UL 486A-486B

Underwriters Laboratories Inc.

Standard for Safety

Wire Connectors

UL Standard for Safety for Wire Connectors, UL 486A-486B

First Edition, Dated November 15, 2003

Summary of Topics

This revision of ANSI/UL 486A-486B includes changes to the UL effective date information in the Preface, typographical corrections to Table 26, and format changes to Table 27. No changes in requirements are involved.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.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

Future Effective Date	Reference
January 25, 2012	Paragraph 7.1.2

Association of Standardization and Certification
NMX-J-543-ANCE-2008
Second Edition

Canadian Standards Association
CAN/CSA-C22.2 No. 65-03
Fourth Edition

Underwriters Laboratories Inc.
UL 486A-486B
First Edition

Wire Connectors

November 15, 2003

(Title Page Reprinted: February 22, 2010)

Approved
by
Standards Council
of Canada

ANSI/UL 486A-486B-2010

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (CSA), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA, or UL at any time. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA, and UL. CSA and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA and UL pages.

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This ANSI/UL Standard for Safety consists of the First Edition including revisions through February 22, 2010.

The most recent designation of ANSI/UL 486A-486B as an American National Standard (ANSI) occurred on January 25, 2010. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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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CONTENTS

Preface

This is the common ANCE, CSA, and UL standard for *Wire Connectors*. It is the second edition of NMX-J-543-ANCE, the fourth edition of C22.2 No. 65, and the first edition of UL 486A-486B. This edition of CSA C22.2 No. 65 supersedes the previous edition published in 1993.

This common standard was prepared by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (CSA), 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 was reviewed by the CSA Subcommittee on C22.2 No. 65, 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 will be submitted to the Standards Council of Canada (SCC) for approval as a National Standard of Canada.

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

A UL standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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, 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 several IEC standards that address electrical wire connectors included in the scope of this standard. The IEC standards for electrical wire connectors are recognized as being generally system specific, containing the requirements for the relevant wire connectors and cables in many discrete IEC standards.

The THC determined the safe use of electrical wire connectors is dependent on the design and performance of the wire connectors in relation to the North American Electrical Codes with which they are intended to be installed. The THC agreed such future investigation will be facilitated by the harmonization of the North American Electrical Codes for wire connectors with IEC installation practices.

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 Effective Date

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

UL Effective Date

As of January 25, 2010 all products Listed or Recognized by UL must comply with the requirements in this standard except for the clause in the following, which is effective January 25, 2012.

Clause 7.1.2

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

Foreword (ANCE)

The present Mexican Standard was developed by the Low Voltage Wires and Cables Subcommittee from the Comité de Normalización de la Asociación de Normalización y Certificación, A.C., CONANCE, with the collaboration of wire and cable manufacturers and users.

ANCE is an Organization for Standardization (ONN) registered by the DGN (Dirección General de Normas) in the electrical sector and household appliances. ANCE develops Mexican Standards (NMX) and collaborates in the development of the Mexican Official Standards (NOM); these are voluntary and normative standards, respectively.

Conformity assessment in accordance with ANCE Mexican Standards is the responsibility of ANCE's Product Certification Division.

ANCE's Product Certification Division is accredited by the EMA (Entidad Mexicana de Acreditación) to certify a variety of products. Certification is carried out following the relevant procedures established and developed by the Technical Committee on Certification in connection with the test reports produced in test labs accredited by the EMA.

The conformity assessment activities developed by ANCE cover quality systems, test labs, and product verification.

Foreword (CSA)

The Canadian Standards Association (CSA) develops standards under the name Canadian Standards Association, and provides certification and testing under the name CSA International. CSA International provides certification services for manufacturers who, under license from CSA, wish to use the appropriate registered CSA Marks on certain products of their manufacture to indicate conformity with CSA Standards.

CSA Certification for a number of products is provided in the interest of maintaining agreed-upon standards of quality, performance, interchangeability and/or safety, as appropriate. Where applicable, certification may form the basis for acceptance by inspection authorities responsible for enforcement of regulations. Where feasible, programs will be developed for additional products for which certification is desired by producers, consumers, or other interests. In performing its functions in accordance with its objectives, CSA does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of the Association represent its professional judgement given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed.

Products in substantial accord with this Standard but which exhibit a minor difference or a new feature may be deemed to meet the Standard providing the feature or difference is found acceptable utilizing appropriate CSA International Operating Procedures. Products that comply with this Standard shall not be certified if they are found to have additional features which are inconsistent with the intent of this Standard. Products shall not be certifiable if they are discovered to contravene applicable laws or regulations.

Testing techniques, test procedures, and instrumentation frequently must be prescribed by CSA International in addition to the technical requirements contained in Standards of CSA. In addition to markings specified in the Standard, CSA International may require special cautions, markings, and instructions that are not specified by the Standard.

Some tests required by CSA Standards may be inherently hazardous. The Association neither assumes nor accepts any responsibility for any injury or damage that may occur during or as the result of tests, wherever performed, whether performed in whole or in part by the manufacturer or the Association, and whether or not any equipment, facility, or personnel for or in connection with the test is furnished by the manufacturer or the Association.

Manufacturers should note that, in the event of the failure of CSA International to resolve an issue arising from the interpretation of requirements, there is an appeal procedure: the complainant should submit the matter, in writing, to the Secretary of the Canadian Standards Association.

If this Standard is to be used in obtaining CSA Certification please remember, when making application for certification, to request all current Amendments, Bulletins, Notices, and Technical Information Letters that may be applicable and for which there may be a nominal charge. For such information or for further information concerning CSA Certification, please address your inquiry to Applications and Customer Service, CSA International, 178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3.

No Text on This Page

Foreword (UL)

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 which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, 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.

1 Scope

1.1 This Standard applies to single-polarity connectors for use with all alloys of copper or aluminum, or copper-clad aluminum conductors, or all three, for providing contacts between current-carrying parts, in accordance with the Canadian Electrical Code, Part I, C22.1, in Canada, the National Electrical Code, NFPA-70, in the United States of America, or the Standard for Electrical Installations, NOM-001-SEDE, in Mexico, as follows:

Note: Copper-clad aluminum conductors are for use only in the United States in accordance with the National Electrical Code, NFPA 70.

a) pressure wire connectors intended to hold one or more conductor(s);

b) connectors intended for use in appliances and equipment that comply with the requirements for such appliances and equipment;

c) soldering connectors;

d) splicing wire connectors intended for use with 4 AWG (21.2 mm^2) or larger conductors;

Note: A splicing wire and cable connector taking a range of conductor sizes may include conductor sizes smaller than 4 AWG (21.2 mm^2).

e) neutral bars;

f) uninsulated connectors that are used in circuits rated 35 000 V and below;

g) ampere-rated connectors not intended for general use; and

h) insulation piercing connectors.

1.2 This Standard is intended for connectors suitable for use with conductors in the size ranges as follows:

a) Aluminum

1) 12 AWG (3.3 mm^2) and 10 AWG (5.3 mm^2) solid;

2) 12 AWG (3.3 mm^2) to 2 000 kcmil (1 010 mm^2) stranded, Class B concentric, compressed, and compact; and

3) 12 AWG (3.3 mm^2) to 1 000 kcmil (508 mm^2) stranded single input wire (SIW).

b) Copper-clad aluminum

1) In Canada, this construction is not allowed.

2) In Mexico, this construction is not allowed.

3) In the United States:

i) 12 AWG (3.3 mm^2) and 10 AWG (5.3 mm^2) solid; and

ii) 12 AWG (3.3 mm^2) to 2 000 kcmil (1 010 mm^2) stranded, Class B concentric, compressed, and Class C concentric.

c) Copper

1) 30 AWG (0.05 mm^2) to 10 AWG (5.3 mm^2) solid; and

2) 30 AWG (0.05 mm^2) to 2 000 kcmil (1 010 mm^2) stranded, Class B concentric and compressed, and Class C concentric.

d) Compact-stranded copper conductors

1) in Canada for 8 AWG (8.4 mm^2) and larger;

2) in the United States for 2 AWG (33.6 mm^2) and larger; and

3) in Mexico for 8 AWG (8.4 mm^2) and larger.

e) Rigid (solid and stranded) metric wire falling within the ranges of the above AWG sizes.

Note: For example, a connector rated for 6 AWG – 250 kcmil may be additionally rated for **16 – 120 mm^2.**

f) Other class and strand configurations as indicated by marking.

1.3 This Standard is intended for connectors suitable for currents not exceeding the ampacity of insulated conductors rated 75°C or 90°C in accordance with the connector rating of the connector, if provided.

1.4 In the United States and Mexico, these requirements cover insulated connectors, insulating caps, and covers intended for use at 600 volts or less (1 000 volts in a sign or luminaire) and uninsulated connectors for use in general use circuits rated 2 000 volts nominal or less.

In Canada, these requirements cover insulated connectors, insulating caps, and covers intended for use at 600 volts or less (1 000 volts in a sign or luminaire) and uninsulated connectors for circuits rated 2 000 volts phase-to-phase or less. Uninsulated connectors may also be used in applications up to 5 000 volts phase-to-phase where allowed and installed in accordance with Section 36 of the Canadian Electrical Code, Part I, C22.1.

1.5 This standard also applies to uninsulated connectors (both terminal and splicing types) for use in circuits rated 35 000 volts or less.

1.6 This Standard does not apply to:

a) *Deleted*;

b) insulated connectors for voltage levels above 600 V (1 000 V in a sign, lighting fixture, or luminaire);

c) manual twist-on connectors;

d) built-in terminal connectors in devices rated less than 30 A intended for outlet box mounting or having provision for stress relief;

e) flat quick connect terminals; and

f) wire binding screw terminals.

2 Reference Publications

2.1 Normative references

2.1.1 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.

2.1.2 **ANCE Standards**

NMX-J-508-ANCE
Electrical Features – Safety Requirements – Specifications and Test Methods

2.1.3 **CSA Standards**

C22.1-02
Canadian Electrical Code, Part I (CEC)

CAN/CSA-C22.2 No. 0.17-00
Evaluation of Properties of Polymeric Materials

2.1.4 **UL Standards**

UL 94
Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 746C
Polymeric Materials – Use in Electrical Equipment Evaluations

2.1.5 **NFPA* Standard**

ANSI/NFPA 70-2005,
National Electrical Code (NEC)

*National Fire Protection Association

2.1.6 **NOM Standards – Mexican Secretary of Energy**

NOM-001-SEDE,
Standard for Electrical Installations

2.2 Informative references

2.2.1 See Annex A for a listing of supplemental standards.

3 Units of Measurement

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

4 Definitions

For the purpose of this Standard, the following terms and definitions apply.

4.1 circular mil (cmil) – the area of a circle with a diameter of 0.001 inch.

4.2 connector – device for connecting a conductor to an equipment terminal or for connecting two or more conductors to each other.

4.3 control conductor – an unbroken conductor, which is included in the current-cycling test loop.

4.4 crimping die – that part of a crimping tool which forms the crimp(s) and usually incorporates the crimp anvil(s), the crimp indentor(s), and the positioner.

Note: Crimping dies may have separate or integral sections for compressing the insulation grip, if provided.

4.5 equalizer – a busbar that provides a point of equipotential and uniform current flow in a stranded conductor without adversely affecting the temperature of the connector(s).

4.6 packaging container – the container in which the unit containers are packaged.

4.7 rated current (ampere rating) – current assigned to the connector by the manufacturer.

4.8 splicing wire connector – establishes a connection between two or more conductors by means of mechanical pressure and is not intended to be permanently mounted.

4.8A Single Input Wire (SIW) – a stranded conductor that varies the number of wires within a range of conductor sizes in order to permit that range of conductor sizes to be constructed from a single wire size.

4.9 stability factor S – the measure of temperature stability of a connector during the current-cycling test.

4.10 temperature rating – the maximum temperature of an insulated connector, assigned by the manufacturer.

4.11 temperature rise – denotes the difference of the temperature of the connector, measured under load, and the ambient temperature.

4.12 terminal connector – establishes a connection between one or more conductors to a terminal plate or stud, or to any similar device, by means of mechanical pressure.

4.13 unit container – the smallest container in which connectors are packaged.

4.14 voltage rating – the maximum voltage of an insulated connector.

5 Symbols and Abbreviations

5.1 ° – Degree

5.2 A – Amps, Amperes

5.3 Al – Aluminum

5.4 AWG – American Wire Gage/gauge

5.5 C – Celsius

5.5A CC or CCA – Copper-clad aluminum

5.6 Cu – Copper

5.7 d – Days

5.8 f – Flexible

5.9 h – Hours

5.10 $HgNO_3$ – Mercurous nitrate

5.11 Hz – Hertz, cycles per second

5.12 in – Inch, Inches

5.13 kcmil – Thousand circular mil

5.14 m – Meter

5.15 mil – Thousandth of an inch

5.16 min – Minutes

5.17 ml – Milliliter

5.18 mm – Millimeter

5.19 mm^2 – Square millimeter

5.20 N – Newton – kilogram meter/sec^2

5.21 NH_4 – Ammonia

5.22 r – Rigid solid and rigid stranded

5.23 rpm – Revolutions per minute

5.24 s – Seconds

5.25 SAE – Society of Automotive Engineers

5.26 sol – Solid

5.27 str – Stranded

5.28 V – Volts

6 Construction Requirements

6.1 General

6.1.1 The design and construction of a connector intended for use with stranded conductors shall be such that all strands of the conductor shall be contained within the connector.

6.1.2 A connector that is suitable for compact-stranded conductors shall also accept all strands of a Class B concentric-stranded conductor of the same size.

6.1.3 A connector intended for use with conductors of different sizes shall have a clamping mechanism that adapts to conductors of different sizes without permanent removal or addition of parts. Some examples of clamping mechanisms are:

a) direct bearing screws with or without use of a pressure plate;

b) a pressure plate or plates and a screw or screws;

c) deformation of the connector barrel (crimping) using a special tool;

d) a nut threading onto a split bolt; and

e) an element for insulation-piercing or displacement.

6.1.4 Any rearrangement or adjustment of a connector that is necessary to adapt it to various sizes of conductors shall be obvious unless the connector is marked as described in 10.11.

6.1.5 There shall be no sharp edges or corners on the outer surface of a connector that result in damage to insulation that the connector contacts.

6.1.6 The construction of a connector intended to secure more than a single conductor shall be such that there will be no intermixing (direct conductor contact) between the conductors of different materials unless the connector is investigated and found to meet the performance requirements of this Standard and is marked in accordance with 10.24.

6.2 Materials

6.2.1 The main current-carrying part of a connector shall be of aluminum, an aluminum alloy, copper, a copper alloy, or other material investigated and found to meet the performance requirements of this Standard.

6.2.2 A connector intended for use with aluminum conductor(s) or a connector body of aluminum or aluminum alloy shall be coated with an electrically conductive coating, such as tin, that will inhibit oxidation and corrosion. The following need not be coated:

a) a splicing connector shipped prefilled with an oxide-inhibiting compound;

b) the conductor-securing (barrel) portion of a terminal connector that is shipped prefilled with an oxide-inhibiting compound;

c) an aluminum-bodied splicing connector that is intended for an aluminum conductor only;

d) the cut ends of a neutral bar;

e) the top cap of a lay-in connector not in contact with the wire; and

f) the mounting hole in a connector that is intended to be secured by a bolt, nut, and washer.

Note: Other coatings may be used if investigated for the purpose and found suitable.

6.2.3 Iron or steel, if protected against corrosion, may be used for screws, plates, yokes, or other parts that are employed as a means of clamping the conductor, if such parts are not the primary current-carrying members.

6.2.4 Insulation employed as a part of the connector shall be suitable for its rated temperature in accordance with Table 1.

6.2.5 The insulating material shall have a minimum flammability classification of V-2 or VTM-2 as determined by tests described in Annex B. The material thickness for determining the flammability shall be measured at points supporting live parts or within 6 mm (0.236 in) of live parts, whichever is less.

Note: Insulating tubing that has a VW1 rating is not considered equivalent. Tubing may be tested using bar samples to achieve a V-2 minimum rating or the glow wire test (see 6.2.6) may be performed.

6.2.6 With reference to 6.2.5, a material other than V-2 or VTM-2 may be used when the insulation of the wire connector complies with the requirements for the glow-wire test as specified in UL 746C, or CSA C22.2 No. 0.17, or NMX-J-508-ANCE with a glow wire at a temperature of 750°C.

6.3 Soldering lugs

6.3.1 A soldering lug shall be made of copper, brass, bronze, or other material that has been shown by investigation to meet the requirements of this Standard.

6.3.2 A lug of other than wrought copper shall be subjected to an investigation that evaluates if the lug has performance equivalent to that of a wrought-copper lug.

6.3.3 The diameter and depth of the conductor hole, the wall thickness, and the contact area of the tang of a wrought-copper lug shall not be less than the values specified in Table 2, according to the maximum size of conductor that the lug is intended to accommodate.

6.3.4 The diameters and areas of screws or bolts have not been standardized, and no addition or subtraction for these has been made in determining the areas specified in Table 2.

7 Test Requirements

7.1 General

7.1.1 A connector shall meet the test requirements when separate specimen sets are subjected to the applicable tests for the design of the connector as specified in Table 3 through Table 5 and in 7.10 through 7.13.

7.1.2 With reference to 7.1.1, a connector of copper or copper alloy need not be subjected to the current-cycling sequence using copper conductor, unless the connector is dependent upon insulation piercing, insulation displacement, or spring action.

7.1.3 With reference to 7.1.1, the initial static-heating test need not be conducted in the static-heating sequence using copper conductor.

7.1.4 With reference to 7.1.1, for other than a tool-applied crimp connector, the current-cycling test using a copper conductor need not be performed when the connector has been current-cycling tested with an aluminum conductor of a size not smaller than the size of the copper conductor required for the current-cycling test.

Note: See Annex C for example.

7.1.5 Conductor sizes 30 – 20 AWG (0.05 – 0.52 mm^2) need not be subjected to the secureness test in the static-heating sequence or mechanical sequence.

7.1.6 Specimen sets shall be subjected to the test sequences using the conductor material specified in Table 6 for the one or more conductor material combinations for which the connector is intended. The dielectric withstand, stress corrosion, secureness of insulation, flexing, and low temperature installation tests shall be permitted to be conducted using either copper or aluminum or copper-clad aluminum conductor. When a connector is rated for copper-to-copper, aluminum-to-aluminum, and copper-to-aluminum (intermixed), or copper-clad aluminum, the mechanical sequence with copper-to-aluminum or copper-clad aluminum conductors may be omitted.

7.1.7 A connector rated for Class 5 and 6 metric conductors (flexible stranded) shall be subjected to all test sequences using flexible metric conductors.

7.1.8 For a connector intended to be used with aluminum, copper-clad aluminum and copper conductor (marked ″AL-CU″), specimens with aluminum conductor, copper-clad aluminum and copper conductor shall be subjected to the current-cycling, static-heating sequence, and mechanical sequence tests. For a connector intended to be used with copper-clad aluminum and copper conductor (marked ″CC-CU″), sample sets with copper-clad aluminum conductor and copper conductor shall be subjected to the heat-cycling, static-heating sequence, and mechanical sequence tests. See 8.2.1.

7.1.8A Tests with aluminum conductor are representative of tests with copper-clad aluminum conductor.

7.1.9 For an aluminum-bodied connector intended to be used with copper conductor only, specimens with copper conductor shall be subjected to the current-cycling, static-heating sequence, and mechanical sequence tests.

7.1.10 Tests conducted on a connector with compact-stranded conductors shall represent tests with concentric and compressed stranded conductors of the same size.

