used for attachment to the system grounding conductor shall comply with the requirements of Clauses 6.1.3, 7.1, and 7.5; and
- d) comply with the requirements of Clauses 6.4 and 10.11.

In the United States, the requirements of Clause 6.10.4.1 apply to all plate electrodes.

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6.11 Ground mesh

6.11.1 Ground mesh shall consist of 8 AWG minimum copper or copper alloy wire, stainless steel wire, or other material found to meet the requirement of this Standard.

6.11.2 The wire shall be fashioned into a grid. The grid pattern shall not have any dimension less than 102 mm (4 in) or greater than 610 mm (24 in). The intersections of the wires of the grid shall be welded or brazed.

6.12 Miscellaneous devices

Grounding or bonding devices not specifically covered in the preceding requirements, such as bonding locknuts, gaskets, grounding wedge lugs, signal reference grids, exothermic welding connection systems (see Annex D), twist-on connecting devices, and adapters, shall be judged under the intent of these requirements. Special 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 suitable grounding or bonding conductors where the use of such conductors is involved. Unusual features and those not contemplated by these requirements shall be investigated to determine if they are suitable for the purpose.

7 Test requirements

7.1 Wire connectors

7.1.1 Except as stated in Clause 7.1.2, wire connectors provided as part of a grounding or bonding device shall comply with the static heating sequence and the mechanical sequence test requirements of NMX-J-543-ANCE, CSA C22.2 No. 65 or UL 486A-486B, or NMX-J-548-ANCE, CSA C22.2 No. 188, or UL 486C, as appropriate. The static heating test of the static heating sequence is not required.

7.1.2 A binding-screw-type connector employed in a grounding device shall not be required to be subjected to these tests.

7.2 Tightening force for ground clamps

7.2.1 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.

7.2.2 With regards to Clause 7.2.1, an acorn style clamp that has been subjected to the requirements in Clause 7.1 need not be subjected to this test.

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7.3 Pull – protective-type ground clamp

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

7.4 Grounding and bonding devices with throat liners

7.4.1 Grounding and bonding devices with throat liners shall comply with the performance requirements for Bushings, Insulating bushings, and Fittings with throat liners of CSA C22.2 No.18.3, NMX-J-017-ANCE, or UL 514B.

7.5 Short-time current

7.5.1 A grounding or bonding device shall not crack, break, or melt when subjected to the current and time specified in Table 5.

Note 1: *Arcing, burning, and melting of a throat insulator is acceptable.*

Note 2: *Burning, cracking, and melting of the insulation or gripping surface of a grounding and/or bonding connector is acceptable.*

7.5.2 After having carried the current specified in Clause 7.5.1, continuity shall be maintained on the test sample assembly.

7.6 Thickness of protective coating

7.6.1 The measured thickness of any protective coating shall comply with the requirements in Clause 6 for that particular device.

7.6.2 The coating on the head of a bolt or screw may be considered to be representative of the shank and thread.

7.6.3 A cut, stencilled, or threaded surface of a device not intended for burial in earth or embedment in concrete need not be tested.

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7.7 Rod electrodes

7.7.1 Adherence of coating

There shall be no separation of the coating from the steel core when subjected to the test described in Clause 9.7.1. Peeling of the coating by the steel plates or the jaws of the vise shall be allowed.

7.7.2 Bending

There shall be no cracking of the coating when subjected to the test described in Clause 9.7.2.

7.8 Coating integrity

The coating of a strap-type ground clamp shall neither flake off nor crack when the strap is subjected to the test described in Clause 9.8.

7.9 Temperature conditioning (communications strap-type clamp)

Prior to performing the short-time current test, a communications strap-type clamp for outdoor use shall be conditioned.

7.10 Grounding and bonding devices for the termination of armor

Grounding and bonding devices for the termination of the armor on armored grounding wire shall comply with the performance requirements for Fittings for armored cable in CSA C22.2 No.18.3, NMX-J-017-ANCE, or UL 514B.

8 Sampling requirements

8.1 Wire connectors

The minimum number of samples shall comply with

- a) NMX-J-543-ANCE, CSA C22.2 No. 65, or UL 486A-486B; or
- b) NMX-J-548-ANCE, CSA C22.2 No. 188, or UL 486C.

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8.2 Tightening force for ground clamps

8.2.1 To determine if a ground clamp complies with the requirement in Clause 7.2, two samples of a representative size of each design shall be subjected to the test described in Clause 9.2.

8.2.2 If the ground clamp is designed for use with a range of electrode sizes, two samples shall be tested for both the largest and smallest sizes specified. If a reversible part is employed, two samples shall be tested in both the normal and reversed positions.

8.3 Pull – protective-type ground clamp

To determine if a protective-type ground clamp complies with the requirement in Clause 7.3, two samples shall be subjected to the test described in Clause 9.3.

8.4 Grounding and bonding devices with throat liners

8.4.1 The minimum number of samples shall comply with CSA C22.2 No. 18.3, NMX-J-017-ANCE, or UL 514B.

8.4.2 For a line of a particular design, not less than three samples of each trade size shall be tested.

8.5 Short-time current

To determine if a grounding or bonding device complies with the requirement in Clause 7.5, three samples shall be subjected to the test described in Clause 9.5.

8.6 Thickness of protective coating

To determine if a grounding or bonding device complies with the requirement in Clause 7.6, three samples shall be subjected to the test described in Clause 9.6.

8.7 Rod electrodes

8.7.1 Adherence of coating

To determine if a grounding or bonding device complies with the requirement in Clause 7.7.1, three samples shall be subjected to the test described in Clause 9.7.1.

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8.7.2 Bending

To determine if a grounding or bonding device complies with the requirement in Clause 7.7.2, three samples shall be subjected to the test described in Clause 9.7.2.

8.8 Coating integrity

To determine if a grounding or bonding device complies with the requirement in Clause 7.8, three samples shall be subjected to the test described in Clause 9.8.