7.2 Current-cycling

7.2.1 The specimen sets shall complete 500 cycles of equal current-on and current-off operations for the periods of time specified in Table 7, other than as noted in 9.2.2 and 9.2.5, while carrying the current specified for the connector temperature rating and conductor size being tested.

7.2.2 The current-cycling test shall be completed without any connector exceeding a 125°C temperature rise above the ambient temperature for any recorded cycle.

7.2.3 The stability factor ″S_i″ (see 7.2.4) shall not exceed ± 10 for connector temperature measurements taken at approximately 25, 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles.

7.2.4 The stability factor ″S_i″ for each of the 11 temperature measurements shall be determined by applying the following equations:

$$S_i = d_i - D$$

$$D = [d_1 + d_2 + ... + d_{11})/11]$$

in which:

D is the average temperature deviation,

i is a number from 1 to 11 and signifies one of the 11 individual temperature measurements, and

d_i is a temperature deviation for an individual temperature measurement.

Note: The value for d_i is determined by subtracting the control conductor temperature from the connector temperature. The value for d_i is a positive number when the connector temperature is more than that of the control conductor and a negative number when the connector temperature is less than that of the control conductor. The average of the 11 temperature deviations is then determined. See Annex D for example.

7.3 Static-heating sequence

7.3.1 The specimen sets shall carry continuously the value of 60 Hz test current specified in Table 7 or Table 8 for the conductor size being tested until stable temperatures are reached without exceeding a 50°C temperature rise above ambient temperature.

Note 1: The temperature rise on an ampere-rated connector may exceed 50°C when the connector, as used in the intended equipment application, does not exceed the maximum allowable temperature rise permitted for the end-use application.

Note 2: A current source may be maintained at or above the required value by regulation or frequent adjustment.

7.3.2 The joint between a connector and the conductor shall be intact after being subjected for 30 min to the secureness test described in 9.3.2.

7.3.3 The joint between a connector and the conductor of a specimen set shall be intact after being subjected for 1 min to the pullout test described in 9.3.4.

7.3.4 As a result of the tests, there shall be no breakage of the conductor or any strand of a stranded conductor, stripping of threads, shearing of parts, or other damage to the connector. Breaking of the conductor or any strand of a stranded conductor shall be determined by examination of the complete connector assembly while still intact after the secureness or pullout tests. Breakage has occurred if the conductor or a strand of a stranded conductor becomes visibly unattached. Strand breakage of 5 percent is allowed for flexible and fine stranded conductors.

7.4 Mechanical sequence

7.4.1 The joint between a connector and the conductor of a specimen set shall be intact after being subjected for 30 min to the secureness test described in 9.3.2.

7.4.2 The joint between a connector and the conductor of a specimen set shall be intact after being subjected for 1 min to the pullout test described in 9.3.4.

7.4.3 As a result of the tests, there shall be no breakage of the conductor or any strand of a stranded conductor, stripping of threads, shearing of parts, or other damage to the connector. Breaking of the conductor or any strand of a stranded conductor shall be determined by examination of the complete connector assembly while still intact after the secureness or pullout tests. Breakage has occurred if the conductor or a strand of a stranded conductor becomes visibly detached. Strand breakage of 5 percent is allowed for flexible and fine stranded conductors.

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7.5 Dielectric-withstand test sequence

7.5.1 An insulated wire connector shall withstand, without breakdown, the dielectric-withstand tests as specified in Table 9.

7.5.2 The insulation of an insulated connector shall not crack or break when the connector is assembled as intended on the conductor.

7.5.3 The oven conditioning described in 9.5.2.2, 9.5.2.3, and Table 10 shall not cause the connector insulation to harden, soften, crack, deform, loosen, or otherwise change so as to adversely affect the insulating properties of the conductor insulation or the connector insulation.

Note: Discoloration of the connector insulation is allowed.

7.6 Secureness of insulation

7.6.1 The insulation of a connector shall not be damaged and shall not become detached from the body of the connector when subjected to the secureness of insulation test described in 9.6.

7.7 Drop

7.7.1 A latch or a lock employed on the cover of an insulated splicing connector intended for use with a 4 AWG (21.1 mm^2) or larger conductor shall not open or break when the connector is subjected to the drop test as specified in 9.7. Cracking or breakage of the remaining insulation shall be allowed when the assembly complies with the dielectric withstand after drop as specified in 7.8.

7.8 Dielectric withstand after drop

7.8.1 An insulated splicing connector that has been subjected to the drop test shall comply with the dielectric voltage-withstand as specified in 9.8.

7.9 Flexing

7.9.1 An insulating cover employing a hinge, a latch, or a lock shall retain its resilience and shall not crack when subjected to the flexing test specified in 9.9.

7.10 Low temperature installation

7.10.1 In Canada, the thermoplastic or thermosetting insulation of a connector of the type assembled by hand or ratchet tools shall not crack or fracture when assembled in accordance with 9.10. This test shall not apply to insulated wire connectors intended for factory installation only. See 10.39.

In the United States and Mexico, this requirement does not apply.

7.11 Moisture absorption

7.11.1 Porcelain or cold-molded composition used as insulation on connectors shall not absorb more than 3 percent of its mass when subjected to the moisture-absorption test as specified in 9.11.

7.12 Stress corrosion/moist ammonia (NH_4)

7.12.1 A copper alloy part of a connector shall be resistant to stress corrosion cracking.

Note: The moist ammonia test is considered an alternative to the mercurous nitrate test.

7.12.2 A copper alloy part containing more than 15 percent zinc shall be tested for stress corrosion cracking.

7.12.3 A copper alloy part containing more than 15 percent zinc shall show no evidence of cracking when examined using a 25X magnification after being subjected to the stress corrosion/moist ammonia (NH_4) test as specified in 9.12.

7.13 Stress corrosion/mercurous nitrate ($HgNO_3$)

7.13.1 A copper alloy part of a connector shall be resistant to stress corrosion cracking.

Note: The mercurous nitrate test is considered an alternative to the moist ammonia test.

7.13.2 A copper alloy part containing less than 80 percent copper shall not crack when subjected to the stress corrosion/mercurous nitrate ($HgNO_3$) test in 9.13.

8 Sampling Requirements

8.1 General

8.1.1 See Table 11 for the minimum number of specimens for test.

8.1.2 Separate specimen sets shall be used for current-cycling, mechanical sequence, static-heating sequence, dielectric-withstand tests and the other tests as applicable. See Table 3, Table 4, Table 5, and Table 9.

8.1.3 The basic specimen set for the current-cycling tests, mechanical sequence, and static-heating sequence shall consist of four connectors for each combination of connector and test conductor or conductors to be tested.

8.1.4 With reference to 8.1.3, for testing a splicing connector or run and tap connector in which each conductor is secured by a separate means, the specimen sets shall consist of two connectors for each combination of connector and test conductor to be tested.

8.1.5 With reference to 8.1.3, for a neutral bar, the basic specimen set shall consist of two specimens of three connector holes cut from a length of the neutral bar. The distance between the holes cut from the neutral bar shall be representative of the minimum distance.

8.1.6 With reference to 8.1.3, for a connector intended for a conductor size range of 30 – 10 AWG (0.05 – 5.3 mm^2) copper and 12 and 10 AWG (3.3 and 5.3 mm^2) aluminum or copper-clad aluminum, the basic sample set for the static-heating sequence shall consist of two connectors for each combination of connector and test conductor to be tested.

8.1.7 For a line of connectors of similar design but of different sizes, the following sizes shall be tested:

a) the largest and the smallest sizes if the line consists of four sizes or less;

b) the largest, smallest, and one representative intermediate size if the line consist of five sizes; and

c) the largest, smallest, and two representative intermediate sizes if the line consists of more than five sizes.

8.1.8 A line of connectors of similar design is determined by the following features:

a) shape of connector, shape of conductor opening, and shape and number of clamping screws;

b) material and surface treatment of the connector body, tang, clamping screw, and pressure bar;

c) torque corresponding to the wire size of each connector;

d) crimping die design and number of crimps for connectors using crimping tools; and

e) for a tangless connector, the material and plating of the associated tang to be used with the connector.

8.1.9 Specimens shall be tested using both solid and stranded conductor for 30 – 10 AWG (0.05 – 5.3 mm^2) conductor sizes, and using stranded conductor for 8 AWG (8.4 mm^2) and larger unless the conductor is marked in accordance with 10.13, in which case the conductor used shall be of the type or types marked on the connector.

8.1.10 If the conductor range of a connector includes sizes 14 – 10 AWG (2.1 – 5.3 mm^2), and these sizes are not included in the test sample selection, additional sample sets shall be tested using the maximum size solid conductor in the range of 14 – 10 AWG (2.1 – 5.3 mm^2).

8.1.11 Testing using AWG/kcmil conductors is representative of Class 1 and 2 metric conductors (rigid solid and rigid stranded) within the cross-sectional area envelope of the rated AWG/kcmil range. Class 5 and 6 metric conductors (flexible stranded) shall additionally comply with the requirements in 7.1.7.

8.1.12 A connector that is designed to employ clamping screws made for either aluminum, brass, or steel shall be tested with clamping screws made of the material specified in Table 12.

8.2 Current-cycling

8.2.1 For a connector without an assigned ampere rating, specimens shall be tested using the maximum size conductor or conductors. For a connector intended for a single conductor and also for paralleling conductors, current-cycling tests shall be conducted on specimens using the maximum single and maximum parallel conductor sizes. For a connector that is intended for a range of conductor sizes and for copper conductor in addition to aluminum conductor or copper-clad aluminum conductor, current-cycling tests with copper conductor need not be performed if the size that is selected results in a test current that is less than or equal to the test current used in the tests with aluminum conductor or copper-clad aluminum conductor. Also see 7.1.4.

Note: The current used in the tests with aluminum conductor or copper-clad aluminum conductor may be raised above the required value with the concurrence of those concerned.

8.2.2 For a connector with an assigned ampere rating, specimens shall be tested using the size or sizes of the conductor corresponding to the assigned maximum ampere rating and connector temperature rating as indicated in Table 7. If the assigned maximum ampere rating of a connector falls between the two values of assigned ampere rating specified in these tables, the test current used shall be that which corresponds to the higher assigned rating. For connectors intended for paralleling conductors, the conductor sizes shall be selected in accordance with Table 7, and the current shall be selected in accordance with Table 13. For a connector that is intended for a range of conductor sizes and for copper conductors in addition to aluminum conductors or copper-clad aluminum conductors, current-cycling tests with copper conductors are not required to be conducted if the size that is selected results in a test current that is less than or equal to the test current used in the tests with aluminum conductors or copper-clad aluminum conductors.

Note: The current used in the tests with aluminum conductors or copper-clad aluminum conductors may be raised above the required value with the concurrence of those concerned.

8.2.3 For a connector with an assigned ampere rating and intended for a single conductor and also for paralleling conductors, the current-cycling test shall be conducted on specimens using the conductor combination or conductor size as selected for the static-heating test. For a connector that is intended for a range of conductor sizes and for copper conductors in addition to aluminum conductors or copper-clad aluminum conductors, heat-cycling tests with copper conductors need not be conducted if the size that is selected results in a test current that is less than or equal to the test current used in the tests with aluminum conductors or copper-clad aluminum conductors.

Note: The current used in the tests with aluminum conductors or copper-clad aluminum conductors may be raised above the required value with the concurrence of those concerned.

8.2.4 With reference to 7.1.6 and Table 6, if the connector is intended for the intermixing of conductors of different materials, the heat-cycling tests shall be conducted using the following conductor material:

a) maximum size copper with maximum size aluminum or copper-clad aluminum;

b) maximum size copper with minimum size aluminum or copper-clad aluminum;

c) minimum size copper with minimum size aluminum or copper-clad aluminum; and

d) maximum size copper in combination with a minimum size aluminum or copper-clad aluminum conductor or conductors where the sum of test currents of the minimum size conductors is approximately equal to the current of the maximum size conductor.

The test currents are based on the lesser current dictated by the two different conductor materials.

8.3 Static-heating sequence

8.3.1 A connector without an assigned ampere rating and intended for use with a range of conductor sizes shall be tested with the maximum size conductor. If more than one conductor is secured by a single clamping means, additional specimens shall be subjected to this test or the mechanical sequence test, as necessary.

8.3.2 For an ampere-rated connector not intended for paralleling conductors, the static-heating sequence shall not be conducted with the larger size(s) of conductor that exceed the size conductor that corresponds to the ampere rating of the conductor as determined from Table 7; only the mechanical sequence tests shall be conducted. A connector specimen set with the size conductor that corresponds to the ampere rating shall be subjected to the full static-heating sequence.

Note: See Annex C for example.

8.3.3 For an ampere-rated connector intended for paralleling conductors, specimens shall be tested with the parallel conductor combinations that equal the assigned ampere rating as determined from Table 7. The ampere rating assigned to the connector shall be divided by the number of conductors. For ampere ratings that fall between two consecutive values, the next larger conductor size shall be used. The values of test current in the static-heating test for the parallel-conductor range shall be selected from Table 8. If the number of conductors is less than the number of conductor openings, the conductors shall be positioned in the connector so that the test current is concentrated in the smallest cross-sectional area of the connector in the current path. If the connector also has single conductor ranges, the conductor sizes and values of test current in the static-heating tests for the single conductor ranges shall be selected from Table 7 using the conductor size that corresponds to the ampere rating of the connector.

Note: See Annex C for example.

8.3.4 For the static-heating sequence where intermixing of conductor types is involved, the same selection of samples as indicated in 8.2.4 shall be tested.

8.4 Mechanical sequence

8.4.1 For the mechanical sequence, connectors intended for use with a range of conductor sizes shall be tested with the maximum and minimum size conductor. The mechanical sequence on any particular conductor size need not be repeated if it has been conducted as part of the static-heating sequence. If more than one conductor is secured by a single clamping means, additional specimens shall be selected for this test, as necessary.

8.5 Dielectric withstand

8.5.1 For a connector intended to secure combinations of conductors of different total cross-sectional areas, tests shall be performed on the combination of conductors of the smallest total cross-sectional area and on the combination of largest total cross-sectional area.

8.5.2 For a connector intended to secure single conductors of different sizes, tests shall be performed on specimens with the smallest and largest conductors.

8.6 Secureness of insulation

8.6.1 The number of specimens as identified in Table 11 shall be subjected to the secureness of insulation test described in 9.6.

8.7 Drop

8.7.1 The number of specimens as identified in Table 11 shall be subjected to the drop test described in 9.7.

8.7.2 Six specimens for each conditioning shall be assembled with the combination of conductors of the smallest total cross-sectional area, and six specimens for each conditioning shall be assembled with the combination of conductors of the largest total cross-sectional area.

8.8 Dielectric withstand after drop

8.8.1 The same samples previously subjected to the drop test in 9.7 shall also be subjected to the dielectric voltage-withstand after drop test as specified in 9.8.

8.9 Flexing

8.9.1 The number of specimens as identified in Table 11 shall be subjected to the flexing test described in 9.9.

8.10 Low temperature installation

8.10.1 In Canada, the number of specimens as identified in Table 11 shall be subjected to the low temperature test in 9.10. Six specimens shall be assembled with the combination of conductors of the smallest total cross-sectional area, and six specimens shall be assembled with the combination of conductors of the largest total cross-sectional area.

In the United States and Mexico, this requirement does not apply.

8.11 Moisture absorption

8.11.1 The number of specimens as identified in Table 11 shall be subjected to the moisture absorption test described in 9.11.

8.12 Stress corrosion/moist ammonia (NH_4)

8.12.1 The number of specimens as identified in Table 11 shall be subjected to the stress corrosion/moist ammonia (NH_4) test described in 9.12.

8.13 Stress corrosion/mercurous nitrate ($HgNO_3$)

8.13.1 The number of specimens as identified in Table 11 shall be subjected to the stress corrosion/mercurous nitrate ($HgNO_3$) test described in 9.13.

8.13.2 The test shall be conducted on a specimen previously unused and not attached to a conductor or otherwise subjected to external stress.

9 Test Methods

9.1 General

9.1.1 Temperature measurement

9.1.1.1 Temperatures shall be measured by thermocouples consisting of conductors not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2).

9.1.2 Ambient temperature measurement

9.1.2.1 Test assemblies shall be located in a substantially vibration and draft-free location where the average ambient air temperature shall be maintained in the range of 15°C – 35°C. The ambient temperature shall be kept within ± 4°C at all times during the test.

9.1.2.2 Thermocouples to measure the ambient temperature for a connector specimen under test shall be installed on 50.8 mm (2 in) square x 6.4 mm (1/4 in) thick sections of unplated copper bus. All buses shall be mounted in a vertical plane at the same elevation as the wire connectors being tested. All measurements shall be made to the centerline of the nearest connector or control conductor. If all thermocouples employed are the same length, they shall be connected in parallel to provide an average ambient temperature.

9.1.2.3 For vertically mounted connectors, one bus shall be located 610 mm (2 feet) in front, one bus 610 mm (2 feet) in back of the specimens and control conductor. For test assemblies employing an insulating backboard as mentioned in 9.1.10.10, no bus section shall be mounted behind the test assembly.

9.1.2.4 For horizontally mounted connectors in an assembly of one or more specimens of connectors, bus sections shall be located 610 mm (2 feet) in front, 610 mm (2 feet) in back, and 610 mm (2 feet) on each side of the test assembly. An alternate method of locating the thermocouple for a horizontal test assembly is to place one bus at the center of a loop formed by the specimens and control conductor.

9.1.3 Control conductor temperature measurement

9.1.3.1 A thermocouple shall be located on each control conductor. For control conductors used when testing a connector intended for paralleling conductors, the thermocouples shall be the same length and connected in parallel to determine the average control conductor temperature.

9.1.3.2 A thermocouple on a control conductor used in the current-cycling test shall be located at the midpoint of the conductor and under the conductor insulation. The thermocouple shall be secured by soldering, by use of an adhesive, or by other equivalent means. The conductor insulation shall be replaced over the thermocouple location. The surface of the conductor metal shall not be penetrated. Drilling and peening shall not be used.

9.1.3.3 For temperature measurements on a copper control conductor, the following technique shall be employed:

a) A small flap shall be cut into the conductor insulation and rolled back to expose the conductor.

b) The thermocouple bead shall be positioned in the valley between conductor strands or on the surface of a solid conductor.

c) The flap of insulation shall be repositioned and secured by a tightly wrapped, double layer of black thermoplastic tape extending not more than 12.7 mm (1/2 in) on each side of the flap, or by another similar means of holding the test conductor insulation in place.

9.1.3.4 For temperature measurements on an aluminum control conductor, if a thermally conductive adhesive which maintains direct contact with the strand of the control conductor is used, the technique specified in 9.1.3.3 shall be used. When a thermally conductive adhesive is not used, the following technique shall be used:

a) A 25.4 mm (1 in) minimum length of insulation over the full circumference of the conductor shall be removed.

b) For a solid conductor, the thermocouple shall be secured to the surface of the conductor.

c) One conductor strand shall be pried out of the stranding just enough to insert the end of a soft copper ribbon measuring 6.4 mm (1/4 in) wide x 0.13 mm (0.005 in) thick to a length that overlaps approximately 3.2 mm (1/8 in) as illustrated in Figure 1. The conductor strand shall then be lightly tapped back down on the copper ribbon.

d) The copper ribbon shall be wrapped partially around the conductor strands back to the one strand that has been pried out.

e) The thermocouple shall be located on the copper ribbon in the valley formed by the pried-out strand and the adjacent strand and shall be soldered in place. The copper ribbon shall be wrapped completely around the bundle of strands and shall be cut off so that a 3.2 mm (1/8 in) overlap results. The ribbon shall be secured in place by reheating the solder behind the ribbon where the thermocouple is located.

f) The section of insulation removed as described in a) shall be attached with the slit side directly opposite the thermocouple junction. Thin-walled heat shrinkable 125°C tubing or a tightly wrapped, double layer of black thermoplastic tape extending not more than 12.7 mm (1/2 in) on each end of the section of insulation shall be used to hold it in place.

9.1.4 Specimen temperature measurement

9.1.4.1 A thermocouple on a wire connector shall be positioned to sense the highest temperatures generated by the connector. In general, the thermocouple sensing bead shall be located on one of the conductor entry sides of the connector and closest to the conductor/connector contact surface. A thermocouple shall be installed so as to obtain thermal and mechanical bonding with the surface of a connector and without causing an appreciable change in the temperature of the connector, for example, by peening thermocouples into small holes drilled in the connector or by the use of small quantities of an adhesive.

9.1.4.2 A test specimen shall be considered stable during the static-heating test when three temperature readings taken at not less than 10 min intervals show no more than a 2°C variation between the three consecutive readings.

9.1.5 Test and control conductors

9.1.5.1 All test specimen conductors and control conductors shall comply with the requirements in Table 14, Table 15, and Table 16. All test specimen conductors and control conductors shall be new (previously unused) or, with the concurrence of those concerned, shall be previously used conductors that have not attained a temperature of over 120°C. For previously used conductors, used conductor ends shall be cut off and the resulting new ends of the conductor re-stripped in accordance with 9.1.6.

9.1.5.2 In Canada and Mexico, test conductors for connectors rated for stranded copper conductors 8 AWG – 1000 kcmil (8.4 – 508 mm^2) shall be Class B and compact rather than concentric or compressed as specified in Table 15.

In the United States, this requirement does not apply.

9.1.5.3 Connectors additionally rated for 2 AWG (33.6 mm^2) and larger compact-stranded copper conductors shall be tested with compact-stranded Class B copper conductors. See also 6.1.2 and 10.40.

9.1.5.4 A connector for flexible copper wire other than Class B or Class C stranding shall be subjected to all test sequences using the other stranding.

9.1.5.5 With the concurrence of those concerned, the test specimens and conductors used in the current-cycling test for the evaluation of a 75°C rated connector may be used to evaluate the connector for a 90°C rating at the required new test current and for an additional 500 cycles.

9.1.5.6 The insulation for conductors shall be black or, with the concurrence of those concerned, insulation color other than black shall be allowed.

9.1.5.7 The conductor shall be examined to verify that the insulation has not penetrated beyond the first strand layer during the manufacturing process.

Note: A separator may be located between the conductor and the insulation of a stranded conductor to attain required separation.

9.1.5.8 The length measured from the conductor entry face of the test connector to the equalizer for the current-cycling test or to the face of the connector at the other end of the test conductor for the mechanical or static-heating test shall be as specified in Table 17.

9.1.5.9 The length of control conductors used in the current-cycling tests shall be a minimum of twice the length of the test conductors used with the connector specimens.

9.1.6 Conductor stripping

9.1.6.1 Conductors shall be stripped immediately prior to installation for a distance that is proper for insertion into the connector and shall be assembled in the connector in the intended manner. The conductor shall not be brushed or abraded prior to the installation of the connector.

Note 1: Care should be taken in stripping conductors to avoid cutting, nicking, scraping, or other damage to the conductors. Care should be taken in removing all foreign materials such as insulation, separators, and the like from the stripped ends.

Note 2: For an insulation piercing connector, the removal of the outer sheath of a cable, if necessary, is not considered to be a previous stripping.

9.1.6.2 For an insulated or non-insulated connector marked with a nominal strip length according to footnote a of Table 18, all tests, except for the dielectric-withstand test, shall be performed with conductors stripped to the nominal value minus the tolerance specified in Table 19. The dielectric voltage-withstand test on an insulated connector shall be performed with conductors stripped to the marked nominal strip length.

9.1.6.3 For an insulated connector marked with a maximum conductor strip length and a minimum conductor strip length according to Table 18, all tests, except the dielectric-withstand test, shall be performed with conductors stripped to the minimum length. The dielectric voltage-withstand test shall be performed with conductors stripped to the maximum length. For a non-insulated connector marked with a minimum conductor strip length, all tests shall be conducted with conductors stripped to the minimum length.

9.1.6.4 If the strip length is not provided in accordance with footnotes b and c of Table 18, the insulation of the test conductor shall be stripped to allow the conductor to make contact with the full available length of the connector collar or barrel that contains the securing means. The conductor shall be positioned so that 6.4 – 12.7 mm (1/4 – 1/2 in) of bare conductor is exposed between the conductor-entry face of the connector and the beginning of the insulation. If the conductor projects through the wire connector without interference, the conductor shall be installed to project a maximum of 6.4 mm (1/4 in).

9.1.7 Equalizer

9.1.7.1 For the current-cycling test, each stranded control conductor and each stranded conductor that has been terminated or is intended to be terminated in a test connector shall have the free end welded or brazed to an equalizer to make a thorough electrical connection for each strand. Tool-applied compression connectors without welding may be used.

Note 1: An equalizer is not required but can be used for a solid test conductor.

Note 2: Equalizers need not be used on specimens intended for any other tests, as it is necessary to insert the open end of the conductor through a bushing for the secureness test.

9.1.7.2 An equalizer shall be constructed using:

a) a short length of copper or aluminum bus having one or more holes slightly larger than the conductor;

b) a tool-applied compression connector; or

c) a pressure screw-type wire connector having an open end opposite the conductor insertion end.

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9.1.7.3 The end of the conductor that projects through the equalizer shall be welded into a homogeneous mass with the bus (see 9.1.7.2 a)) or the connector (see 9.1.7.2 c)). For a connector intended for paralleling conductors, the hole spacing pattern in the equalizer shall be identical to the hole spacing pattern in the connector. A wire connector used as an equalizer shall not be larger than that needed for the conductor size involved, and an equalizer bus shall not be larger than the applicable bus size indicated in Table 20. For test currents over those in Table 20, the size of the equalizer shall be based on 1.55 A/mm^2 (1 000 A/in^2) of cross-section for a copper bus equalizer and 1.16 A/mm^2 (750 A/in^2) of cross-section for an aluminum bus equalizer.

9.1.8 Preparation of specimens

9.1.8.1 Representative specimens of the connector shall be assembled to conductors of the proper type, length, and size and in the manner used in service. For the current-cycling test, control-conductor assemblies shall also be prepared. These control-conductor assemblies shall be wired in series with the specimens used for the current-cycling test and shall carry the same test current. For a connector intended for paralleling conductors, the number of control conductors shall be equal to the number of conductors being tested.

9.1.8.2 If a connector is intended for assembly by means of a specific tool, this tool shall be used in the intended manner.

9.1.8.3 If a connector is intended to be assembled to a conductor by means of more than one type of specific tool, the connector shall meet the requirements when any of the specific tools are employed in the assembly operation.

9.1.8.4 With reference to 9.1.8.3, in selecting tools for assembly of a connector to a conductor, the following features shall be considered:

a) profile, width, and depth of the connector;

b) material of connector body;

c) crimping die geometry;

d) the number of crimps; and

e) similarity of crimp forces.

9.1.8.5 If specific instructions for assembling the connector to the conductor are furnished with the connector, such instructions shall be followed in the preparation of the specimens, except that the conductor shall not be brushed or abraded and an antioxidant shall be used only if the connector is prefilled with the antioxidant. See 10.15.

9.1.8.6 A tangless terminal connector (e.g., collar or meter-socket construction) shall be mounted for test purposes on a tang representative of the intended use; see 9.1.8.8. The length of the tang shall not exceed twice the length of the connector body. For the static-heating sequence and mechanical sequence, individual tangs with a mounting hole in the end opposite the connector shall be used. For the current-cycling test, one tang with connectors mounted as illustrated in Figure 2 shall be used. If the specified mounting means includes auxiliary antirotation means, such means shall not increase the thermal mass or heat-radiating capabilities of the assembly.

9.1.8.7 With reference to 9.1.8.6, a terminal connector integral with a fuse clip, meter-socket jaw, or similar feature, intended for connection to a bus having a low conductivity shall have the tang sized to reduce the risk of over-heating of the tang. The test tang shall not be so large that it operates cooler than the bodies of the connector as determined by thermocouples placed on the tangs and connector bodies.

9.1.8.8 For a tangless connector (see Figure 2), the following information shall be provided:

a) material of tang;

b) plating on tang;

c) minimum cross-section of tang;

d) material of mounting screw;

e) use of a washer, type and size; and

f) torque to be used to secure the connector to the tang.

9.1.9 Tightening torque

9.1.9.1 The connection between the conductor and the connector shall be made before the start of the first test on any specimen set. No additional tightening shall be performed during the testing program.

9.1.9.2 A connector shall be mounted to a test bus according to the manufacturer's minimum specifications. During application of the tightening torque the connector assembly shall be free to turn about its mounting means except as restricted by the design of the connector or the specified mounting means. Subsequent turning of the connector about its mounting means shall only occur due to test procedures such as those for the secureness test. The mounting means shall not be retightened during the testing program.

9.1.9.3 The specified torque shall be applied by tightening the connection between the conductor and the connector until the specified value of torque is attained and maintaining this value, with a constant torque reading, for 5 s.

9.1.9.4 Except as allowed in 9.1.9.5, the tightening torque values specified in Table 21, Table 22, or Table 23 shall apply to all connectors employing conductor clamping nuts or bolts of the types described in the tables. The values in Table 21 are based on the size of the installed test conductor, while the torque values specified in Table 22 and Table 23 are independent of the installed test conductor. Table 22 is limited for use with connectors intended for 8 AWG (8.4 mm^2) or smaller conductors. If more than one conductor is secured under the same clamping nut or bolt, the torque value in Table 21 shall be applied based on the largest conductor installed. Specimens prepared for the current-cycling test shall be tightened using the values of torque shown in column A. All other tests shall have the specimens prepared using the values in column B.

9.1.9.5 With reference to 9.1.9.4, when a tightening torque value is assigned, the current-cycling test specimens shall be prepared using 90 percent of the assigned torque value. All other tests shall have the specimens prepared using the assigned value of torque. See 10.27 for marking requirements.

9.1.9.6 Connectors having clamping screws with multiple tightening means (for example, a combination slotted, hexagonal head screw) shall be tested using the multiple values of torque as specified in Table 21, Table 22, and Table 23.

9.1.10 Test assembly

9.1.10.1 Specimens and the control conductor shall be connected in series and to a current source. Tang-type connectors shall be bolted back-to-back, and equalizers shall be bolted together or to lengths of bus using the hardware specified in 9.1.10.2.

9.1.10.2 The following hardware shall be used to make the connections mentioned in 9.1.10.1; once the initial assembly is completed, there shall be no subsequent retightening:

a) A bolt shall be plated steel, SAE Grade 2, UNC thread having a maximum standard diameter compatible with the hole or holes in the connector tang and a minimum standard length allowing at least a 2-thread projection through the nut, and the projection shall not exceed 6.4 mm (1/4 in) after assembly.

b) A single flat washer shall be used on each side of the tang-to-tang or tang-to-bus connection. These washers shall be plated steel having an SAE configuration compatible with the diameter of the bolt.

c) A nut shall be plated steel, and shall have a Class 2B, UNC thread and a hexagonal configuration.

d) Clean, dry, nonlubricated screws and bolts and nuts shall be used.

e) The assembled hardware shall be torqued to the values in Table 24.

9.1.10.3 When the installation instructions (see 10.26) specify that a dished washer shall be used, the design of the dished washer shall be such that the force needed to flatten the washer is as specified for the corresponding bolt size in Table 25. The hardware shall be as follows:

a) One plated or stainless steel dished washer per securing bolt shall be used.

b) A flat washer as mentioned in 9.1.10.2 b) shall be used on the side of the tang-to-tang or tang-to-bus connection opposite the dished washer.

c) Tests on a connector shall be conducted using other hardware, part securement torque values, and dished or other washers having different characteristics, if the installation instructions specify all necessary hardware and torque. See 10.26.

9.1.10.4 The lengths of the busbars mentioned in 9.1.10.1 shall be the minimum necessary to provide sufficient contact area for the equalizers while maintaining the center-to-center specimen spacing specified in 9.1.10.5. The cross-section dimensions of the bar shall be sufficient to prohibit a test-current density in excess of 1.55 A/mm^2(1 000 A/in^2) for copper or 1.24 A/mm^2(800 A/in^2) for aluminum bus. See Table 20.

9.1.10.5 Individual connector/conductor specimens shall be separated by at least 457 mm (18 in) when measured center-to-center.

9.1.10.6 With reference to 9.1.10.5, the spacing may be reduced with the concurrence of those concerned.

9.1.10.7 With reference to 9.1.10.5, the spacing may be reduced to a minimum of 152 mm (6 in) if a thermal barrier is used between assemblies. The thermal barrier shall extend at least 152 mm (6 in) in a vertical direction and 25.4 mm (1 in) in a horizontal direction beyond the extremities of the connector.

9.1.10.8 Test assemblies and the control conductor shall be suspended vertically or horizontally in free air by the use of loose-fitting, nonmetallic tie straps around the conductors or by suspension from the equalizers supported in turn by nonmetallic blocks. The method used shall reduce the disturbance of the test connections during handling of the specimens and reduce the transmission of tensile loads to the test connectors through test or supply conductors. See Figure 3 for an example of a vertical arrangement.

9.1.10.9 The temperature measurement location for the control conductor and connector samples shall be located a minimum of 610 mm (24 in) from the building floor, ceiling, and walls.

9.1.10.10 With reference to 9.1.10.9, the spacing need not be maintained if a solid insulating backboard separates the test samples from the building floor, ceiling, or walls. Samples shall be spaced at least 102 mm (4 in) from the insulating backboard.

9.2 Current-cycling

9.2.1 Connectors intended for use with snap-on molded insulating covers or packaged with insulating materials that are intended to be wrapped around the completed connector/conductor termination shall be tested without the insulating covers or material installed.

9.2.2 For a connector intended for paralleling conductors, the on-time shall be the time it takes for the connector to reach stable temperatures. The off-time shall be the time it takes to reach room temperature. These times shall be determined in the first 25 cycles of operation. A test specimen has attained a stable temperature during the current on-time when three readings show no more than a 2°C variation between any two of the readings. The time to temperature stabilization for the current-off time is the first of three readings indicating stable temperature.

9.2.3 Temperatures shall be measured and recorded for at least 1 cycle of each working day.

9.2.4 Temperatures shall be measured no sooner than the last 5 min of the normal current-on time. If the size of the test specimen set or the speed of the data acquisition system is such that not all measurements are completed within 5 min, the current-on time shall be extended as necessary to complete such measurements.

9.2.5 The current-off times may be reduced after the first 25 cycles of testing to 5 min more than the maximum time it takes any connector to reach a stable temperature during the current-off period. Forced-air cooling may be employed to reduce the current-off time with the concurrence of those concerned. A test specimen has attained a stable temperature during the current-cycling test when three readings at 10 min intervals show no more than a 2°C variation between any two of the readings. The time to temperature stabilization is the current-off time at which the first of three readings indicating stable temperature was recorded.

9.2.6 For a connector intended for paralleling conductors, the initial currents through the conductors shall be balanced so that the highest current in a conductor is not more than 125 percent of the current in any parallel conductor. Current balance need not be attained if agreeable to those concerned.

9.3 Static-heating sequence

9.3.1 Static-heating test

9.3.1.1 Specimens shall be selected and prepared as described in 8 and 9.1.8, except that equalizers shall not be used.

9.3.1.2 The test assembly and securing hardware shall be as described in 9.1.10.

9.3.1.3 *Deleted.*

9.3.2 Secureness test

9.3.2.1 A connector shall be fastened to a length of conductor not less than 76 mm (3 in) longer than the height specified in Table 26, and shall be rigidly secured in a vertical position simulating actual service conditions. The free end of the conductor shall be passed through a bushing of the size specified in Table 26. The bushing shall be attached to an arm driven by a motor at a rate of approximately 9 rpm and in such a manner that the center of the bushing describes a circle in a horizontal plane. See Figure 4. The circle shall have a diameter of 76 mm (3 in), and its center shall be vertically below the center of the conductor opening in the connector. The distance between the upper side of the bushing and the mouth of the connector shall be within 12.7 mm (1/2 in) of height specified in Table 26. The bushing shall be lubricated so there is no binding, twisting, or rotation of the insulated conductor. A mass as specified in Table 26 shall be suspended from the free end of the conductor.

9.3.2.2 If a wire connector is intended to secure more than one conductor at a time by a single clamping means, only one conductor in each combination shall be tested for secureness. If the conductors in the combination are of different sizes, separate specimens shall be used for testing each size of conductor.

9.3.2.3 For the test of a splicing connector in which the conductors lie parallel to or in line with each other, the set-up shall be as illustrated in Figure 5. If the connector is secured to conductors of different sizes, the mass shall be attached to the smallest conductor and the entire assembly of connector, conductors, and mass shall be suspended by means of the largest conductor. The values of the mass W and the height H shall be selected from Table 26 according to the size of the conductor to which the mass is attached. Terminal connectors or other means that will distribute the stress uniformly among the strands of the conductor shall be employed for attaching the mass and for securing the assembly to the frame of the testing machine.

9.3.2.4 A splicing connector in which the conductors do not lie parallel to or in line with each other shall be assembled to a length of through conductor and a length of tap conductor, each of the size for which the connector is intended. The assembly shall be supported by a U-shaped yoke, the arms of which grasp the through conductor on each side of the connector approximately 50 mm (2 in) from the ends of the connector. The depth of the yoke shall be approximately 76 mm (3 in). The yoke shall be secured firmly to the frame of the testing machine so that the tap conductor hangs vertically. The mass, which shall be suspended from the free end of the tap conductor after it has passed through the bushing of the testing machine, shall be as specified in Table 26 according to the size of the tap conductor. The length of the tap conductor shall be not less than 76 mm (3 in) more than the height specified in Table 26, corresponding to the size of the tap conductor. See Figure 6.

9.3.2.5 On a connector intended for paralleling conductors, the test shall be performed on four specimens of entry hole if all conductor entry holes are identical in construction. If entry holes are not identical, then the test shall be repeated using four different entry holes to represent the different constructions.

9.3.3 Repeated static-heating test

9.3.3.1 The sample sets previously subjected to the static-heating test and the secureness test shall be subjected to another static-heating test as described in 9.3.1.

9.3.3.2 With reference to 9.3.3.1, a connector designed for paralleling conductors need not be subjected to this test.

9.3.4 Pullout test

9.3.4.1 The same connectors and entry holes subjected to the secureness test shall be subjected to a direct pull of the applicable value specified in Table 27. For a connector intended to secure more than one conductor at a time by a single clamping means, only those conductors that have been subjected to the secureness test shall be subjected to the pullout test.

9.3.4.2 For an insulated connector in which the insulation is assembled to the connector during installation, the test shall be conducted with the insulation in place if it is always supplied with the connector by the manufacturer. Otherwise the test shall be made without the insulation assembled to the connector.

9.3.4.3 The pull shall be exerted by means of a tension-testing machine, dead weights, or other equivalent means so that there is no sudden application of force or jerking during the test.

Note: Breakage or tearing of the insulation of an insulated connector is allowed in the pullout test.