8.9 Temperature conditioning (communications strap-type clamp)

To determine if a grounding or bonding device complies with the requirement in Clause 7.9, three samples shall be subjected to the test described in Clause 9.9.

8.10 Grounding and bonding devices for the termination of armor

The minimum number of samples shall comply with CSA C22.2 No. 18.3, NMX-J-017-ANCE, or UL 514B.

9 Test methods

9.1 Wire connectors

Test methods shall be in accordance with

- a) NMX-J-543-ANCE, CSA C22.2 No. 65, or UL 486A-486B; or
- b) NMX-J-548-ANCE, CSA C22.2 No. 188, or UL 486C.

9.2 Tightening force for ground clamps

A tightening torque of 16.9 N•m (150 lbf-in) shall be applied to each clamping bolt or screw. For a clamping screw intended to be tightened only by a screwdriver, a torque of 5.6 N•m (50 lbf-in) shall be applied.

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9.3 Pull – protective-type ground clamp

The armor (of the armored cable) shall be assembled to the protective-type ground clamp in the intended manner. The conductor (of the armored cable) shall not be connected. Bolts and screws shall be tightened with the torque specified in Clause 9.2. The protective-type ground clamp shall be fixed. The specified tensile pull shall then be applied to the armor.

9.4 Grounding and bonding devices with throat liners

9.4.1 The throat of a bushing made of an insulating material shall have a thickness not less than the thickness used to determine the vertical burning rate.

9.4.2 Test methods shall be in accordance with CSA C22.2 No. 18.3, NMX-J-017-ANCE, or UL 514B.

9.4.3 The throat insulator shall be assigned one of the temperature ratings specified in Table 6, and it shall be marked where visible after installation with its temperature rating.

9.5 Short-time current

9.5.1 If the grounding or bonding devices are provided with specific instructions for assembling the connector to the conductor, such instructions shall be followed in the preparation of the test specimen.

Note: In Clauses 9.5.2 to 9.5.10, grounding or bonding devices are referred to as devices.

9.5.2 A device intended for use with a grounding conductor shall be mounted on a length of maximum size ground rod, rebar, conduit, galvanized pipe, or brass fitting for which it is intended to be used; or on an enclosure or outlet box in the intended manner.

9.5.3 A device intended to bond conduit to an enclosure shall be tested by assembling the device, with the maximum intended size conduit, to a typical enclosure, such as a 102 mm (4 in) square outlet box.

9.5.4 A device, such as a twist-on wire connector, not intended for attachment to a ground rod, rebar, conduit, pipe, outlet box, etc., shall be assembled in the intended manner using its largest rated conductors.

9.5.5 A grounding conductor of the maximum intended size, not less than 610 mm (2 ft) long, shall be installed. A wire connector employed to hold the conductor(s) shall be tightened using a torque specified in NMX-J-543-ANCE, CSA C22.2 No. 65, or UL 486A-486B, or NMX-J-548-ANCE, CSA C22.2 No. 188, or UL 486C.

9.5.6 The specified torque shall be applied by

- a) tightening the fastening until the specified value of torque is attained; and
- b) maintaining this value, with a static torque reading, for 5 s.

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9.5.7 If the device is designed to be assembled to a conductor by means of more than one type of specific tool, the device shall meet the performance requirements when any intended type of specific tool is employed in the assembly operations.

Note: In some cases, an additional series of tests will have to be carried out in order to assess the performance of the device when assembled using each intended type of specific tool.

9.5.8 The test current shown in Table 5 shall pass through the assemblies specified in Clauses 9.5.2 to 9.5.4. The current shall be applied for the time specified in Table 5.

The test current shall be based on either the conduit size involved, rebar size, or the largest size of wire for which the device is marked, whichever is less.

For a plate electrode intended for concrete encasement, the test shall be conducted between the plate and the means of attachment. The test current in Table 5 shall be determined by the means of attachment.

Exception: When the conductor can not maintain minimum current as defined in Table 5, the current may be reduced to a lesser value, but not less than 5000 A, provided the test time is increased to a higher value, not to exceed 1 min. The values for test current and time shall be calculated using the formula in Table 5.

9.5.9 After having carried the current specified in Clause 9.5.8, the test assembly shall have continuity, when measured between a point on the ground rod, rebar, wire, conduit, pipe, enclosure, brass fitting, or outlet box 6.4 mm (1/4 in) from the connection of a grounding or bonding device and a similar point on the conductor (see Figure 1). For a test assembly in accordance with Clause 9.5.4, continuity shall be maintained between the conductors as measured at a connection point 6.4 mm (1/4 in) from the device.

Note: If the grounding conductor opens and fails to carry the required current for the time specified in Clause 9.5.8, the test is inconclusive. The test may be repeated using an alternate grounding conductor capable of carrying the required current for the time specified. An example would be substituting copper for an aluminum conductor.

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

9.6 Thickness of protective coating

9.6.1 The thickness of a protective coating shall be determined by a reliable electronic or magnetic method, or by an electrochemical method; see Clauses 9.6.2 to 9.6.10.

9.6.2 To calculate the thickness of a protective coating being tested, select from Table 7 the thickness factor appropriate for the temperature at which the test was conducted, multiply by 0.00025 mm (0.00001 in), and multiply by the time in seconds required to expose base metal as described in Clause 9.6.9.

9.6.3 The method of determining the thickness of zinc coatings by the electrochemical method is described in Clauses 9.6.4 to 9.6.10.

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9.6.4 The solution to be used for the electrochemical method shall contain distilled water, 200 g per litre of reagent grade chromic acid (CrO_3), and 50 g per litre of reagent-grade concentrated sulphuric acid (H_2SO_4).

Note: *The latter is equivalent to 27 mL per litre of reagent-grade concentrated sulphuric acid, specific gravity 1.84, containing 96% of H_2SO_4 .*

9.6.5 The test solution shall 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 0.64 mm (0.025 in) and a length of 140 mm (5.5 in). The lower end of the capillary tube shall be tapered to form a tip, the drops from which are about 0.05 mL each. To preserve an effectively constant level, a small glass tube shall be inserted in the top of the funnel through a rubber stopper, and its position shall be adjusted so that, when the stopcock is opened, the drop rate shall be 100 ± 5 drops per minute.

Note: *An additional stopcock may be used in place of the glass tube to control the drop rate.*

9.6.6 The test shall be conducted at a room temperature of 21°C to 32°C (70°F to 90°F). The sample and the test solution shall be kept in the test room long enough to acquire the temperature of the room, which shall be noted and recorded.

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

9.6.8 The sample to be tested shall be supported from 18 mm to 25 mm (0.7 in to 1 in) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested shall be inclined to $45^\circ \pm 5^\circ$ from horizontal.

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

9.6.10 Each sample of a test lot shall be subjected to the test at three or more points 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.

Note: *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.*

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9.7 Rod electrodes

9.7.1 Adherence of coating

A 457 mm (18 in) length of the rod with one end cut to a 45° point shall be driven between two steel clamping plates or the jaws of a vise set 1.02 mm (0.04 in) less than the diameter of the rod, so as to shear off sufficient metal to expose the bond between the coating and rod.

9.7.2 Bending

A length of the rod shall be rigidly held in a clamp or vise. A force shall be applied normal to the free end of the rod at a distance from the clamping device equal to 40 times the rod diameter. The application of force shall be such that the rod is permanently bent through a 30° angle (see Figure 2).

9.8 Coating integrity

The steel strap of a strap-type ground clamp shall be tightly wrapped at least half-way around a 12.7 mm (1/2 in) diameter mandrel.

9.9 Temperature conditioning (communications strap-type clamp)

Prior to performing the short-time current test, a communications strap-type clamp for outdoor use shall be conditioned for 20 cycles, each cycle consisting of exposure to a temperature of 0°C for 8 h followed by 60°C for 16 h.

9.10 Grounding and bonding devices for the termination of armor

Test methods shall be in accordance with CSA C22.2 No. 18.3, NMX-J-017-ANCE, or UL 514B.

10 Marking, labeling, and packaging

Advisory Note: *In Canada, there are two official languages, English and French. Annex B provides French translations of the markings specified in this Standard. All markings required by this Standard may be in other languages to conform with the language requirements of the country where the product is to be used.*

10.1 A ground clamp shall be permanently marked where readily visible as follows:

- a) A clamp shall be marked with
 - i) the manufacturer's name, trade name, or both, or any other acceptable marking whereby the organization responsible for the product can be readily identified; and
 - ii) the size of electrode, pipe, tubing, or rebar and the size of the grounding conductor with which the clamp is intended to be used.

Note: *Electrode, pipe, and tubing trade sizes are usually stated in fractions such as 1/2, 5/8, etc., whereas rebar sizes can be specified by fractions or a number such as 3, 4, 5, etc. (This number represents the numerator of the fraction when stated in eighth inch increments, i.e., 4 = 4/8ths).*

- b) A protective clamp shall be marked with the size of metal conduit or armor, unless the size is obvious.

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- c) A clamp larger than the 53 (2) trade size shall be marked with a distinctive catalog number or equivalent identification.
- d) For a 53 (2) trade size or smaller clamp, the catalog number or an equivalent identification shall be marked on at least one of the following:
 - i) clamp;
 - ii) smallest unit, carton, or package;
 - iii) clamp and the package; or
 - iv) durable tag with an eyelet or other means found to be acceptable.
- e) A ground clamp rated for direct burial in earth and embedment in concrete shall be marked "Direct Burial", "DB", or an equivalent marking.
- f) A clamp that is suitable for use with aluminum wire only shall be marked "AL".
- g) A clamp that is suitable for use with both aluminum and copper wire shall be marked "AL-CU".
- h) A clamp that is suitable for use with copper water tubing shall be marked as specified in Item (a)(ii) and either preceded or followed by the words "Copper Water Tubing" or the equivalent.
- i) A clamp that is suitable for use with a brass fitting shall be marked "Brass Fitting – X", or "BF – X", where "X" is a numeric number or fraction representing the fitting size. See Clause 10.12.

Note: *UPC labels do not meet the intent of readily identifying the organization responsible for the product.*

10.2 A grounding or bonding bushing shall be permanently marked where readily visible as follows:

- a) A bushing shall be marked with the manufacturer's name, trade name, or both, or any other distinctive marking whereby the organization responsible for the product can be readily identified.
- b) A bushing larger than the 53 (2) trade size shall be marked with a distinctive catalog number or equivalent identification.
- c) For a 53 (2) trade size or smaller bushing, the catalog number or equivalent identification shall be marked on at least one of the following:
 - i) bushing;
 - ii) smallest unit, carton, or package;
 - iii) bushing and the package; or
 - iv) durable tag with an eyelet or other means found to be acceptable.
- d) A bushing that does not have a mounting for a separable wire connector shall be marked with the size of the grounding conductor with which the bushing is intended to be used.

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e) For a bushing provided with a separable wire connector, the connector shall be marked with the size of the grounding conductor with which the connector is intended to be used.

f) For a bushing having a mounting for a separate wire connector, but supplied without a wire connector as permitted by Clause 6.6.5, the size of conductor accommodated by each connector shall be marked on the connector, and the identity of the connector intended for use with the bushing shall be marked on at least one of the following:

- i) bushing;
- ii) smallest unit, carton, or package; or
- iii) bushing and the package.