9.4 Mechanical sequence

9.4.1 Secureness test

9.4.1.1 The test procedure described in 9.3.2 shall be conducted.

9.4.2 Pullout test

9.4.2.1 The test procedure described in 9.3.4 shall be conducted.

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9.5 Dielectric withstand

9.5.1 General

9.5.1.1 No specimen shall be subjected to more than one dielectric-withstand test.

9.5.1.2 With reference to 9.5.1.1, with the concurrence of those concerned, the unconditioned as-received specimens used for Test A, insulation puncture (see 9.5.2) may be used for Test B, flashover (see 9.5.3).

9.5.2 Test A, insulation puncture

9.5.2.1 Three specimen sets shall be subjected to this testing, in the as-received condition, conditioned to 9.5.2.2 and conditioned to 9.5.2.3.

9.5.2.2 Specimens previously assembled to conductors shall be conditioned in an air-circulating oven at an elevated temperature corresponding to the insulation temperature rating, according to Table 10.

9.5.2.3 The specimens not previously assembled to conductors shall be conditioned for 168 h in an air-circulating oven at 100°C. Connectors employing extended covers or sleeves may have the wires pre-installed, but not crimped, prior to the oven aging. The specimens shall then be allowed to cool to room temperature. Following the oven conditioning, the specimens having insulation of hygroscopic material, such as nylon, shall be conditioned for 24 h at a relative humidity of 85 ± 5 percent at 30 ± 2°C. The specimens shall then be assembled (or crimped) to conductors in the intended manner.

9.5.2.4 Each specimen shall be connected to a conductor(s) in the intended manner, and be subjected to a test voltage applied between the conductor(s) and an outer electrode. The test voltage shall be applied for 1 min and shall be in accordance with Table 28 based on the rated connector voltage. Puncture of the conductor insulation during this test is inconclusive and shall require retesting.

9.5.2.5 Only that portion of the outer insulating surface that covers current-carrying parts shall be covered with the outer electrode. Each specimen shall be embedded in No. 7-1/2 conductive shot that is to serve as the outer electrode. A smaller than No. 7-1/2 (higher size number) shot may be used with the concurrence of those concerned. Conductive metal foil shall be used as the outer electrode for a connector that uses a separable cap that is intended to be applied after assembly of the conductors to the connector, or when a connector has openings that will allow entry of the shot.

9.5.2.6 A connector that has openings that allow the entrance of shot, potentially resulting in flashover, shall have those openings closed with tape, petrolatum, epoxy, silicone, rubber, or other suitable material. The exposed tang of a terminal connector shall be similarly treated. This supplementary insulating material shall not be applied so as to supplement the connector insulation where it covers live parts. If flashover between the electrode and a normally insulated live part occurs, the supplementary insulation may be repaired and the test repeated.

9.5.3 Test B, flashover

9.5.3.1 Each specimen shall be connected to a conductor(s) in the intended manner, and be subjected to a maximum test voltage applied between the conductor(s) and an outer electrode. The maximum test voltage specified in Table 28 shall be selected based on the rated connector voltage. Puncture of the connector insulation during this test is inconclusive and shall require retesting.

9.5.3.2 With reference to 9.5.1.2, the Test A voltage specified in 9.5.2.4 shall be applied for 1 min. The connector shall then be repositioned such that the conductor opening is even with the outer electrode. The voltage shall then be rapidly and steadily increased to the maximum test voltage specified in Table 28.

9.5.3.3 With reference to 9.5.3.2, after being held at the required test voltage for 1 min, the connector shall be repositioned and the voltage may be reduced to 0 volts and then rapidly and steadily increased to the maximum test voltage.

9.5.3.4 A connector having insulation in the form of a cap shall be embedded up to the conductor opening of the insulator in No. 7-1/2 conductive shot that is to serve as the outer electrode. A smaller than No 7-1/2 (higher size number) shot may be used with the concurrence of those concerned. Any other connector shall have the surface immediately adjacent to the conductor opening covered with conductive metal foil to serve as the outer electrode.

9.5.3.5 To reduce the occurrence of insulation puncture, the outer surface of the connector insulation and any exposed tang shall be supplemented with tape, petrolatum, epoxy, silicone, rubber, or other similar insulating material so that it does not interfere with the position of the outer electrode immediately adjacent to the connector opening.

9.5.4 Test C, flashover

9.5.4.1 The test voltage specified in Table 29 shall be selected based on the rated connector voltage and be applied for 1 min.

9.5.4.2 Specimens shall not be assembled to conductors. The open end of the connector shall be placed on a flat metal plate in a position most likely to result in flashover. The test voltage shall be applied between the metal plate and all insulated metal parts of the connector.

9.6 Secureness of insulation

9.6.1 For other than a connector as described in 9.6.2, the insulation of a connector shall be subjected to a direct pull of 89 N (20 lb) for a connector employing 30 – 18 AWG (0.05 – 0.82 mm^2) conductor or 133 N (30 lb) for any other connector. The force shall be applied for 1 min between the insulation and the connector.

9.6.2 Connector insulation in the form of a tubular sleeve and intended for use with 10 AWG (5.3 mm^2) or smaller conductors shall be subjected to a direct pull applied for 1 min between the insulation and connector as specified in 9.6.3.

9.6.3 The test shall consist of applying:

a) a 4.4 N (1 lb) pull on the following:

1) unassembled, as-received specimens; and

2) unassembled specimens after conditioning for 168 h at 100 ± 1°C in an air-circulating oven; cooling to room temperature; and, if made of a hygroscopic material such as nylon, conditioning for 24 h at a relative humidity of 85 ± 5% and a temperature of 30 ± 2°C; and

b) a 22 N (5 lb) pull on the following:

1) assembled as-received specimens;

2) specimens that have been assembled to a conductor and then subjected to the oven conditioning in accordance with Table 10; and

3) specimens that have been assembled to a conductor after conditioning for 168 h at 100 ± 1°C in an air-circulating oven, cooling to room temperature, and, if made of a hygroscopic material such as nylon, conditioning for 24 h at a relative humidity of 85 ± 5% and a temperature of 30 ± 2°C.

9.6.3A The pull shall be exerted by means of a tension-testing machine, dead weights, or other equivalent means so that there is no sudden application of force or jerking during the test.

9.6.4 A temporary distortion of flexible insulating material during the test shall be allowed. Tearing or breaking of the insulation shall be allowed, provided that the connector complies with the dielectric-withstand test when retested. The variety of designs of connectors is such that it is not practicable to specify in detail how to apply the pull. The arrangement shall be such that the tendency for the insulation to be damaged or to be separated from the body is greatest.

9.6.5 A connector having flexible insulation that is assembled to the body of the connector after the latter is assembled to a conductor or conductors shall not be subjected to the test specified in 9.6.1 and 9.6.2 until the insulation has regained its normal shape after being assembled to the connector.

9.7 Drop

9.7.1 The connectors shall be assembled so that 76 mm (3 in) of conductor extends from the ends of the insulating cover. The test shall be conducted on as-received specimens, on insulating covers that have been oven-conditioned to an elevated temperature corresponding to the insulation temperature ratings as specified in Table 10, and on specimens that have been subjected to minus 10°C for 2 h. The assemblies that were oven conditioned shall be cooled to room temperature and subjected to the drop test. The assemblies that have been subject to minus 10°C for 2 h shall be subjected to the drop test within 30 s after removal from the cold box.

9.7.2 The drop test shall consist of dropping the insulation covers and connectors onto a maple board from a height of 914 mm (3 feet). Each as-received assembly and oven-conditioned assembly shall be dropped four times so that an impact occurs at the top, bottom, sides, and edges. Specimens subjected to minus 10°C conditioning shall be dropped only once so that the point of impact is that judged to be the most severe from observation of the drop test on the as-received and oven-conditioned specimens.

Cracks shall be allowed if the assemblies successfully comply with the requirement in 9.8.

9.8 Dielectric voltage-withstand after drop

9.8.1 An insulating splicing connector that has been subjected to the drop test described in 9.7 shall additionally be subjected to the insulation puncture test in 9.5.2.

9.9 Flexing

9.9.1 The flexing test shall be conducted on insulating covers in the as-received condition, after oven conditioning to an elevated temperature corresponding to the insulation temperature ratings as specified in Table 10 and after conditioning at minus 10°C for 2 h. The specimens conditioned at minus 10°C shall be allowed to attain room temperature after the removal from the cold chamber before flexing is conducted.

9.9.2 The cover shall be completely opened and closed 20 times. If flexible extensions are provided around the conductors, the conductors shall also be flexed 20 times. Distortion of the flexible extensions shall be allowed if, after 24 h, they return to their original shape and position.

9.10 Low temperature installation

9.10.1 *Deleted.*

9.10.2 In Canada, the connectors, short lengths of insulated wires, and the applicable hand or ratchet tools shall be placed in a cold chamber for 1 h to allow all of the parts to reach a uniform temperature of 0 ± 1°C. The installation of the connectors on the wires shall be performed in the cold chamber and the specimens shall be removed from the cold chamber and immediately examined for any evidence of damage.

In the United States and Mexico, the requirements of 9.10 do not apply.

9.11 Moisture absorption

9.11.1 Specimens used for the moisture-absorption test shall be clean and dry. The insulation of each connector shall be broken, weighed, and then submerged in distilled water at room temperature for 24 h. After removal from the water, it shall be dried with a soft cloth to remove all surface water before reweighing.

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9.12 Stress corrosion/moist ammonia (NH_4)

9.12.1 Each test specimen shall be subjected to the physical stresses normally imposed on or within a part as the result of assembly. Such stresses shall be applied to the specimens prior to and maintained during the test. Specimens shall be assembled to a 152 mm (6 in) length of the maximum rated size conductor and torqued to the value in 9.1.9.4 or 9.1.9.5.

9.12.2 The specimens shall be degreased and then continuously exposed in a set position for 10 d to a moist ammonia-air mixture maintained in a glass chamber approximately 305 x 305 x 305 mm (12 x 12 x 12 in) having a glass cover.

9.12.3 Approximately 600 ml of aqueous ammonia having a specific gravity of 0.94 shall be maintained at the bottom of the glass chamber below the specimens. The specimens shall be positioned 38 mm (1-1/2 in) above the aqueous ammonia solution and supported by an inert tray. The moist ammonia-air mixture in the chamber shall be maintained at atmospheric pressure and a temperature of 34 ± 2°C.

9.13 Stress corrosion/mercurous nitrate ($HgNO_3$)

9.13.1 Specimens shall be immersed in an aqueous solution of 100 g of mercurous nitrate and 13 ml of nitric acid (specific gravity of 1.42) per liter for 15 min. Evidence of cracking shall be determined with normal or corrected vision without magnification.

10 Marking, Labeling, and Packaging

> ***Advisory Note:*** *In Canada, there are two official languages, English and French. All markings required by this standard may be in other languages to conform with the language requirements where the product is to be used.*

10.1 Required marking locations shall be in accordance with 10.2 – 10.42. Refer to Annex E as a guide for marking locations.

10.2 A connector shall be legibly marked with:

a) the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identified;

b) a distinctive catalog number or the equivalent; and

c) the conductor size or ranges of sizes.

10.3 In lieu of the markings in 10.2 b) or c), or both, a connector that is for use only with conductors smaller than 8 AWG (8.4 mm^2) shall be marked with a single identifying symbol. This symbol may be an individual catalog number, a type designation, a size designation, such as 12, or an equivalently significant symbol. Each unit container containing connectors so identified or an information sheet packed in the unit container shall be marked with the information specified in 10.2 a), b), and c). A type designation is intended primarily to identify a particular design, which may include various features covered by different catalog numbers.

10.4 With reference to 10.2, a soldering lug shall be marked with the manufacturer's name or trademark.

10.5 With reference to 10.2 c), the conductor-size marking on a connector intended for assembly to a conductor(s) by means of a specific tool may be a symbol or color, provided that its significance, in terms of a conductor size or sizes, is clearly marked on the tool (die).

10.6 A connector intended for copper conductor only shall be legibly marked with ″CU″ on:

a) the connector;

b) its unit container; or

c) an information sheet packed in the unit container.

10.7 A connector rated for use with aluminum conductor only shall be legibly marked with the letters ″AL″. In lieu of the marking on the connector, for connectors used with 6 AWG (13.3 mm^2) or smaller conductors, the letters ″AL″ may be marked on the unit container or on an information sheet packed in the unit container.

10.8 A connector intended for use with aluminum, copper-clad aluminum and copper conductor shall be legibly marked ″AL-CU″ or ″CU-AL″. In lieu of the marking on the connector, for connectors used with 6 AWG (13.3 mm^2) or smaller conductors, the letters ″AL-CU″ or ″CU-AL″ may be printed on the unit container or on an information sheet packed in the unit container.

10.9 If a connector is intended for use with an aluminum or copper-clad aluminum conductor of one size or range of sizes and with a copper conductor of a different size or range of sizes, the conductor-size marking shall clearly differentiate the size or range of sizes of the aluminum or copper-clad aluminum conductors, and also the size or range of sizes of the copper conductor, for which the connector is rated.

10.10 In regards to 10.9, a single wire range may be marked when:

a) the maximum wire size for both copper and aluminum or copper-clad aluminum is the same; and

b) the minimum aluminum and copper-clad aluminum wire size for both copper and aluminum or copper-clad aluminum is the same or the minimum copper wire size is smaller than 12 AWG (3.31 mm^2).

Note: It is understood that the minimum available aluminum or copper-clad aluminum conductor size is 12 AWG (3.31 mm^2), even though a wire range may include smaller copper wire sizes. For example: a wire range of 1/0 – 14 AWG (53.5 – 2.08 mm^2) is interpreted as 1/0 – 14 AWG (53.5 – 2.08 mm^2) copper conductors and 1/0 – 12 AWG (53.5 – 3.31 mm^2) aluminum or copper-clad aluminum conductors.

10.11 Unless any rearrangement or adjustment of a connector that is necessary to adapt it to various sizes of conductor is obvious, it shall be clearly indicated by size markings or other instructions appearing on:

a) the connector;

b) its unit container; or

c) an information sheet packed in the unit container.

10.12 A connector, a unit container, or an information sheet packed in the unit container for a connector tested with conductors other than Class B, SIW, or Class C stranding (see 9.1.5.4) shall also be marked with the conductor class or classes and the number of strands.

10.13 A connector tested with a solid or stranded conductor other than as specified in 8.1.9 shall be marked ″Solid″ or ″Stranded″ or with both markings as applicable. See 10.14.

10.14 The ″Solid″ and ″Stranded″ markings in 10.13 may be:

a) abbreviated ″Sol″ and ″Str″ respectively; or

b) provided on the unit container or on an information sheet packed in the unit container, if there is insufficient space on the connector for either the complete or the abbreviated marking.

10.15 A procedure that must be followed for proper assembly of a wire connector to a conductor shall be provided as follows:

a) **USE OF A SPECIFIC TOOL REQUIRED** – If a connector is intended to be assembled to a conductor(s) by a specific tool, the tool designation or the designation of a removable tool part, such as a pressing die, shall be marked on the connector, or on or within the unit container in which the connector is packed. The marking shall be by at least one of the following means:

1) catalog or type designation;

2) color coding;

3) die index number; or

4) other equivalent means.

b) **MULTIPLE CRIMPING OPERATIONS** – Information shall appear either:

1) on the unit container in which the connector is packed;

2) on the tool or pressing die that must be used for its application;

3) on the carrying case provided for permanent storage of the tool and dies; or

4) on the connector.

Location of the crimping points only, without additional instructions, may be marked on the connector if the additional required information is located as indicated in item 1), 2), or 3).

c) **CONDUCTOR STRIP LENGTH** – Strip length marking as specified in Table 18 shall appear:

1) on the connector;

2) on the unit container or on an information sheet contained therein;

3) on an insulating cover; or

4) on the tool or on the carrying case provided for its permanent storage if:

i) the connector requires the use of a specific tool for its application; and

ii) the strip length applies to all insulated connectors with which the tool is used.

d) **PRELIMINARY PREPARATION OF CONDUCTOR REQUIRED** – Instructions for preparation of the conductors, such as use of compound or twisting conductors together before assembly, shall appear on the unit container or an information sheet packed in the unit container.

10.16 An insulated connector shall be marked with the voltage rating. The marked voltage rating shall be: ″300 volts maximum″, ″600 volts maximum″, or ″600 volts maximum, building wiring: 1000 volts maximum, signs or luminaries″, or equivalent wording. The marking shall be allowed to be on the unit container or on an information sheet packed in the unit container.

10.17 Copper-bodied connectors intended for copper conductors only are rated 90°C and are not required to be marked with a connector temperature rating. For an insulated copper-bodied connector, the operating temperature rating of the insulation shall be allowed to exceed 90°C when tested and so marked. See Table 1 and Table 10.

10.18 An aluminum-bodied connector intended for copper conductors only (see 7.1.9) shall be marked with a connector temperature rating in accordance with 10.19 (e.g., CU75, CU7, CU90, or CU9).

10.19 A connector rated for AL or AL-CU shall be marked with the connector temperature rating, 75°C or 90°C, as tested in the current-cycling test. For a connector with integral insulation, the temperature rating shall not exceed the operating temperature rating of the insulation. In lieu of the marking on the connector, for connectors used with 6 AWG (13.3 mm^2) or smaller conductors, the temperature rating shall be printed on the unit container or on an information sheet packed in the unit container.

10.20 With reference to 10.19, a 7 may be used to represent a 75°C marking and a 9 may be used to represent a 90°C marking. For a connector marked for use with only aluminum, the single digit shall follow the letters; for example, ″AL7.″ The 7 or 9 shall be incorporated in place of the dash in a marking such as ″AL-CU″ or ″CU-AL″; for example, ″AL7CU″ or ″CU7AL.″

10.21 An insulated connector shall be marked with the maximum operating temperature limit of 75°C or 90°C.

10.22 With reference to 10.21, the marking may be on the unit container or on an information sheet packed in the unit container.

10.23 With reference to 10.21, a unit container or an information sheet packed in the unit container may be marked with a temperature rating that exceeds 75°C or 90°C provided the marking clearly states that the rating is that of the insulating material such as ″Temperature Rating of Insulating Material ____°C .″ See Table 1.

10.24 A connector intended for intermixing between conductor types shall be additionally marked ″(intermixed – dry locations)″ immediately following the marking in 10.19 or 10.20; for example, AL7CU (intermixed – dry locations). See 6.1.6.

10.25 *Deleted.*

10.26 Installation instructions specifying the proper assembly procedures as mentioned in 9.1.8.5 and for the securing hardware mentioned in 9.1.10.3 and 9.1.10.3 c) shall be provided on the unit container in which the connector is packaged or on an information sheet packed in the unit container.

10.27 If the connector has an assigned tightening torque value, as described in 9.1.9.5, the assigned value shall be marked where readily visible on:

a) the connector;

b) the unit container; or

c) an information sheet packed in the unit container.

10.28 A blank tang connector (no mounting hole) shall be provided with installation instructions specifying:

a) the minimum mounting hole size or range and the mounting hole location; or

b) that the connector tang is to be welded.

10.29 With reference to 10.28, the installation instructions shall be on the unit container in which the connector is packaged or on an information sheet packed in the unit container.

10.30 A connector with an assigned ampere rating shall be marked with the assigned ampere rating; for example, ″100 A″ in addition to the other applicable markings. For a connector intended for conductor sizes 6 AWG (13.3 mm^2) or smaller, the marking may be on the unit container or on an information sheet packed in the unit container.