Note: *UPC labels do not meet the intent of readily identifying the organization responsible for the product.*

10.3 A grounding or bonding locknut shall be permanently marked where readily visible as follows:

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

b) A locknut larger than the 53 (2) trade size shall be marked with a distinctive catalog number or equivalent identification.

c) For a 53 (2) trade size or smaller locknut, the catalog number or equivalent identification shall be marked on at least one of the following:

- i) locknut;
- ii) smallest unit, carton, or package; or
- iii) locknut and the package.

Note: *UPC labels do not meet the intent of readily identifying the organization responsible for the product.*

10.4 A fitting with the environmental ratings specified in Clause 6.1.8 shall be marked in accordance with CSA C22.2 No. 18.3, NMX-J-017-ANCE, or UL 514B.

10.5 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 identifies the assembled device.

Note: *As an example of compliance of devices with the requirement in Clause 10.5, threaded parts for the connection of metal conduit might be designated and marked A for trade size 1/2 (16), B for trade size 3/4 (21), C for trade size 1 (27), D for trade size 1-1/4 (35), and the like. Clamp parts for water-pipe or rod electrodes might be designated and marked 2 for trade size 1/2 (16), 3 for trade size 3/4 (21), 4 for trade size 1 (27), 5 for trade size 1-1/4 (35), 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.*

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10.6 The temperature rating of an insulating bushing shall be marked or color-coded in accordance with CSA C22.2 No. 18.3, NMX-J-017-ANCE, or UL 514B.

10.7 The marking of a ground rod shall be located within 305 mm (12 in) 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; and
- c) the length of the rod.

Note: UPC labels do not meet the intent of readily identifying the organization responsible for the product.

10.8 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, or the information may be printed or stencilled 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 "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; and
- c) the wire size of the grounding conductor.

Note: UPC labels do not meet the intent of readily identifying the organization responsible for the product.

10.9 An armored grounding conductor shall have a distinctive marking throughout its entire length by which it may be readily identified as the product of a particular factory. The marking shall consist of a letter or symbol legibly indented or embossed in the armor at intervals of not more than 305 mm (12 in).

10.10 A plate electrode conforming to Clause 6.10.4.1 shall be marked with the manufacturer's name, trade name, or both, or any other distinctive marking whereby the organization responsible for the product can readily be identified.

Note: UPC labels do not meet the intent of readily identifying the organization responsible for the product.

10.11 A plate electrode for concrete encasement conforming to Clause 6.10.4.2 shall be marked within 50 mm (2 in) of the top of the means for attachment of the system-grounding conductor with the information in Clause 10.10.

10.12 A clamp intended for use with brass fittings shall be provided with installation instructions that include the size(s) of the fitting nut for which it is intended to be used.

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Table 1
Sizes of terminal screws

(See Clause 6.1.5.)

| Size of conductor | | Minimum size of screw* | |
|-------------------|--------------------|------------------------|-------|
| AWG | (mm ²) | in | (mm) |
| 14 – 8 | (2.1 – 8.4)* | No. 10 | (4.8) |
| 6 | (13.3) | 1/4 | (6.4) |
| 4 | (21.2) | 5/16 | (7.9) |

* The common form of wire-binding screw shall not be acceptable for securing a wire larger than 8 AWG (8.4 mm²) solid or 10 AWG (5.3 mm²) stranded.

Table 2
Straps for protective-type clamps

(See Clause 6.2.4.)

| Metal conduit | | Minimum number of straps |
|-------------------|------------|--------------------------|
| Metric designator | Trade size | |
| 16 | 1/2 | 1 |
| 21 | 3/4 | 2 |
| 27 | 1 | 3 |

Table 3
Sizes of connected conductors

(See Clause 6.6.4.)

| Bushing | | Minimum size of grounding or bonding conductor | |
|-------------------|-------------------|--|--------------------|
| Metric designator | Trade size | AWG | (mm ²) |
| 35 and smaller | 1-1/4 and smaller | 8 | (8.4) |
| 41 | 1-1/2 | 6 | (13.3) |
| 53 | 2 | 4 | (21.2) |
| 63 | 2-1/2 | 2 | (33.6) |
| 78 | 3 | 1/0 | (53.5) |
| 91, 103 | 3-1/2, 4 | 2/0 | (67.4) |
| 129, 155 | 5, 6 | 3/0 | (85.0) |

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Table 4
Weights of single-strip armor

(See Clauses 6.9.2 and 6.9.3.3.)

| Size of conductor | | Minimum weight, kg/30.5 m (lb/100 ft) | | | |
|-------------------|--------------------|---------------------------------------|---------|--------------------|---------|
| AWG | (mm ²) | Solid conductor | | Stranded conductor | |
| 8 | (8.4) | 3.2 | (7.05) | 3.6 | (7.97) |
| 6 | (13.3) | 3.9 | (8.60) | 4.3 | (9.53) |
| 4 | (21.2) | 4.7 | (10.30) | 5.2 | (11.48) |

Table 5
Short-time test currents

(See Clauses 7.5.1 and 9.5.8.)

| Rebar | | Conduit | | Equipment grounding and bonding conductor size | | Test current, A | | | |
|-------------------|------------|-------------------|--------------|--|--------------------|-----------------|--------|----------|-------------|
| Metric designator | Trade size | Metric designator | Trade size | AWG or kcmil | (mm ²) | Time, s | Copper | Aluminum | Steel rebar |
| — | — | — | — | 20 AWG | (0.52) | 4 | 70 | 40 | — |
| — | — | — | — | 18 | (0.82) | 4 | 115 | 65 | — |
| — | — | — | — | 16 | (1.3) | 4 | 185 | 105 | — |
| — | — | — | — | 14 | (2.1) | 4 | 300 | 170 | — |
| — | — | — | — | 12 | (3.3) | 4 | 470 | 270 | — |
| — | — | — | — | 10 | (5.3) | 4 | 750 | 430 | — |
| — | — | 16 | 1/2 | 8 | (8.4) | 4 | 1180 | 680 | — |
| — | — | 21, 27 | 3/4, 1 | 6 | (13.3) | 6 | 1530 | 880 | — |
| — | — | 35, 41 | 1-1/4, 1-1/2 | 4 | (21.2) | 6 | 2450 | 1400 | — |
| — | — | — | — | 3 | (26.7) | 6 | 3100 | 1770 | — |
| — | — | 53 | 2 | 2 | (33.6) | 6 | 3900 | 2230 | — |
| — | — | 63 | 2-1/2 | 1 | (42.4) | 6 | 4900 | 2800 | — |
| — | — | 78, 91, 103 | 3, 3-1/2, 4 | 1/0 | (53.5) | 9 | 5050 | 2900 | — |
| #10 | #3 (3/8) | — | — | 2/0 | (67.4) | 9 | 6400 | 3600 | 2900 |
| — | — | 129, 155 | 5, 6 | 3/0 | (85.0) | 9 | 8030 | 4600 | — |
| — | — | — | — | 4/0 | (107) | 9 | 10100 | 5800 | — |
| #13 | #4 (1/2) | — | — | 250 kcmil | (127) | 9 | 12000 | 6900 | 5300 |
| — | — | — | — | 300 | (152) | 9 | 14300 | 8200 | — |
| — | — | — | — | 350 | (177) | 9 | 16700 | 9600 | — |
| #16 | #5 (5/8) | — | — | 400 | (203) | 9 | 19100 | 11000 | 8200 |
| #19 | #6 (3/4) | — | — | 500 | (253) | 9 | 23900 | 13700 | 11700 |
| — | — | — | — | 600 | (304) | 9 | 28700 | 16500 | — |
| — | — | — | — | 700 | (355) | 9 | 33500 | 19250 | — |
| #22 | #7 (7/8) | — | — | 750 | (380) | 9 | 35900 | 20600 | 16000 |
| — | — | — | — | 800 | (405) | 9 | 38300 | 22000 | — |
| — | — | — | — | 900 | (456) | 9 | 43100 | 24700 | — |
| #25 | #8 (1) | — | — | 1000 | (507) | 9 | 47900 | 27500 | 21000 |

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Table 5 Continued on Next Page

Table 5 Continued

| Rebar | | Conduit | | Equipment grounding and bonding conductor size | | Test current, A | | | |
|--|------------|-------------------|------------|--|--------------------|-----------------|--------|----------|-------------|
| Metric designator | Trade size | Metric designator | Trade size | AWG or kcmil | (mm ²) | Time, s | Copper | Aluminum | Steel rebar |
| <p>Note: Test current values are derived from the following formula and have been rounded. To derive test current values for electrode materials other than the ones listed above, see Annex C of IEEE Std 837-2002.</p> $I = A \sqrt{\frac{\ln \frac{K_o + T_m}{K_o + T_a}}{\beta * t}}$ <p>where</p> <p>T_m = 1083°C for melting point for copper and 657°C for melting point for aluminum and 1510°C for melting point for steel T_a = 40°C = ambient temperature I = short time current (amperes) in kA A = conductor cross section in mm² t = time (s) K_o = reciprocal of thermal coefficient of resistivity at 0°C = 234 for copper and 228 for aluminum and 605 for steel β = material constant = 19.8 for copper and 45.1 for aluminum and 77.5 for steel</p> | | | | | | | | | |

Table 6
Temperatures for conditioning bushings and parts

(See Clause 9.4.3.)

| Temperature rating of device, °C | Oven temperature, °C |
|----------------------------------|----------------------|
| 90 | 112 |
| 105 | 128 |
| 150 | 173 |

Table 7
Coating thickness factors

(See Clause 9.6.2.)

| Temperature, °C | Thickness factors for zinc protective coatings |
|-----------------|--|
| 21.1 | 0.980 |
| 21.7 | 0.990 |
| 22.2 | 1.000 |
| 22.8 | 1.010 |
| 23.3 | 1.015 |
| 23.9 | 1.025 |
| 24.4 | 1.033 |
| 25.0 | 1.042 |
| 25.6 | 1.050 |
| 26.1 | 1.060 |
| 26.7 | 1.070 |
| 27.2 | 1.080 |

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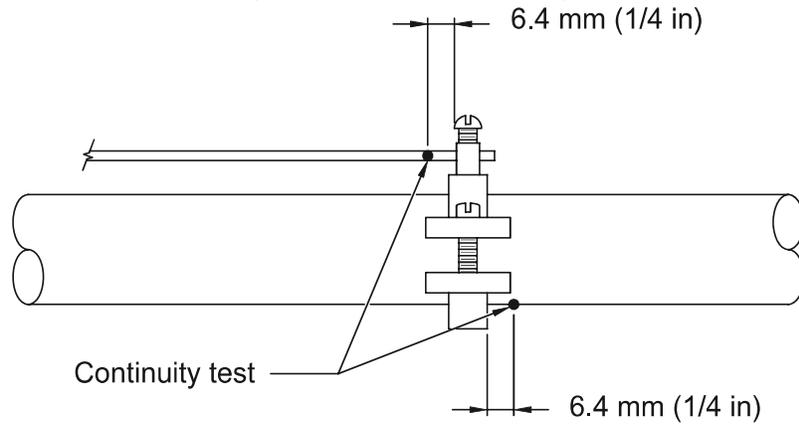
Table 7 Continued on Next Page