10.31 A unit container or an information sheet shall be marked with:

a) the manufacturer's name; and

b) a distinctive catalog number of the connector or the equivalent if the marking is provided as specified in 10.36.

10.32 A separable insulating cover of a splicing connector shall be marked with:

a) the manufacturer's name;

b) a distinctive catalog number or the equivalent;

c) the voltage rating (see 10.16); and

d) the maximum operating temperature of the insulation (see 10.21 – 10.23).

10.33 With reference to 10.32, the voltage rating, c), and operating-temperature limit, d), may be marked on the unit container if such container is also marked as specified in a) and b).

10.34 A connector additionally rated for use with metric conductors shall have the metric wire range marked in close proximity to the rated AWG/kcmil wire range either on the connector, unit container, or information sheet within the unit container.

10.35 A connector rated for use with specific metric conductors shall be marked in close proximity to the metric wire range marking with the following, as applicable:

a) the letter ″r″ for rigid solid and rigid stranded; or

b) the letter ″f″ for flexible.

A connector rated for both rigid and flexible conductors need not be marked.

10.36 The information in a marking shall not be divided between a unit container and an information sheet. If any of the required markings are placed either on the unit container or on the information sheet packed in the unit container, rather than on the connector, then all applicable markings as specified in the clauses in their entirety shall be so placed.

10.37 With reference to 10.36, a unit container of ten or fewer connectors may be marked with a reference to an identifying number on an information sheet as described in 10.38.

10.38 The information sheet mentioned in 10.36 shall be marked with the manufacturer's name, an identifying number as mentioned in 10.37, the catalog number of the connector to which it pertains or equivalent, and all the necessary information required by 10.14 b), 10.15, 10.16, 10.19, 10.27, 10.30, and 10.42. The information sheet, one for each unit container, shall be packed in the packaging container.

10.39 A connector meeting the requirements of 7.10.1 shall be marked with the letters ″OEM″.

10.40 In the United States, connectors additionally rated for 2 AWG (33.6 mm^2) and larger compact copper shall be marked ″For compact-stranded copper conductors″ or the equivalent on the connector, unit container, or an information sheet packed in the unit container.

10.41 In Canada and Mexico, connectors for use with compact copper need not be marked as required by 10.40.

10.42 The flammability classification of the insulating material shall be allowed to be marked on the connector, smallest unit container, or on an information sheet placed in the smallest unit container. See 6.2.5.

Table 1 – Operating temperature ratings of connector insulation materials

(Clauses 6.2.4, 10.17, and 10.23)

Material	Temperature
	°C
Thermoplastic[a]	75
	90
	105
	125
	150
Phenolic[b]	150
Urea[c]	100
Melamine[d]	130
Melamine[e]	150

[a] Assigned by the manufacturer.

[b] Composition may be filled or unfilled.

[c] Unless the compound has been found by test to meet the requirements for use at a higher temperature.

[d] Composition with a specific gravity less than 1.55.

[e] Composition with a specific gravity 1.55 or more. Compound may have cellulosic filler material.

Table 2 – Soldering lug minimum dimensions

(Clauses 6.3.3 and 6.3.4)

Size of conductor		Diameter of conductor hole		Depth of conductor hole		Wall thickness		Contact area	
AWG or kcmil	(mm^2)	mm	(in)	mm	(in)	mm	(in)	mm^2	(in^2)
10	(5.26)	3.6	(0.143)	8.64	(0.34)	1.14	(0.045)	75.5	(0.117)
8	(8.4)	4.1	(0.164)	6.1	(0.24)	0.81	(0.032)	113	(0.175)
6	(13.3)	5.8	(0.232)	8.9	(0.35)	0.81	(0.032)	161	(0.250)
5	(16.9)	5.8	(0.232)	8.9	(0.35)	0.81	(0.032)	178	(0.275)
4	(21.2)	6.4	(0.253)	9.6	(0.38)	0.81	(0.032)	226	(0.350)
3	(26.7)	7.6	(0.300)	11.4	(0.45)	1.02	(0.040)	258	(0.400)
2	(33.6)	8.5	(0.336)	12.7	(0.50)	1.02	(0.040)	290	(0.450)
1	(42.4)	9.5	(0.375)	14.2	(0.56)	1.02	(0.040)	323	(0.500)
1/0	(53.5)	10.1	(0.398)	15.2	(0.60)	1.30	(0.051)	403	(0.625)
2/0	(67.4)	11.4	(0.450)	17.0	(0.67)	1.30	(0.051)	484	(0.750)
3/0	(85.0)	12.7	(0.500)	19.1	(0.75)	1.30	(0.051)	565	(0.875)
4/0	(107.2)	14.2	(0.559)	21.3	(0.84)	1.57	(0.062)	726	(1.125)
250	(127)	16.5	(0.650)	24.6	(0.97)	1.57	(0.062)	806	(1.250)
300	(152)	17.8	(0.700)	26.7	(1.05)	1.57	(0.062)	887	(1.375)
350	(177)	18.8	(0.750)	28.2	(1.11)	1.57	(0.062)	968	(1.500)
400	(203)	19.7	(0.775)	29.5	(1.16)	1.83	(0.072)	1 048	(1.625)
500	(253)	21.1	(0.830)	31.5	(1.24)	1.83	(0.072)	1 290	(2.000)
600	(304)	23.4	(0.920)	33.8	(1.33)	2.29	(0.090)	1 451	(2.250)
700	(354)	26.7	(1.050)	39.9	(1.57)	2.44	(0.096)	1 613	(2.500)
800	(405)	27.4	(1.080)	41.1	(1.62)	2.44	(0.096)	1 774	(2.750)
900	(456)	28.6	(1.125)	42.7	(1.68)	2.44	(0.096)	1 965	(3.000)
1 000	(508)	30.7	(1.209)	46.0	(1.81)	2.79	(0.110)	2 096	(3.250)
1 100	(558)	33.5	(1.320)	50.3	(1.98)	2.79	(0.110)	2 225	(3.450)
1 200	(609)	34.9	(1.375)	52.3	(2.06)	2.79	(0.110)	2 354	(3.650)
1 300	(660)	36.6	(1.440)	54.9	(2.16)	3.68	(0.145)	2 483	(3.850)

Table 2 – Soldering lug minimum dimensions Continued on Next Page

Table 2 – Soldering lug minimum dimensions Continued

Size of conductor		Diameter of conductor hole		Depth of conductor hole		Wall thickness		Contact area	
AWG or kcmil	(mm^2)	mm	(in)	mm	(in)	mm	(in)	mm^2	(in^2)
1 400	(708)	37.1	(1.460)	55.6	(2.19)	3.68	(0.145)	2 612	(4.050)
1 500	(759)	37.1	(1.460)	55.6	(2.19)	3.68	(0.145)	2 741	(4.250)
1 600	(812)	41.1	(1.620)	61.7	(2.43)	3.68	(0.145)	2 870	(4.450)
1 700	(862)	42.2	(1.660)	63.2	(2.49)	3.68	(0.145)	2 999	(4.650)
1 800	(912)	42.2	(1.660)	63.2	(2.49)	3.96	(0.156)	3 128	(4.850)
1 900	(964)	42.2	(1.660)	63.2	(2.49)	3.96	(0.156)	3 257	(5.050)
2 000	(1 016)	42.2	(1.660)	63.2	(2.49)	3.96	(0.156)	3 386	(5.250)

Table 3 – Test sequences for all connectors

(Clauses 7.1.1 and 8.1.2)

Sequence			
1	2[a]	3[b]	4[c]
Current-cycling	Static-heating Secureness Static-heating (repeated) Pullout	Secureness Pullout	Stress Corrosion

[a] This series of tests is referred to as static-heating sequence.

[b] This series of tests is referred to as mechanical sequence.

[c] The stress corrosion test, either moist ammonia or mercurous nitrate, need only be conducted for copper alloy parts not conforming to the copper requirements in 7.12 and 7.13.

Note – Table 3 applies to connectors for non-parallel applications, in which case Table 4 would not be applicable. However, some connectors may have dual functionality, both parallel and non-parallel, in which case both Tables are applicable.

Table 4 – Test sequences for all connectors intended for parallel conductors

(Clauses 7.1.1 and 8.1.2)

Sequence			
1	2	3[a]	4[b]
Current-cycling	Static-heating	Secureness Pullout	Stress Corrosion

[a] This series of tests is referred to as mechanical sequence.

[b] The stress corrosion test, either moist ammonia or mercurous nitrate, need only be conducted for copper alloy parts not conforming to the copper requirements in 7.12 and 7.13.

Note – Table 4 applies to connectors for parallel applications, in which case Table 3 would not be applicable. However, some connectors may have dual functionality, both parallel and non-parallel, in which case both Tables are applicable.

Table 5 – Additional tests for insulated connectors or connectors employing insulating covers

(Clauses 7.1.1 and 8.1.2)

Sequence					
1	2	3	4	5[a]	6[b]
Dielectric withstand	Secureness of insulation	Drop Dielectric withstand (after drop)	Flexing	Low temperature installation	Moisture absorption
For connectors employing separable insulating covers, latches, and locks, Sequences 1 and 3 shall be followed.					
For connectors employing separable insulating covers with hinges, latches, and locks, Sequences 1, 3, and 4 shall be followed.					
For all other insulated connectors, Sequences 1 and 2 shall be followed.					
[a] Applicable to insulated connectors where the crimping application is applied through the insulating material. This is an additional test for Canada only.					
[b] Applicable only to porcelain or cold molded insulating materials.					

Table 6 – Conductor materials to be used in test sequences

(Clauses 7.1.6 and 8.2.4)

Conductor for which connector is intended	Conductor used in test sequences
Copper[a]	Copper
Aluminum[a]	Aluminum
Copper-clad aluminum	Copper-clad aluminum
Copper to copper[b]	Copper
Aluminum to aluminum[b]	Aluminum
Copper-clad aluminum to copper-clad aluminum[b]	Copper-clad aluminum
Copper to aluminum[b], intermixed	Copper to aluminum
Note 1) Any conductor material may be used for the Dielectric Voltage-Withstand Test sequence. 2) If a connector is rated for copper to copper, aluminum to aluminum, and copper to aluminum (intermixed), the mechanical sequence with copper to aluminum conductor may be omitted. 3) In all test sequences, aluminum conductor represents tests with copper-clad aluminum conductor. [a] Single conductor in an opening. [b] Two or more conductors in an opening.	

Table 7 – Test current for connectors intended for a single conductor, A

(Clauses 7.2.1, 7.3.1, 8.2.2, 8.3.2, and 8.3.3)

Conductor size, AWG or kcmil (mm^2)		Copper				Aluminum and copper-clad aluminum				On (and off) times for current-cycling hours[f]
		Assigned maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]		Assigned maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]		
				75°C[d,g]	90°C[e,g]			75°C[d,g]	90°C[e,g]	
30	(0.05)	0.5	3	3.5	4	–	–	–	–	1
28	(0.08)	0.8	3.5	4	5	–	–	–	–	1
26	(0.13)	1	5.5	6	8	–	–	–	–	1
24	(0.20)	2	7	8	10	–	–	–	–	1
22	(0.32)	3	9	12	13	–	–	–	–	1

Table 7 – Test current for connectors intended for a single conductor, A Continued on Next Page

Table 7 – Test current for connectors intended for a single conductor, A Continued

Conductor size, AWG or kcmil (mm^2)		Copper						Aluminum and copper-clad aluminum						On (and off) times for current-cycling hours[f]
		Assigned maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]				Assigned maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]				
				75°C[d,g]		90°C[e,g]				75°C[d,g]		90°C[e,g]		
20	(0.52)	5	12	16		17		–	–	–		–		1
18	(0.82)	7	17	19		24		–	–	–		–		1
16	(1.31)	10	18	20		31		–	–	–		–		1
14	(2.08)	15	[20] 30	[22] 33		[27] 40		–	–	–		–		1
12	(3.31)	20	[25] 35	[28] 39		[40] 54		15	[20] 30	[22] 33		[29] 43		1
10	(5.26)	30	[40] 50	[45] 56		[60] 75		25	[30] 40	[34] 45		[46] 60		1
8	(8.37)	50	70	80		100		40	55	60		77		1
6	(13.3)	65	95	105		131		50	75	85		102		1
4	(21.2)	85	125	140		175		65	100	110		140		1
3	(26.7)	100	145	165		205		75	115	125		160		1
2	(33.6)	115	170	190		240		90	135	150		190		1
1	(42.4)	130	195	220		275		100	155	175		215		1
1/0	(53.5)	150	230	255		320		120	180	200		250		1
2/0	(67.4)	175	265	300		370		135	210	230		295		1
3/0	(85.0)	200	310	345		435		155	240	270		335		1
4/0	(107)	230	360	405		505		180	280	315		390		1-1/2
250	(127)	255	405	445		565		205	315	350		440		1-1/2
300	(152)	285	445	500		625		230	350	390		490		1-1/2
350	(177)	310	505	555		708		250	395	435		555		1-1/2
400	(203)	335	545	605		765		270	425	470		595		1-1/2
500	(253)	380	620	690		870		310	485	540		680		2
600	(304)	420	690	775		968		340	540	600		760		2
700	(355)	460	755	850		1055		375	595	675		835		2
750	(380)	475	785	885		1100		385	620	700		870		2
800	(405)	490	815	920		1140		395	645	725		905		2
900	(456)	520	870	980		1220		425	700	785		980		2
1000	(507)	545	935	1045		1310		445	750	840		1050		2
1250	(633)	590	1065	1185		1490		485	855	950		1195		3
1500	(760)	625	1175	1320		1645		520	950	1065		1330		3
1750	(887)	650	1280	1435		1790		545	1050	1175		1470		3
2000	(1010)	665	1385	1540		1940		560	1150	1280		1610		3

[a] See 7.2, 8.2, and 9.2.

[b] Values are for 75°C, not more than three conductors in raceway or cable ampacities, National Electrical Code, ANSI/NFPA 70, free air Tables 1, 3, and 5B of the Canadian Electrical Code, C22.1, except that for 14 – 10 AWG (2.08 – 5.26 mm^2) aluminum conductor, the values are load-current ratings, and Table 310-16 of the Standard for Electrical Installations, NOM-001-SEDE.

[c] Values are for 75°C single conductor in free air ampacities, National Electrical Code, ANSI/NFPA 70, Table 3 of the Canadian Electrical Code, C22.1, and Table 310-16 of the Standard for Electrical Installations, NOM-001-SEDE.

[d] Values are approximately 112 percent of the static-heating test currents.

[e] Values for 8 AWG (8.4 mm^2) and larger conductors are approximately 140 percent of the static-heating test current.

[f] See 9.2.5.

[g] Values in brackets apply to connectors with assigned ampere ratings.

Table 8 – Static test currents for connectors intended for paralleling conductors, A

(Clauses 7.3.1 and 8.3.3)

Conductor sizes, AWG or kcmil (mm^2)		Number and material of conductors					
		Two		Three		Four	
		Copper	Aluminum and copper-clad aluminum	Copper	Aluminum	Copper	Aluminum and copper-clad aluminum
1/0	(53.5)	300	240	450	360	480	384
2/0	(67.4)	350	270	525	405	560	432
3/0	(85.0)	400	310	600	465	640	496
4/0	(107)	460	360	690	540	736	576
250	(127)	527	410	790	615	1 053	820
300	(152)	579	455	868	683	1 158	910
350	(177)	657	514	985	770	1 314	1 028
400	(203)	709	553	1 063	829	1 418	1 106
500	(253)	806	631	1 209	946	1 612	1 262
600	(304)	1 035	810	1 554	1 215	2 070	1 620
700	(355)	1 133	893	1 699	1 339	2 266	1 786
750	(380)	1 178	930	1 767	1 395	2 356	1 860
800	(405)	1 223	968	1 834	1 452	2 446	1 936
900	(456)	1 305	1 050	1 958	1 575	2 610	2 100
1 000	(507)	1 403	1 125	2 104	1 688	2 806	2 250
1 250	(633)	1 598	1 383	2 397	1 924	3 196	2 566
1 500	(760)	1 763	1 425	2 644	2 138	3 526	2 850
1 750	(887)	1 920	1 575	2 880	2 363	3 840	3 150
2 000	(1 010)	2 078	1 725	3 117	2 588	4 156	3 450

NOTES –

1) The currents for conductor sizes 1/0 – 4/0 AWG (53.5 – 107 mm^2) are based on the National Electrical Code (NEC), NFPA 70, Table 310-16, 75°C column, multiplied by the number of conductors and de-rated by 80 percent.

2) The currents for conductor sizes 250 kcmil (127 mm^2) and larger are in accordance with the NEC, NFPA 70, Sections 392-11(b) (1) and 392-11(b) (2) for Table 310-17 (free air ampacities), 75°C column, multiplied by the number of conductors and de-rated as follows:

250 – 500 kcmil (127 – 253 mm^2) – de-rated by 65 percent

600 kcmil (304 mm^2) and larger – de-rated by 75 percent

3) Any number of conductors other than tabulated are to be de-rated in accordance with the NEC, NFPA 70, Table 310-16, Note 8.

4) The current for conductors sizes are based on Tables 2, 4, and 5C of the Canadian Electrical Code, C22.1.

Table 9 – Dielectric-withstand test sequence

(Clauses 7.5.1 and 8.1.2)

Connector construction	Required test
1. A connector having insulation in the form of a tubular sleeve and intended to accommodate only one conductor in each opening and intended for use with:	
a) 10 AWG (5.26 mm^2) or smaller conductor	A, C
b) 8 – 4/0 AWG (8.4 – 107 mm^2)	A
2. Connectors having insulation in other than a tubular form and for conductor size not covered in item 1	A, B
Test A as described in 9.5.2.	
Test B as described in 9.5.3.	
Test C as described in 9.5.4.	

Table 10 – Oven-conditioning temperatures

(Clauses 7.5.3, 9.5.2.2, 9.6.3, 9.7.1, 9.9.1, and 10.17)

Insulating temperature rating °C	Minimum oven temperature, °C	
	168 h test	Optional 1440 h test
60[a, b]	110	70
70[a]	113	81
75	113	81
90	121	97
105	136	113
125	158	133
150	180	158

[a] This is an additional rating for Canada. Not applicable in the United States.

[b] This is an additional rating for Mexico. Not applicable in the United States.

Table 11 – Minimum number of specimens for test

(Clauses 8.1.1, 8.6.1, 8.7.1, 8.9.1, 8.10.1, 8.11.1, 8.12.1, and 8.13.1)

Clause	Test	Number of specimens
9.2	Current-cycling	4 of each combination of connector and test conductor(s) to be tested
9.3	Static-heating sequence	4 of each combination of connector and test conductor(s) to be tested
9.4	Mechanical sequence	4 of each combination of connector and test conductor(s) to be tested
	Dielectric withstand	
	Thermosetting, e.g., porcelain, cold-molded melamine, phenolic, or urea-compound	
9.5.2	Test A	
	– as received	12[a]
9.5.3	Test B	
	– as received	12[a]
9.5.4	Test C	
	– as received	6
	Thermoplastic, e.g., vinyl or nylon	
9.5.2	Test A – As received	12[a]

Table 11 – Minimum number of specimens for test Continued on Next Page

Table 11 – Minimum number of specimens for test Continued

Clause	Test	Number of specimens
9.5.3	– After oven conditioning with specimens assembled to conductor before such conditioning	12[a]
9.5.4	– After oven conditioning with specimens assembled to conductor after such conditioning	12[a]
9.5.3	Test B	
	– as received	12[a]
9.5.4	Test C	
	– as received	6
	Secureness of insulation	
9.6.1	As received	6
9.6.3	a) Unassembled	
	– as received	6
	– after oven conditioning	6
	b) Assembled	
	– as received	12[a]
	– connected to a conductor before oven conditioning	12[a]
	– connected to a conductor after oven conditioning	12[a]
9.7	Drop	
	– as received	12
	– after oven conditioning	12
	– after cold conditioning	12
9.8	Dielectric withstand (after drop)	use same specimens
9.9	Flexing	
	– as received	6[b]
	– after oven conditioning	6[b]
	– after cold conditioning	6[b]
9.10	Low temperature installation	12[a]
9.11	Moisture absorption	3
9.12 or 9.13	Stress corrosion	3

[a] Six specimens with maximum conductor size and six specimens with minimum conductor size.