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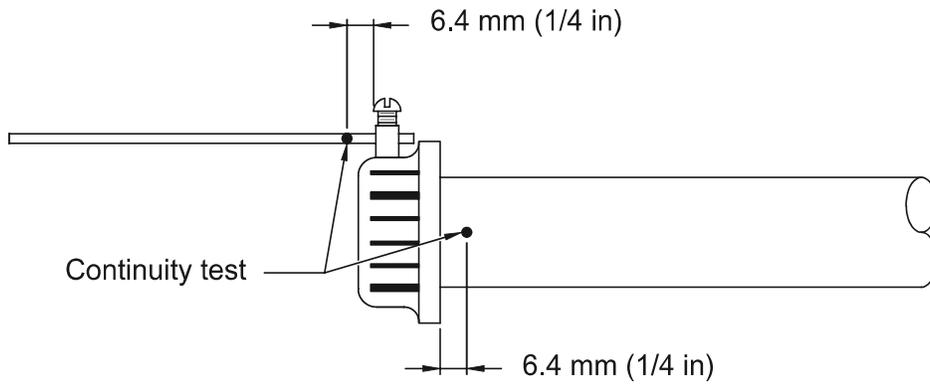
| Temperature, °C | Thickness factors for zinc protective coatings |
|-----------------|--|
| 27.8 | 1.085 |
| 28.3 | 1.095 |
| 28.9 | 1.100 |
| 29.4 | 1.110 |
| 30.0 | 1.120 |
| 30.6 | 1.130 |
| 31.1 | 1.141 |
| 31.7 | 1.150 |
| 32.2 | 1.160 |

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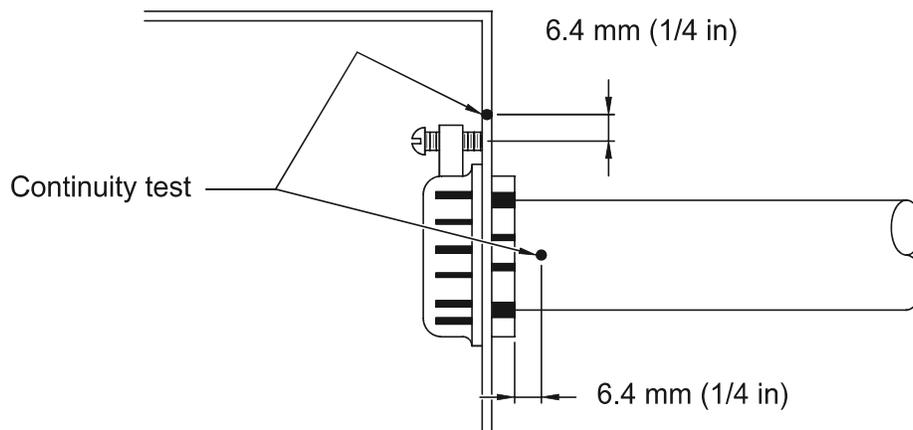
Figure 1
Continuity test points
 (See Clauses 4 and 9.5.9.)



(a) Typical ground clamp



(b) Typical grounding bushing

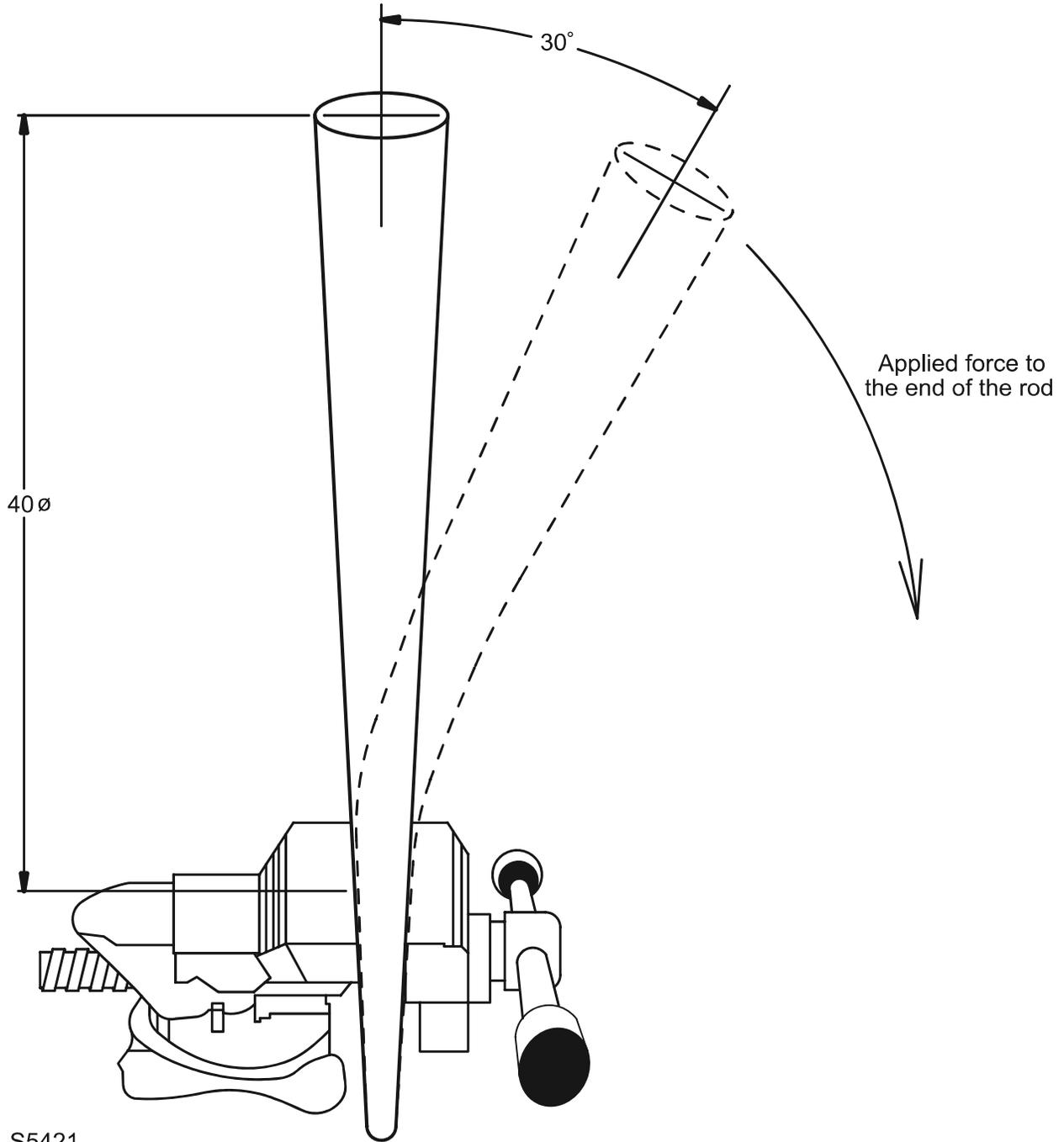


(c) Typical bonding bushing

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Figure 2
Rod bending test
(See Clause 9.7.2.)