[b] Test with the maximum conductor size.

Table 12 – Material of clamping screws for tests

(Clause 8.1.12)

Screw material	Static-heating and mechanical sequences			Current-cycling		
	Steel	Copper alloy	Aluminum	Steel	Copper alloy	Aluminum
Steel, copper alloy, or aluminum	X	–	X	X	–	X[a]
Steel or aluminum	X	–	X	X	–	X[a]
Steel or copper alloy	X	X	–	X	X[b]	–
Aluminum or copper alloy	–	X	X	–	X[b]	X

Note – An X indicates that the test shall be conducted.

[a] Tests need not be conducted on aluminum screws if the temperature for the aluminum screws in the static sequence is less than that for the alternate screw material.

[b] Tests need not be conducted if the temperature recorded for a copper alloy clamping screw in the static sequence is less than that determined for the alternate screw material.

Table 13 – Cycling test currents for 75°C and 90°C connectors intended for paralleling conductors, A

(Clause 8.2.2)

Conductor size, AWG or kcmil (mm^2)		Number and material of conductors											
		Two				Three				Four			
		Copper		Aluminum and copper-clad aluminum		Copper		Aluminum and copper-clad aluminum		Copper		Aluminum and copper-clad aluminum	
		75°C	90°C	75°C	90°C	75°C	90°C	75°C	90°C	75°C	90°C	75°C	90°C
1/0	(53.5)	336	420	269	336	504	630	403	504	538	672	431	538
2/0	(67.4)	392	490	302	378	588	735	454	567	628	784	484	605
3/0	(85.0)	448	560	347	434	672	840	521	651	717	896	556	695
4/0	(107)	515	644	403	504	773	966	605	756	824	1 030	645	806
250	(127)	590	738	460	574	885	1 106	689	861	1 180	1 476	920	1 148
300	(152)	649	811	510	637	97203	1 215	765	95678	1 298	1 622	1 020	1 274
350	(177)	736	920	476	720	1 103	1 379	862	1 078	1 472	1 840	1 132	1 440
400	(203)	794	993	620	771	1 191	1 488	928	1 161	1 588	1 986	1 240	1 548
500	(253)	903	1 129	707	883	1 354	1 693	1 060	1 324	1 806	2 258	1 414	1 766
600	(304)	1 160	1 450	907	1 145	1 400	2 176	1 361	1 718	2 320	2 900	1 815	2 290
700	(355)	1 269	1 587	1 000	1 250	1 903	2 379	1 500	1 875	2 538	3 174	2 000	2 500
750	(380)	1 320	1 650	1 041	1 302	1 979	2 474	1 562	1 953	2 640	3 300	2 082	2 604
800	(405)	1 370	1 713	1 084	1 355	2 054	2 568	1 626	2 033	2 740	3 426	2 168	2 710
900	(456)	1 462	1 828	1 176	1 470	2 193	2 741	1 764	2 205	2 924	3 656	2 352	2 940
1 000	(507)	1 572	1 965	1 260	1 575	2 356	2 946	1 891	2 363	3 144	3 930	2 520	3 150
1 250	(633)	1 790	2 238	1 437	1 796	2 684	3 356	2 155	2 694	3 580	4 476	2 874	3 592
1 500	(760)	1 975	2 469	1 596	1 995	2 961	3 701	2 395	2 993	3 950	4 938	3 192	3 990
1 750	(887)	2 150	2 688	1 764	2 205	3 226	4 032	2 647	3 308	4 300	5 376	3 528	4 410
2 000	(1 010)	2 328	2 910	1 932	2 415	3 491	4 364	2 899	3 623	4 656	5 820	3 864	4 830

Table 14 – Conductor stranding

(Clause 9.1.5.1)

Size of conductor to which connector is to be assembled		Number of strands, if stranded conductors				
		Copper		Aluminum	Copper-clad aluminum	
AWG or kcmil	(mm^2)	Class B	Class C	Class B	Class B	Class C
24 – 30	(0.20 – 0.05)	[a]	–	–	–	–
22	(0.32)	7	–	–	–	–
20	(0.52)	10	–	–	–	–
18	(0.82)	16	–	–	–	–
16	(1.3)	26	–	–	–	–
14 – 2	(2.1 – 33.6)	7	19	7 [b]	7[b]	19[b]
1 – 4/0	(42.4 – 107)	19	37	19	19	37
250 – 500	(127 – 253)	37	61	37	37	61
600 – 1 000	(304 – 508)	61	91	61	61	91
1 250 – 1 500	(635 – 759)	91	127	91	91	127
1 750 – 2 000	(886 – 1 016)	127	271	127	127	271

[a] Number of strands vary.

[b] Aluminum and copper-clad aluminum 14 AWG (2.1 mm^2) are not available.

Table 15 – Conductor materials

(Clauses 9.1.5.1 and 9.1.5.2)

		AWG or kcmil (mm^2)	Test and control conductors shall be as follows:
Aluminum	Solid	12 (3.31) and larger	Aluminum wire stock for use as an electrical conductor
	Stranded[a, c]	12 – 3 (3.31 – 26.7)	AA-1350 conductors, Class B or SIW, with compact, compressed or concentric stranding
		2 AWG – 1 000 (33.6 – 507)	AA-1350 conductors, Class B or SIW, with compact, compressed or concentric stranding
		Larger than 1 000 (507)	AA-1350 conductors, Class B or SIW with compact, compressed, or concentric stranding
Copper	Solid	30 – 16 (0.05 – 1.31)	Soft annealed, tinned or untinned
		14 (2.08) and larger	Soft annealed and untinned
	Stranded	30 – 16 (0.05 – 1.31)	Soft annealed, tinned or untinned
		14 (2.08) and larger	Soft annealed, tinned or untinned. The stranding shall be concentric or compressed Class B or concentric Class C[b]
Copper-clad aluminum	Solid	12 AWG (3.31) and larger	Soft annealed and untinned
	Stranded	12 AWG (3.31) and larger	Soft annealed, tinned or untinned. The stranding shall be concentric or compressed Class B or concentric Class C[b]

[a] Conductors of AA-8000 series alloy conductor material shall not be used for testing purposes.

[b] In Canada and Mexico, 8 AWG (8.4 mm^2) and larger compact-stranded copper conductors shall be used.

[c] The hardness of the alloy and iron content is not specified.

Table 16 – Conductor insulation

(Clause 9.1.5.1)

		AWG or kcmil (mm^2)	Type of insulation
Aluminum	Solid and stranded	12 (3.31) and larger	THHN or T90 THW or TW75 RW90 (1000V) or USE RW90 (600V) or XHHW
Copper	Solid and stranded	30 – 24 (0.05 – 0.20)	Black thermoplastic at least 0.254 (0.010 in) thick
		22 – 16 (0.32 – 1.31)	Black thermoplastic at least 0.762 mm (0.030 in) thick
		14 (2.08) and larger	T90 or THHN THW or TW75 RW90 (1000V) or USE RW90 (600V) or XHHW
Copper-clad aluminum	Solid and stranded	12 (3.31) and larger	T90 or THHN THW RW90 (1000V) or USE RW90 (600V) or XHHW

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Table 17 – Test conductor length

(Clause 9.1.5.8)

Conductor size		Minimum conductor length[a]	
AWG or kcmil	(mm^2)	mm	(in)
30 – 8	(0.05 – 8.4)	203	(8)
6 – 3	(13.3 – 26.7)	305	(12)
2 – 500	(33.6 – 253)	457	(18)
Larger than 500	(Larger than 253)	660	(26)

[a] The conductor length for the secureness test in the mechanical or static-heating sequence shall not be less than that specified in 9.3.2.1 – 9.3.2.4.

Table 18 – Wire strip length

(Clauses 9.1.6.2, 9.1.6.3, 9.1.6.4, and 10.15)

	Required wire strip length marking	
Connector type	Maximum strip length	Minimum strip length
Insulated	X[a,b]	X[a,b,c]
Non-insulated	–	X[a,b,c]

Note: An X indicates marking is required.

[a] Strip length shall be specified as a single – nominal – value if tested as specified in 9.1.6.2.

[b] Strip length marking shall be optional if the connector is provided with an open end opposite the conductor insertion end through which the end of the conductor is visible after it is connected.

[c] Strip length marking shall be optional if the connector is provided with an inspection hole opposite the conductor insertion end through which the end of the conductor is visible after it is connected.

Table 19 – Strip-length tolerances for conductors

(Clause 9.1.6.2)

Conductor size		Tolerance	
AWG or kcmil	(mm^2)	mm	(in)
30 – 14	(0.05 – 2.1)	± 0.8	(± 1/32)
12 – 10	(3.3 – 5.3)	± 1.2	(± 3/64)
8 – 250	(8.4 – 127)	± 1.6	(± 1/16)
300 – 2 000	(152 – 1 016)	± 3.2	(± 1/8)

Table 20 – Busbar dimensions

(Clauses 9.1.7.3 and 9.1.10.4)

Range of test current, A	Maximum cross-section, mm (in)	
	Copper	Aluminum
0 – 50	3.2 x 12.7 (1/8 x 1/2)	3.2 x 12.7 (1/8 x 1/2)
51 – 125	3.2 x 25 (1/8 x 1)	3.2 x 32 (1/8 x 1 - 1/4)
126 – 225	3.2 x 48 (1/8 x 1 - 7/8)	3.2 x 57 (1/8 x 2 - 1/4)
226 – 400	6.4 x 38 (1/4 x 1 - 1/2)	6.4 x 50 (1/4 x 2)
401 – 600	6.4 x 50 (1/4 x 2)	6.4 x 76 (1/4 x 3)
601 – 800	6.4 x 76 (1/4 x 3)	6.4 x 102 (1/4 x 4)
801 – 1 000	6.4 x 102 (1/4 x 4)	9.5 x 89 (3/8 x 3 - 1/2)
1 001 – 1 400	12.7 x 76 (1/2 x 3) or two 6.4 x 102 (1/4 x 4)	12.7 x 89 (1/2 x 3 - 1/2)
1 401 – 2 000	12.7 x 102 (1/2 x 4) or two 6.4 x 102 (1/4 x 4)	12.7 x 127 (1/2 x 5)
2 001 – 3 000	25 x 76 (1 x 3)	19 x 127 (3/4 x 5)
3 000 – 4 000	25 x 102 (1 x 4)	25 x 140 (1 x 5 - 1/2)
4 000 – 4 800	32 x 102 (1 - 1/4 x 4)	50 x 102 (2 x 4)

Table 21 – Tightening torque for screws

(Clauses 9.1.9.4 and 9.1.9.6)

Test conductor size installed in connector		Tightening torque, N·m (lbf-in)									
		Slotted head No. 10 and larger[a]				Hexagonal head – external drive socket wrench					
		Slot width – 1.2 mm (0.047 in) or less and slot length – 6.4 mm (1/4 in) or less		Slot width – over 1.2 mm (0.047 in) or slot length – over 6.4 mm (1/4 in)		Split-bolt connectors		Other connectors	
AWG or kcmil	(mm^2)	A	B	A	B	A	B	A	B
30 – 10	(0.05 – 5.3)	1.7 (15)	2.3 (20)	2.8 (25)	4.0 (35)	7.3 (65)	9.0 (80)	6.8 (60)	8.5 (75)
8	(8.4)	2.3 (20)	2.8 (25)	3.4 (30)	4.5 (40)	7.3 (65)	9.0 (80)	6.8 (60)	8.5 (75)
6 – 4	(13.2 – 21.2)	2.8 (25)	4.0 (35)	4.0 (35)	5.1 (45)	15.3 (135)	18.6 (165)	10.2 (90)	12.4 (110)
3	(26.7)	2.8 (25)	4.0 (35)	4.5 (40)	5.6 (50)	25.4 (225)	31.1 (275)	14.1 (125)	16.9 (150)
2	(33.6)	3.4 (30)	4.5 (40)	4.5 (40)	5.6 (50)	25.4 (225)	31.1 (275)	14.1 (125)	16.9 (150)
1	(42.4)	–	–	4.5 (40)	5.6 (50)	25.4 (225)	31.1 (275)	14.1 (125)	16.9 (150)
1/0 – 2/0	(53.5 – 67.4)	–	–	4.5 (40)	5.6 (50)	35.6 (315)	43.5 (385)	16.9 (150)	20.3 (180)
3/0 – 4/0	(85.0 – 107.2)	–	–	4.5 (40)	5.6 (50)	45.2 (400)	56.5 (500)	22.6 (200)	28.2 (250)
250 – 350	(127 – 177)	–	–	4.5 (40)	5.6 (50)	62.1 (550)	73.4 (650)	28.2 (250)	36.7 (325)
400	(203)	–	–	4.5 (40)	5.6 (50)	76.3 (675)	93.2 (825)	28.2 (250)	36.7 (325)
500	(253)	–	–	4.5 (40)	5.6 (50)	76.3 (675)	93.2 (825)	33.9 (300)	42.4 (375)
600 – 750	(304 – 380)	–	–	4.5 (40)	5.6 (50)	90.4 (800)	113.0(1000)	33.9 (300)	42.4 (375)
800 – 1000	(406 – 508)	–	–	4.5 (40)	5.6 (50)	111.7 (900)	124.3(1100)	45.2 (400)	56.5 (500)
1250 – 2000	(635 – 1010)	–	–	–	–	111.7 (900)	124.3(1100)	56.5 (500)	67.8 (600)

[a] For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length shall be measured at the bottom of the slot.

Table 22 – Tightening torque for slotted head screws smaller than No. 10 intended for use with 8 AWG (8.4 mm^2) or smaller conductors

(Clauses 9.1.9.4 and 9.1.9.6)

Slot length of screw[a]		Tightening torque, N·m (lbf·in)			
		Slot width of screw smaller than 1.2 mm (0.047 in)[b]		Slot width of screw 1.2 mm(0.047 in) and larger[b]	
mm	(in)	A	B	A	B
Less than 4	(Less than 5/32)	0.68 (6)	0.79 (7)	0.79 (7)	1.0 (9)
4	(5/32)	0.68 (6)	0.79 (7)	1.1 (10)	1.4 (12)
4.8	(3/16)	0.68 (6)	0.79 (7)	1.1 (10)	1.4 (12)
5.6	(7/32)	0.68 (6)	0.79 (7)	1.1 (10)	1.4 (12)
6.4	(1/4)	0.79 (7)	1.0 (9)	1.1 (10)	1.4 (12)
7.1	(9/32)			1.4 (12)	1.7 (15)
Above 7.1	(Above 9/32)			1.8 (16)	2.3 (20)

[a] For slot lengths of intermediate values, select torques pertaining to next shorter slot lengths. Also, see 9.1.9.6 for screws with multiple tightening means. Slot length shall be measured at the bottom of the slot.

[b] Slot width is the nominal design value.

Table 23 – Tightening torque for screws with recessed allen or square drives

(Clauses 9.1.9.4 and 9.1.9.6)

Socket width across flats[a]		Tightening torque, N·m (lbf·in)			
mm	(in)	A		B	
3.2	(1/8)	4.0	(35)	5.1	(45)
4.0	(5/32)	9.0	(80)	11.3	(100)
4.8	(3/16)	11.3	(100)	13.6	(120)
5.6	(7/32)	13.6	(120)	16.9	(150)
6.4	(1/4)	16.9	(150)	22.6	(200)
7.9	(5/16)	25.4	(225)	31.1	(275)
9.5	(3/8)	33.9	(300)	42.4	(375)
12.7	(1/2)	45.2	(400)	56.5	(500)
14.3	(9/16)	56.5	(500)	67.8	(600)

[a] See 9.1.9.6 for screws with multiple tightening means.

Table 24 – Tightening torque for connecting hardware

(Clause 9.1.10.2)

Screw or bolt size		Tightening torque	
Metric	SAE	N·m	(lbf·ft)
–	No. 8 or smaller	2	(1.5)
–	No.10	3	(2.0)
M6	1/4	8	(6)
–	5/16	15	(11)
M10	3/8	26	(19)
–	7/16	41	(30)
M12	1/2	54	(40)
–	9/16, 5/8 or larger	75	(55)

Table 25 – Flattening force

(Clause 9.1.10.3)

Bolt size		Force, minimum	
Metric	SAE	N	(lb)
M6	1/4	3 560	(800)
–	5/16	4 450	(1 000)
M10	3/8	6 230	(1 400)
M12	7/16, 1/2	12 015	(2 700)
–	9/16, 5/8 or larger	15 130	(3 400)

Table 26 – Secureness test values

(Clauses 9.3.2.1, 9.3.2.3, and 9.3.2.4)

Size of conductor		Diameter of bushing hole[a]		Height		Mass			
						Copper		Aluminum/Copper-clad aluminum	
AWG or kcmil	(mm^2)	mm	(in)	mm	(in)	kg	(lb)	kg	(lb)
18	(0.82)	6.4	(1/4)	260	(10-1/4)	0.9	(2)	–	–
16	(1.3)	6.4	(1/4)	260	(10-1/4)	0.9	(2)	–	–
14	(2.1)	9.5	(3/8)	279	(11)	1.4	(3)	–	–
12	(3.3)	9.5	(3/8)	279[b]	(11)[b]	2.3	(5)	0.7	(1.5)
10	(5.3)	9.5	(3/8)	279[b]	(11)[b]	2.3	(5)	0.7	(1.5)
8	(8.4)	9.5	(3/8)	279[b]	(11)[b]	3.6	(8)	1.4	(3)
6	(13.3)	12.7	(1/2)	298[b]	(11-3/4)[b]	8.2	(18)	4.5	(10)
4	(21.2)	12.7	(1/2)	298[b]	(11-3/4)[b]	13.6	(30)	6.8	(15)
3	(26.7)	14.3	(9/16)	318	(12-1/2)	13.6	(30)	6.8	(15)
2	(33.6)	14.3	(9/16)	318	(12-1/2)	13.6	(30)	6.8	(15)
1	(42.4)	15.8	(5/8)	343	(13-12)	22.7	(50)	11.4	(25)
1/0	(53.5)	15.8	(5/8)	343	(13-1/2)	22.7	(50)	11.4	(25)
2/0	(67.4)	19.1	(3/4)	368	(14-1/2)	22.7	(50)	11.4	(25)
3/0	(85.0)	19.1	(3/4)	368	(14-1/2)	27.2	(60)	13.6	(30)
4/0	(107)	19.1	(3/4)	368	(14-1/2)	27.2	(60)	13.6	(30)
250	(127)	22.2	(7/8)	406	(16)	27.2	(60)	13.6	(30)
300	(156)	22.2	(7/8)	406	(16)	36.3	(80)	18.2	(40)
350	(177)	25.4	(1)	432	(17)	36.3	(80)	18.2	(40)
400	(203)	25.4	(1)	432	(17)	36.3	(80)	18.2	(40)

Table 26 – Secureness test values Continued on Next Page

Table 26 – Secureness test values Continued

Size of conductor		Diameter of bushing hole[a]		Height		Mass			
						Copper		Aluminum/Copper-clad aluminum	
AWG or kcmil	(mm^2)	mm	(in)	mm	(in)	kg	(lb)	kg	(lb)
500	(253)	28.6	(1-1/8)	464	(18-1/4)	45.4	(100)	22.7	(50)
600	(304)	28.6	(1-1/8)	464	(18-1/4)	45.4	(100)	22.7	(50)
700	(354)	31.8	(1-1/4)	495	(19-1/2)	45.4	(100)	22.7	(50)
750	(380)	31.8	(1-1/4)	495	(19-1/2)	49.9	(110)	25.0	(55)
800	(406)	34.9	(1-3/8)	540	(21-1/4)	49.9	(110)	25.0	(55)
900	(456)	34.9	(1-3/8)	540	(21-1/4)	49.9	(110)	25.0	(55)
1 000	(508)	38.1	(1-1/2)	565	(22-1/4)	49.9	(110)	25.0	(55)
1 250	(635)	44.5	(1-3/4)	660	(26)	70.4	(155)	34.1	(75)
1 500	(759)	50.8	(2)	711	(28)	81.7	(180)	40.9	(90)
1 750	(886)	54.0	(2-1/8)	762	(30)	93.1	(205)	45.4	(100)
2 000	(1 010)	54.0	(2-1/8)	762	(30)	109.0	(240)	54.5	(120)

[a] If a hole with the diameter given is insufficient to accommodate the conductor without binding, a bushing having a hole of slightly large diameter shall be allowed to be used.

[b] For 12 – 4 AWG (3.3 – 21.2 mm^2) aluminum conductor, use 318 mm (12-1/2 in).

Table 27 – Pullout test values

(Clause 9.3.4.1)

Size of conductor		Pullout force, N (lb)			
		Copper		Aluminum/Copper–clad aluminum	
AWG or kcmil	(mm^2)				
30	(0.05)	6.7	(1-1/2)	–	–
28	(0.08)	8.9	(2)	–	–
26	(0.13)	13.4	(3)	–	–
24	(0.20)	22.3	(5)	–	–
22	(0.32)	35.6	(8)	–	–
20	(0.52)	57.9	(13)	–	–
18	(0.82)	89.0	(20)	–	–
16	(1.3)	134	(30)	–	–
14	(2.1)	223	(50)	–	–
12	(3.3)	312	(70)	156	(35)
10	(5.3)	356	(80)	178	(40)
8	(8.4)	401	(90)	200	(45)
6	(13.3)	445	(100)	223	(50)
4	(21.2)	623	(140)	312	(70)
3	(26.7)	712	(160)	356	(80)
2	(33.6)	801	(180)	401	(90)
1	(42.4)	890	(200)	445	(100)
1/0	(53.5)	1 113	(250)	556	(125)
2/0	(67.4)	1 235	(300)	668	(150)
3/0	(85.0)	1 558	(350)	779	(175)
4/0	(107)	2 003	(450)	1 001	(225)
250	(127)	2 225	(500)	1 113	(250)
300	(156)	2 448	(550)	1 224	(275)
350	(177)	2 670	(600)	1 335	(300)
400	(203)	2 893	(650)	1 446	(325)
500	(253)	3 560	(800)	1 780	(400)

Table 27 – Pullout test values Continued on Next Page

Table 27 – Pullout test values Continued

Size of conductor		Pullout force, N (lb)			
AWG or kcmil	(mm^2)	Copper		Aluminum/Copper–clad aluminum	
600	(304)	4 005	(900)	2 003	(450)
700 – 2 000	(354 – 1 010)	4 450	(1 000)	2 225	(500)

Table 28 – Insulation puncture and flashover test voltages, Tests A and B

(Clauses 9.5.2.4, 9.5.3.1, and 9.5.3.2)

Connector insulation voltage rating, V	Test voltage, V	
	Puncture (1 min)	Flashover (Maximum)
300	2 200	4 000
600 (1 000 in signs and luminaires)	3 400	8 000

Table 29 – Flashover test voltage, Test C

(Clause 9.5.4.1)

Connector insulation voltage rating, V	Flashover test voltage, V
300	1 600
600 (1 000 in signs and luminaires)	3 000

Table 30 – Marking locations guide

Table 30 revised and relocated to Annex E

Figure 1 – Method for attaching thermocouples to stranded aluminum control conductors used for current-cycling tests

(Clause 9.1.3.4)

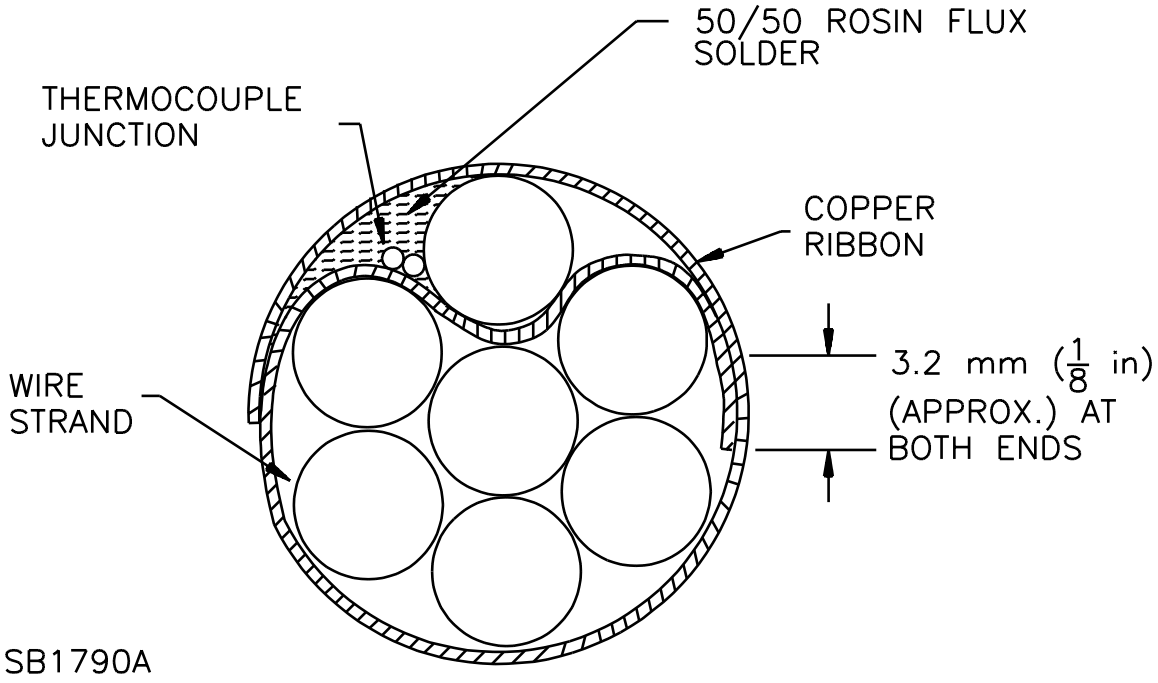


Figure 2 – Method for mounting tangless connectors

(Clauses 9.1.8.6 and 9.1.8.8)

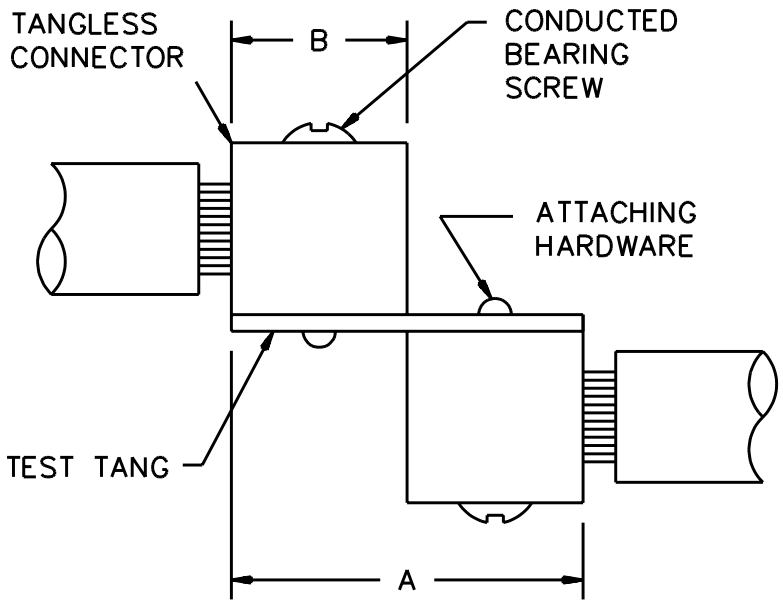
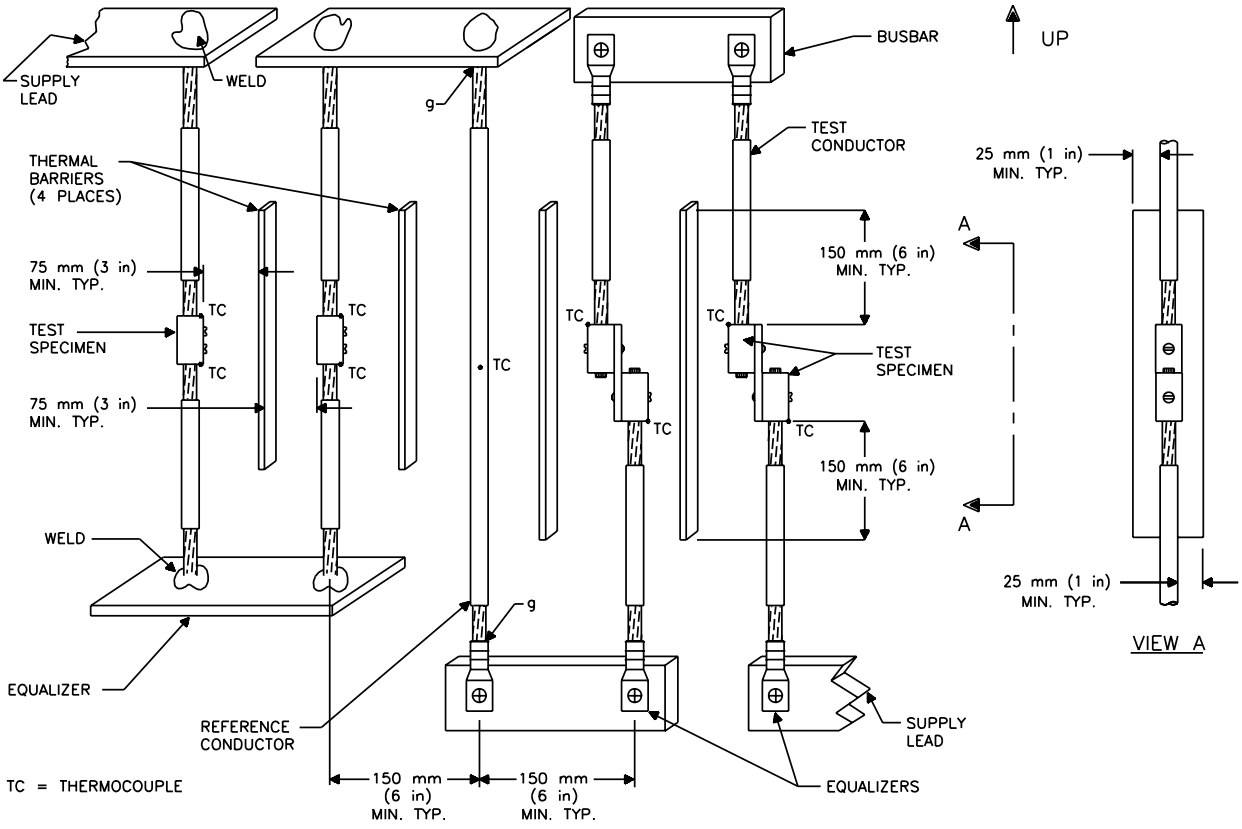


Figure 3 – Vertical arrangement of specimen for current-cycling test

(Clause 9.1.10.8)



FOR A TANGLESS CONNECTOR, THE FOLLOWING INFORMATION SHALL BE PROVIDED:

a) MATERIAL OF TANG;
b) PLATING ON TANG;
c) MINIMUM CROSS–SECTION OF TANG;
d) MATERIAL OF MOUNTING SCREW;
e) USE OF A WASHER, TYPE AND SIZE;
f) TORQUE TO BE USED TO SECURE THE CONNECTOR TO THE TANG.
g) EQUALIZERS ON BOTH ENDS TO BE THE SAME TYPE (EITHER WELDED OR COMPRESSION).

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Figure 4 – Secureness test setup

(Clause 9.3.2.1)

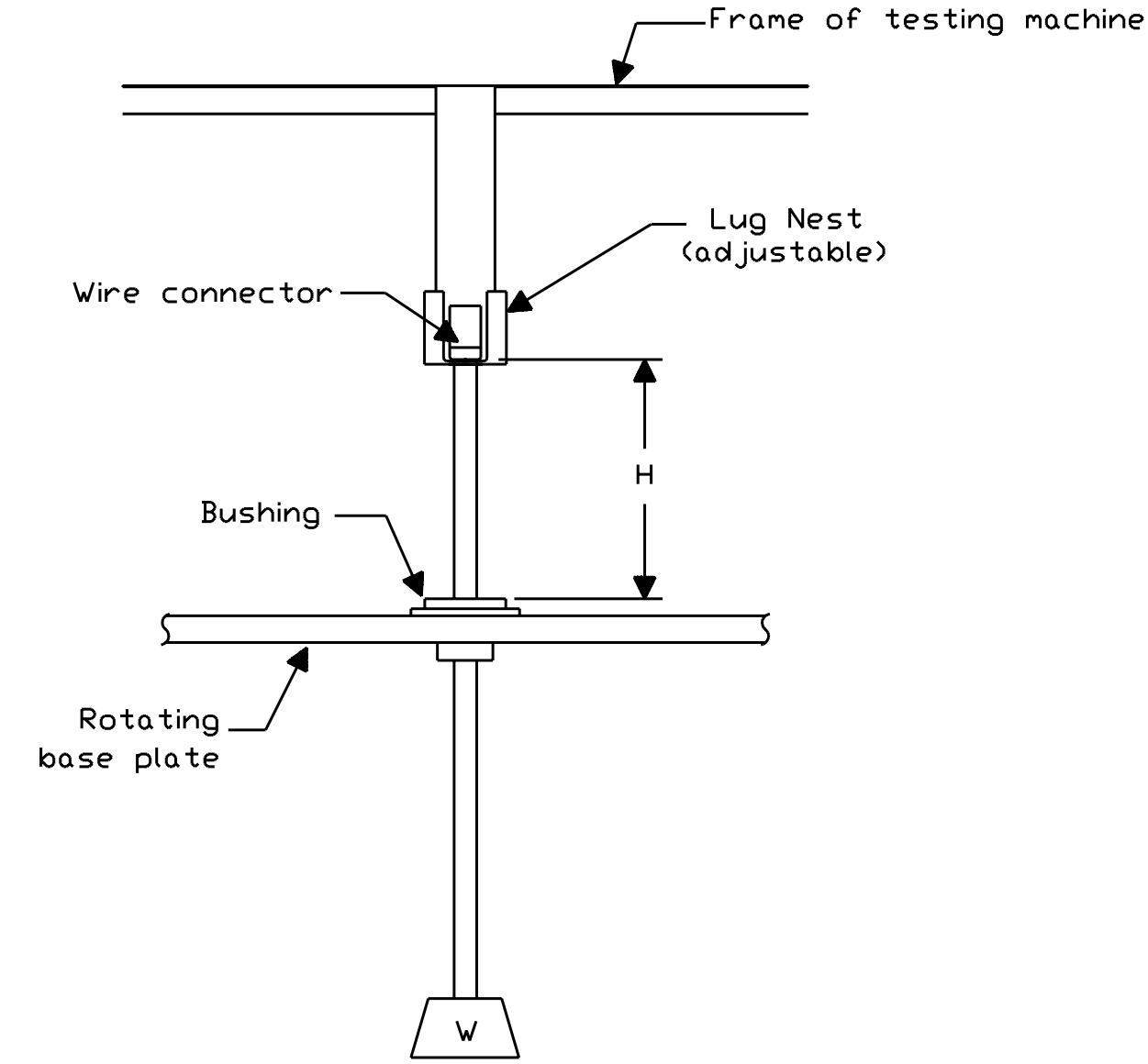


Figure 5 – Splicing connector test arrangement

(Clause 9.3.2.3)