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Annex A – (Normative – United States and Mexico only)

Hospital Grounding Equipment

A.1 General

The requirements in Clauses A.2 to A.4 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.

A.2 Construction

A.2.1 Cord

A.2.1.1 The cord of a grounding cord assembly shall be stranded copper wire not smaller than 10 AWG (5.3 mm²), with the individual strands of wire not larger than 0.4 mm (0.0159 in) in diameter.

A.2.1.2 The insulation on the conductors shall not be less than 1.2 mm (3/64 in) thick and shall comply with the requirements in Clauses A.3.4.1 and A.3.5. A cord insulated with rubber shall also comply with the requirements in Clause A.3.6.

A.2.1.3 With reference to Clause A.2.1.2, the surface of the insulation on the conductor shall be green with or without one or more yellow stripes.

A.2.1.4 The connection between a plug and cord shall comply with the requirements for strain relief in Clause A.3.3.

A.2.2 Field-wiring terminals and leads

A.2.2.1 A grounding jack shall have a wiring terminal for connection to a field-installed conductor or a 10 AWG 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. The pressure screw of a wiring terminal and the nut of a stud terminal may be of other acceptable metal.

A.2.2.2 A wiring terminal shall be suitable for the connection of a 10 AWG (5.3 mm²) copper conductor and may hold conductors of other sizes if the connection complies with the secureness and pull-out tests described in UL 486A-486B or NMX-J-543-ANCE.

A.2.2.3 A terminal shall be crimped to the conductor at the end of a grounding cord assembly opposite the plugs, 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 UL 486A-486B or NMX-J-543-ANCE. A connection other than a crimp connection, such as brazed or welded connection, may be used.

A.2.2.4 Insulation on a handle shall be green and shall comply with the flammability requirements in Clause A.3.4.2. Rubber and rubberlike materials shall also comply with the requirements in Clauses A.3.6.1 and A.3.6.2.

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A.2.2.5 A handle shall be positively secured to a grounding plug.

A.2.2.6 A pin shall be copper or copper alloy.

A.2.3 Grounding jacks

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

A.2.4 Samples

A.2.4.1 Six samples of a grounding cord assembly shall be subjected to the tests described in Clauses A.3.1 to A.3.6.

A.2.4.2 Samples that consist of a terminal connector, cord, plug, and grounding jack shall be assembled to simulate the end-use application.

A.3 Performance

A.3.1 Contact resistance

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

A.3.2 Endurance

A.3.2.1 The samples used for the contact resistance test shall be subjected to 6000 cycles of insertion, twisting to lock and unlock if appropriate, and withdrawal. There shall be no mechanical damage to the plug or the grounding jack.

A.3.2.2 Following the endurance test described in Clause A.3.2.1, the samples shall be subjected to a repeated contact resistance test. The resistance shall not have increased by more than 0.005 Ω .

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A.3.3 Strain relief

Six new samples shall be assembled as intended. With the plug held by the pin in the horizontal plane, the cord shall withstand for 1 min, without more than 0.8 mm (1/32 in) displacement from the handle or the plug, a 156 N (35 lbf) vertical force applied to the grounding cord terminal. For an assembly having a plug handle molded on the pin, the force shall be applied to both molded and unmolded samples.

A.3.4 Flame resistance

A.3.4.1 Insulated wire shall comply with the flammability requirements for the vertical flame test as described in UL 83 or UL 44, whichever is appropriate.

A.3.4.2 Rubber and rubber-like insulation on a grounding jack shall comply with the requirements in Clauses A.3.6.1 and A.3.6.2.

A.3.5 Dielectric voltage withstand

Insulation on a wire shall withstand for 1 min without breakdown the application of 1500 V applied as described in UL 83 or NMX-J-010-ANCE or UL 44 or NMX-J-451-ANCE, whichever is appropriate.

A.3.6 Accelerated aging

A.3.6.1 A rubber-insulated cord or handle shall show no apparent deterioration and shall show no greater change in hardness than 10 units as a result of a 70 h air-oven test at $100^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($212^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$).

A.3.6.2 The hardness of the rubber shall be determined as the average of five readings with a suitable gauge such as a Rex hardness gauge or a Shore durometer. The device shall then be exposed to air-oven aging for 70 h at $100^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($212^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$). The device shall be allowed to rest at room temperature for at least 4 h after removal from the air oven. The hardness shall 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 air oven aging is the change in hardness.

A.4 Marking

A.4.1 A plug handle or grounding jack body shall be marked with the manufacturer's name and the catalog number or the equivalent.

A.4.2 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."

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Annex B (informative) – French translations and markings
(See Clause 10.)

The following are acceptable French translations of markings:

| Clause | English | French |
|----------------|------------------------|---|
| 10.1, Item (e) | Direct Burial | Enfouissement direct |
| 10.1, Item (h) | Copper Water Tubing | Accessoire de tube en cuivre pour l'eau |
| 10.8, Item (a) | armored grounding wire | câble de mise à la terre armé |

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Annex C – (Normative – United States only)
Protector Grounding Conductor – For Use in Communications Circuits

INTRODUCTION

C.1 Scope

The requirements in Clauses C.2 through C.6 apply to Protector Grounding Conductors. These conductors are intended to be used for the grounding of the metallic members of a cable sheath or of a primary protector as described in Sections 770.100, 800.100, 820.100, 830.100 and other applicable parts of the National Electrical Code (NEC), NFPA 70.

CONSTRUCTION

C.2 Conductors

C.2.1 The conductor shall be 14 AWG or larger solid or stranded, bare or metal-coated copper, aluminum, or copper clad aluminum as described in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, copper-clad steel as described in the Standard Specification for Copper-Clad Steel Wire for Electronic Application, ASTM B452 and the Standard Specification for Annealed Copper-Clad Steel Wire, ASTM B910/B910M.

C.3 Covering

C.3.1 The covering shall be thermoplastic complying with the requirements for Type TW insulation in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, except as noted by the following construction and performance requirements in this Annex.

C.3.2 The temperature rating shall be minimum 60°C.

C.3.3 The covering shall be colored light olive gray or green.

C.3.4 The thickness of the covering shall be as shown in Table C.1.

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Table C.1
Covering thickness, average and minimum at any point
(See Clause C.3.4)

| Conductor size | | Minimum average | | Minimum at any point | |
|----------------|-----------------|-----------------|------|----------------------|------|
| AWG | mm ² | mm | mils | mm | mils |
| 14 | 2.1 | 0.52 | 20.5 | 0.43 | 17 |
| 12 | 3.3 | 0.52 | 20.5 | 0.43 | 17 |
| 10 | 5.3 | 0.52 | 20.5 | 0.43 | 17 |
| 8 | 8.4 | 0.52 | 20.5 | 0.43 | 17 |
| 6 | 13.3 | 0.71 | 28 | 0.64 | 25 |
| 4 | 21.2 | 0.71 | 28 | 0.64 | 25 |
| ≥4 | ≥21.2 | TBD | TBD | TBD | TBD |

Mils = Thousandth of an inch
TBD = To be determined

C.4 Marking

C.4.1 General

C.4.1.1 The surface marking on the covered conductor shall include the following:

- a) Identification of the organization responsible for the product.
- b) "Protector Grounding Conductor".
- c) Conductor size expressed in AWG or kcmil.
- d) Temperature rating.

C.4.1.2 The marking on the tag, reel or carton shall include the following:

- a) All surface markings required in Clause C.4.1.1.
- b) "For use in accordance with NEC 770.100, 800.100, 820.100 and 830.100".
- c) For aluminum conductors, "AL" after the conductor size, wherever the size of the conductor appears on the wire, cable, or package marking. The additional marking "ACM shall be optional.
- d) For copper-clad aluminum conductors, "AL (CU-CLAD)", "ALUM (COPPER-CLAD)", "CU-CLAD AL", or "COPPER-CLAD ALUM" wherever the size of the conductor appears on the wire, cable, or package marking.
- e) Any auxiliary information which aids in the wire dispensary function or inventory management.
- f) For copper-clad steel conductors, "STEEL(CU-CLAD), CU-CLAD STEEL or COPPER-CLAD STEEL" wherever the size or the conductor appears on the wire, cable or package marking.

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C.4.2 Month and year of manufacture

The month and year of manufacture shall be included among the markings described in Clause C.4.1.2 or shall be included among the product markings described in Clause C.4.1.1. The use of a code shall be allowed.

C.4.3 Multiple manufacturing locations

When the organization responsible for the product operates more than one manufacturing location, a distinctive identification for each location shall be included among the markings described in Clause C.4.1.2 or shall be included among the product markings described in Clause C.4.1.1.

PERFORMANCE

C.5 Physical properties

The Protective Grounding Conductor shall comply with the physical properties requirements (tensile strength and elongation – before and after aging) for Type TW insulation as contained in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

C.6 Flammability

The Protective Grounding Conductor shall comply with the VW-1 Flame test requirements as contained in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

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Annex D – Normative
Exothermic Welding Connection Systems
(Normative)

INTRODUCTION

D.1 Scope

D.1.1 The requirements in Clauses D.2 through D.6 apply to exothermic welding connection systems. These systems are intended for the connection of grounding conductors and bonding jumpers as described in Section 250.8 and other applicable parts of the National Electrical Code (NEC), NFPA 70.

CONSTRUCTION

D.2 General

D.2.1 An exothermic welding connection system shall be evaluated to all applicable construction requirements in the Standard for Grounding and Bonding Equipment, UL 467.

D.3 Markings

D.3.1 An exothermic welding connection system shall be marked to indicate that it is suitable for grounding and bonding equipment.

D.3.2 The smallest unit container containing the components of the system shall be marked with the following:

- a) manufacturer's name, trade name, or both, or any other acceptable marking whereby the organization responsible for the product can be readily identified; and
- b) a distinctive catalog number or equivalent identification.

Note: *UPC labels do not meet the intent of readily identifying the organization responsible for the product.*

D.4 Installation instructions

D.4.1 Installation instructions shall be provided and include the following (or equivalent):

- a) identification of all materials involved in the process;
- b) the recommended weight of mixture for the size and type of electrode;
- c) installer's and inspector's guide for electrical connections;
- d) solid or stranded copper wire conductors and wire size for each "connection" process; and
- e) type of grounding electrode which can be connected to the wire conductor.

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PERFORMANCE

D.5 Short-time current

D.5.1 The exothermic welding connection system shall be subjected to the short-time current test specified in Clauses 7.5, 8.5 and 9.5 using the applicable wire combinations and grounding electrodes.

D.6 Mechanical sequence

D.6.1 The exothermic welding connection system shall be subjected to the applicable static heating sequence and mechanical sequence tests specified in Clauses 7.1, 8.1 and 9.1. The static heating test of the static heating sequence is not required.

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