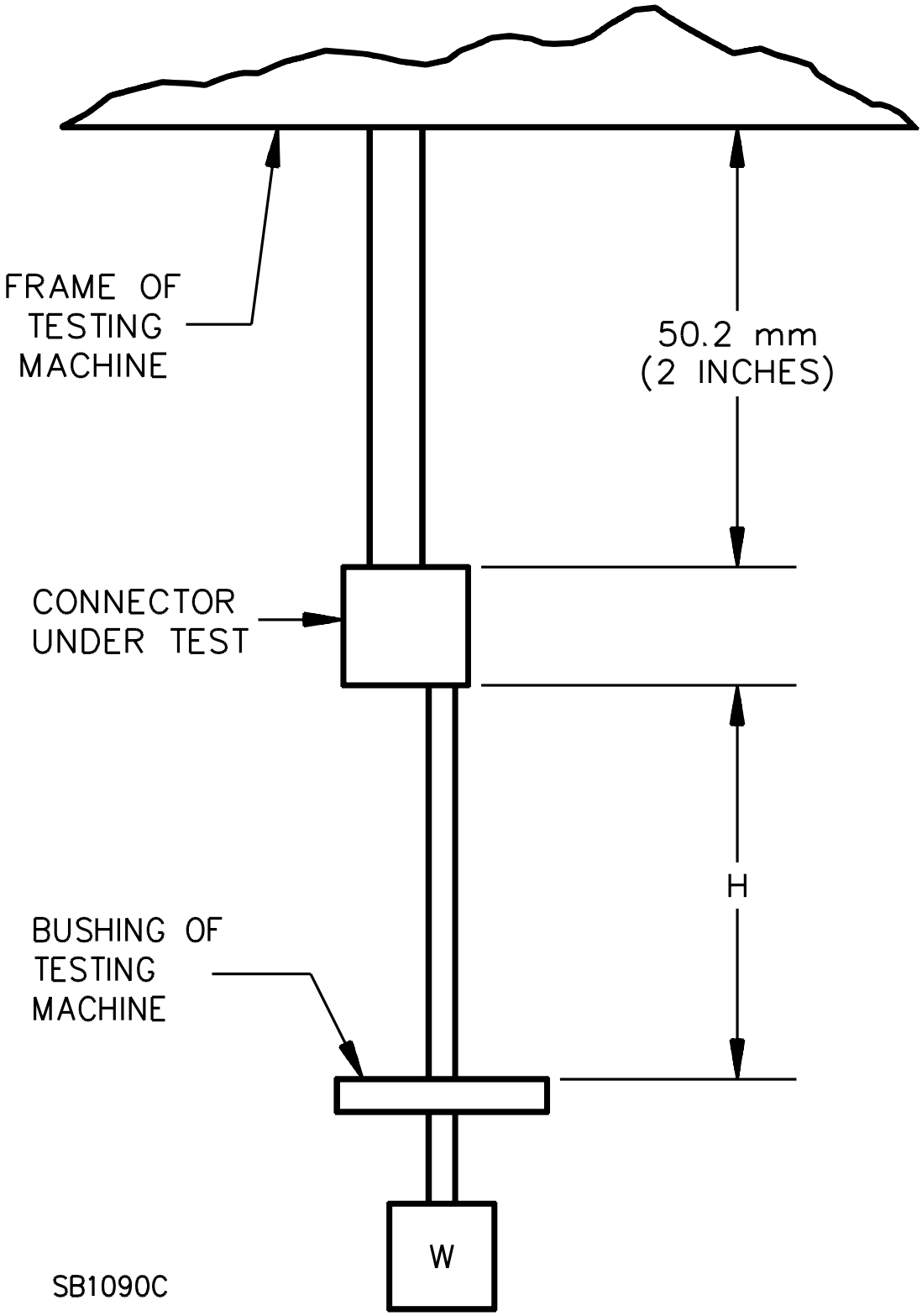
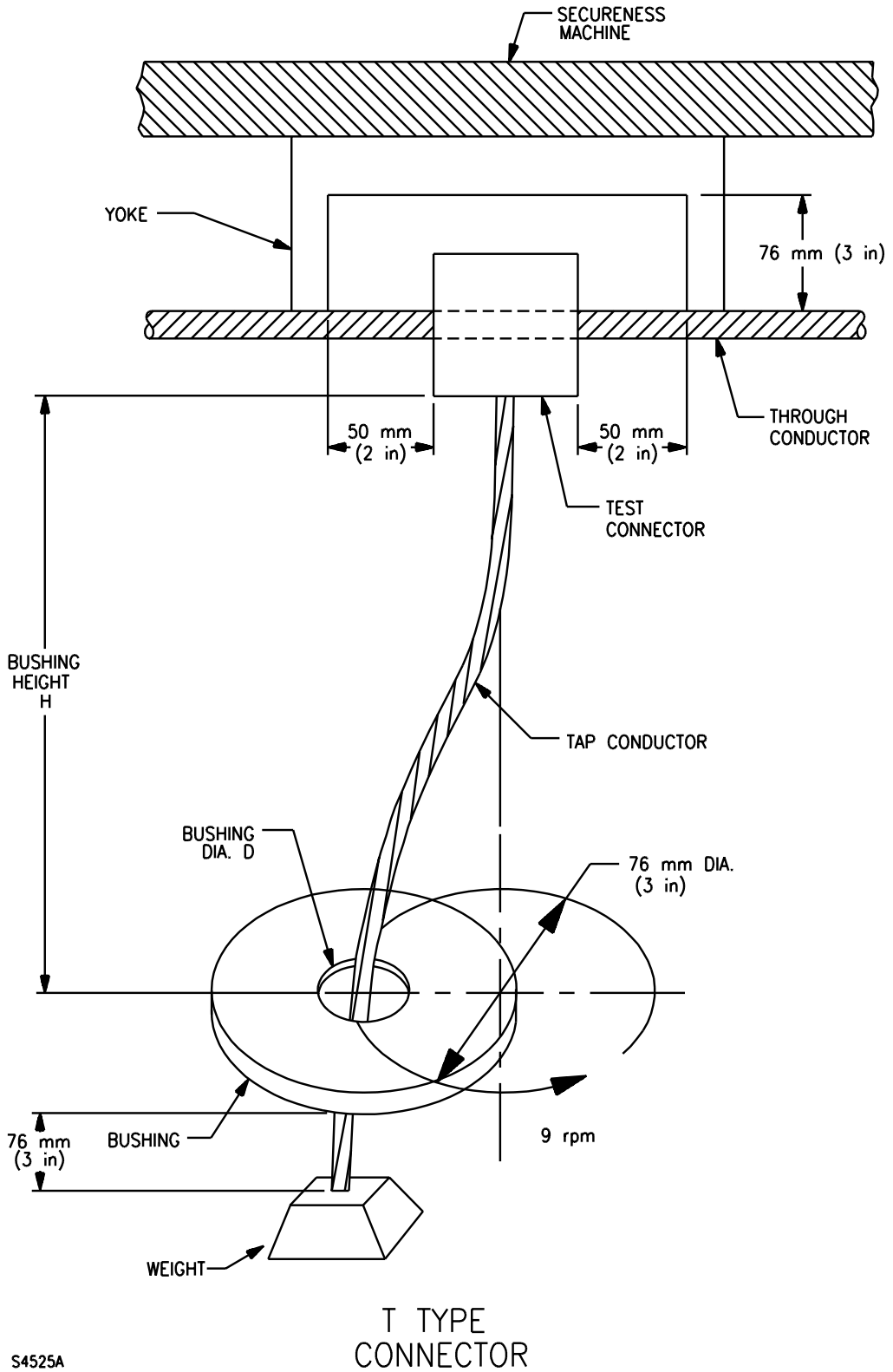


Figure 6 – Secureness test arrangement

(Clause 9.3.2.4)



ANNEX A – Informative References

(Informative)

(Clause 2.2.1)

The following references contain information on conductors and materials in this Standard. At the time of publication, the editions indicated were valid.

ANCE Standard

NMX-J-218-ANCE
Electrical Products – Wires and Cables – Aluminum 1350 Drawing Stock for Electrical Purposes – Specifications

CSA Standards

C22.2 No. 38-95 (R1999)
Thermoset Insulated Wires and Cables

C22.2 No. 75-M1983 (R1999)
Thermoplastic-Insulated Wires and Cables

UL Standards

UL 94
Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 746C
Polymeric Materials – Use in Electrical Equipment Evaluations

ASTM* Standards

B 8-99
Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

B 154-95
Standard Test for Method for Mercurous Nitrate Test for Copper and Copper Alloys

B 172-95
Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

B 173-95
Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors

B 174-95
Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors

B 230/B 230M-99
Standard Specification for Aluminum 1350-H19 Wire for Electrical Purposes

B 231/B 231M-99
Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors

B 400-94
Standard Specification for Compact Round Concentric-Lay-Stranded Aluminum 1350 Conductors

B 496-99
Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors

B 566-04a
Standard Specification for Copper-Clad Aluminum Wire

B 609/B 609M-99
Standard Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes

B 638-99
Standard Test Method for Tensile Properties of Plastics

B 836-00 (Reapproved 2005)
Standard Specification for Compact Round Stranded Aluminum Conductors Using Single Input Wire Construction

B 901-04
Standard Specification for Compressed Round Stranded Aluminum Conductors Using Single Input Wire Construction

IEC† Standards

IEC 60228 (1978-01)
Conductors of Insulated Cables

IEC 60228A (1993-01)
Conductors of Insulated Cables – Amendment No. 1
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**American Society for Testing and Materials.*

†*International Electrotechnical Commission.*

ANNEX B – Flammability Test (Material V-2 and VTM-2)

(Normative)

(Clause 6.2.5)

B.1 General

If only one specimen from a set of five specimens does not comply with the requirements, another set of five specimens shall be tested. In the case of the total number of seconds of flaming, an additional set of five specimens shall be tested if the totals are in the range of 251 – 255 s for V-2 and VTM-2.

B.2 Reference Publications

ANCE Standards

NMX-J-192-ANCE
Electrical Products – Wires and Cables – Flame Test on Electrical Wires – Test Method

NMX-J-417-ANCE
Wires and Cables – Convection Laboratory Ovens for Evaluation of Electrical Insulation – Specifications and Test Methods

CSA Standard

CAN/CSA-C22.2 No. 0.17-00
Evaluation of Properties of Polymeric Materials

UL Standards

UL 94
Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 746C
Polymeric Materials – Use in Electrical Equipment Evaluations

ASTM* Standards

D 5207-98
Standard Practice for Calibration of 20 and 125 mm Test Flames for Small-Scale Burning Tests on Plastic Materials

D 5374-93
Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

D 5423-93 (1999)
Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

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B.3 Apparatus

The following apparatus shall be used:

a) the apparatus described in paragraphs 3.6 and 5A7 of UL 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances; parts 4.1.3 and 4.1.5 of CSA 22.2 No. 0.17, or NMX-J-192-ANCE;

b) conditioning oven as indicated by ASTM D 5423-93 and ASTM D 5374-93, or NMX-J-417-ANCE;

c) a desicator containing anhydrous calcium chloride; and

d) specimen mandrel guide – 13 mm (0.5 in) diameter rod.

B.4 Test Specimens

B.4.1 General

If the material is to be considered in a range of colors, melt flows, or reinforcements, specimens representing those ranges shall be provided. Specimens in the natural (if used in this color) and in the most heavily pigmented light and dark colors shall be provided and considered representative of the color range, if the burning characteristics are essentially the same. An additional set of specimens shall be provided in the heaviest organic pigment loading, unless the most heavily pigmented light and dark colors include the highest organic pigment level. When certain color pigments (for example, red, yellow, or the like) are known by experience to have particular critical effects, they shall be provided. Specimens in the extremes of the melt flows and reinforcement contents shall be provided and considered representative of the range, if the burning characteristics are essentially the same. If the burning characteristics are not essentially the same for all specimens representing the range, evaluation shall be limited only to the material in the colors, melt flows, and reinforcement contents tested, or additional specimens in intermediate colors, melt flows, and reinforcement contents shall be provided for tests.

B.4.2 V-2

Test specimens, 130 mm (5.0 in) in length by 13 mm (0.50 in) in width in the minimum and maximum thicknesses, shall be tested, covering the thickness range to be considered. Specimens tested by this method shall be limited to a maximum thickness of 13 mm (0.50 in). Specimens in intermediate thicknesses shall be provided and may be tested if the results obtained on the minimum or maximum thickness indicate a need. Intermediate thicknesses shall not exceed increments of 3 mm (0.125 in). The specimens shall comply with the following:

a) The maximum width shall be 13 mm (0.50 in).

b) The edges shall be smooth and the radius on the corners shall not exceed 1 mm (0.05 in).

B.4.3 VTM-2

The test specimens shall be cut from the sheet material to a size 200 mm (8.0 in) in length x 50 mm (2.0 in) in width. Test specimens shall be prepared by marking a line across the specimen width, 125 mm (5.0 in) from one end (bottom) of the cut specimen. The longitudinal axis of the test specimen then shall be wrapped tightly around the longitudinal axis of a 13 ± 1 mm (0.5 ± 0.02 in) diameter mandrel to form a lapped cylinder 200 mm (8.0 in) in length with the 130 mm (5.0 in) line exposed. The overlapping ends of the specimen shall be secured within the 76 mm (3.0 in) portion at the 130 mm (5.0 in) mark and at the

upper tube section by means of pressure sensitive tape, after which the mandrel shall be removed. If the material is prone to developing static charges, which make the formation of a cylinder difficult, the unformed specimen shall be deionized by a device or material suitable for the purpose.

Different generic materials, although capable of being wrapped and taped around the mandrel, may exhibit varying degrees of flaring out of the untaped ″U″ type specimen. These various forms shall be considered acceptable to test if the upper end can be formed into the cylinder.

B.5 Specimen Conditioning

Specimens sets shall be conditioned as follows:

a) Sets of five specimens each shall be conditioned for at least 48 h at a temperature of 23 ± 2°C (73 ± 3.6°F) and a relative humidity of 50 ± 5 percent prior to testing.

b) Sets of five specimens each shall be conditioned in an air-circulating oven for 168 h at 70 ± 1°C (158 ± 1.8°F) and then cooled in a desiccator, over anhydrous calcium chloride, for at least 4 h at room temperature prior to testing. As an alternative to 168 h at 70 ± 1°C (158 ± 1.8°F), industrial laminates may be conditioned for 24 h at 125 ± 1°C (257 ± 1.8°F).

B.6 Test Method

The burning test shall be conducted in a chamber or enclosure free of induced or forced draft.

Each specimen shall be supported by the clamp on the ring stand from the upper 6 mm (0.25 in) of the specimen, with the longitudinal axis vertical. The lower end of the specimen shall be 10 mm (0.38 in) above the top of the burner tube and 305 mm (12.0 in) above a horizontal layer of dry absorbent surgical cotton. To form the horizontal layer of cotton, a small portion, approximately 13 x 25 mm (0.50 x 1.0 in) shall be pulled from the supply with thumb and forefinger, and formed into a 50 mm (2.0 in) square having a thickness of 6 mm (0.25 in).

The flame shall be adjusted to produce a blue flame 20 mm (0.75 in) high. The method to adjust the flame is indicated in ASTM D 5207-91 or Annex A of NMX-J-192-ANCE.

The test flame shall be placed centrally under the lower end of the test specimen and allowed to remain for 10 s in the case of V-2 materials and 3 s for VTM-2 materials. For specimens that are not lapped, the flame shall be applied in line with the longitudinal axis of the specimen.

The test flame then shall be withdrawn at least 150 mm (6.0 in) away and the duration of flaming of the specimen noted. When flaming of the specimen ceases, the cycle shall be repeated again. If it is difficult to visually distinguish between flaming and glowing, a small piece of surgical cotton, approximately 50 mm (2.0 in) as described before, shall be brought into contact with the area in question. Ignition of the cotton will be indicative of flaming.

If the specimen drips molten or flaming material during either flame application, the burner may be tilted to an angle up to 45 degrees and also slightly withdrawn from one of the 13 mm (0.50 in) sides of the specimen during the flame application, to avoid material dripping into the tube of the burner. If the specimen drips molten or flaming material or is consumed during the test, the burner shall be hand-held, and the 10 mm (0.38 in) distance between the bottom of the specimen and the top of the burner tube shall be maintained during the flame application. Any molten strings of the material shall be ignored, and the flame shall be applied to the major portion of the specimen.

The following shall be observed and recorded:

a) duration of flaming after first flame application;

b) duration of flaming after second flame application;

c) duration of flaming plus glowing after second flame application;

d) whether or not specimens burn up to the holding clamp, or up to the 130 mm (5.0 in) mark for VTM-2; and

e) whether or not specimens drip flaming particles that ignite cotton swatch.

B.7 Results

The specimens meet the requirements if:

a) no specimen burns with flaming combustion for more than 30 s after either application of the test flame;

b) total flaming combustion time does not exceed 250 s for the 10 flame applications for each set of five specimens;

c) no specimen burns with flaming or glowing combustion up to the holding clamp, or up to the 130 mm (5.0 in) bench mark for VTM-2; and

d) after the second removal of the test flame, no specimen exhibits glowing combustion persisting for more than 60 s.

The specimens may drip flaming particles that ignite the dry absorbent surgical cotton.

ANNEX C – Examples

(Informative)

(Clauses 7.1.4, 8.3.2, and 8.3.3)

C.1 Examples from Clause 7.1.4

C.1.1 A setscrew connector is rated 4 AWG – 250 kcmil CU/AL. The conductor sizes required for current-cycling testing are 250 kcmil CU and 250 kcmil AL. In accordance with Clause 7.1.4, the current-cycling test using copper conductor need not be conducted because the size of the aluminum conductor to be current-cycling tested is not smaller than the size of the copper conductor.

C.1.2 A setscrew connector is rated 4 AWG – 250 kcmil CU, 4 – 1/0 AWG AL. The conductor sizes required for current-cycling testing are 250 kcmil CU and 1/0 AWG AL. As the size of the aluminum conductor to be tested is smaller than the size of the copper conductor, Clause 7.1.4 does not apply and the current-cycling test needs to be conducted for both copper and aluminum conductors.

C.2 Example from Clause 8.3.2 (ampere-rated, non-parallel)

For a connector rated 200 amperes, 250 kcmil (127 mm^2) through 1/0 AWG (53.5 mm^2), AL-CU, the required conductor sizes selected for the current-cycling, static-heating sequence, and mechanical sequence would be as follows:

Conductor size		Copper conductor[a]	Aluminum conductor
AWG/kcmil	(mm^2)		
250	(127)	Mechanical sequence	Static-heating sequence/ current-cycling
4/0	(107.2)	–	–
3/0	(85)	Static-heating sequence/ current-cycling[b]	–
2/0	(67.3)	–	–
1/0	(53.5)	Mechanical sequence	Mechanical sequence

[a] Also applicable for an aluminum-bodied connector rated for copper wire only.

[b] Current cycling may be waived; see 7.1.4 and 8.2.1 – 8.2.4.

The following example is for a connector rated 200 amperes 4/0 AWG to 1/0 AWG (107.2 to 55.3 mm^2) rated CU only and copper-bodied.

Conductor size		Copper conductor
AWG	(mm^2)	
4/0	(107.2)	Mechanical sequence
3/0	(85)	Static-heating sequence
2/0	(67.3)	–
1/0	(53.5)	Mechanical sequence

C.3 Example from Clause 8.3.3 (ampere-rated, both parallel and non-parallel)

For a connector rated 400 amperes with a conductor range of a single 700 kcmil – 2/0 AWG (355 – 67.4 mm^2) and a parallel range of (2) 250 – 1/0 AWG (127 – 53.5 mm^2) rated CU-AL, the required tests are as follows:

Number of conductors	Conductor size		Conductor type	
	AWG/kcmil	(mm^2)	Copper[a]	Aluminum
1	700	(355)	Mechanical sequence	Static-heating sequence/ current-cycling
1	600	(304)	Static-heating sequence/ current-cycling[b]	–
1	2/0	(67.4)	Mechanical sequence	Mechanical sequence
2	250	(127)	Mechanical sequence	Static-heating sequence/ current-cycling
2	3/0	(85)	Static-heating sequence/ current-cycling[b]	–
2	1/0	(53.5)	Mechanical sequence	Mechanical sequence

[a] Also applicable for an aluminum-bodied connector rated for copper wire only.

[b] Current cycling may be waived; see 7.1.4 and 8.2.1 – 8.2.4.

ANNEX D – Stability Factor Calculation

(Informative)

(Clause 7.2.4)

Example of stability factor calculation:

Cycle number	Temperature °C		d	S_i
	Specimen	Control conductor		
25	130	135	−5	−6.5
50	131	136	−5	−6.5
75	133	135	−2	−3.5
100	136	135	1	−0.5
125	136	135	1	−0.5
175	138	135	3	1.5
225	139	136	3	1.5
275	138	135	3	1.5
350	141	136	5	3.5
425	142	136	6	4.5
500	142	136	6	4.5
		Sum 16 Average (D) = +1.5		

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ANNEX E – Marking Locations Guide

(Informative)

(Clause 10.1)

Clause	Subject[a]	Location Options[a,b]
	General	
10.2, 10.4	Manufacturer's name or trademark	A
10.2	Catalog number	A[c]
10.2, 10.5, 10.9, 10.10	Conductor size or range of sizes	A[c], C
	Conductor type and connector ratings	
10.6	Conductor material, CU	A, B
10.7, 10.8	Conductor material, AL, AL-CU, etc.	A, E
10.17, 10.18, 10.19, 10.20	Connector rating, 75, 90, CU7, AL9CU, etc.	A, E
10.24	Intermixing, (intermixed – dry locations)	A, E
	Stranding and other conductor types	
10.13, 10.14	Solid and/or stranded	A, B
10.12	Other conductor classes and stranding	A, B
10.34, 10.35	Metric conductors	A, B
10.40, 10.41	Compact copper	A, B
	Miscellaneous ratings	
10.27	Assigned tightening torque	A, B
10.30	Assigned ampere rating	A, E
10.28, 10.29	Blank tang	B
10.39	'OEM' for factory installation only	A
	Installation and assembly instructions	
10.15	Proper assembly procedure for connector	
a)	– Specific tool usage	A, B
b)	– Multiple crimping	A, B, C
c)	– Strip length	A, B, C, D
d)	– Preliminary preparation	B
10.26	Dished washer and hardware assembly instructions	B
10.11	Rearrangement/adjustment instructions to adapt to different sizes	A, B
	Insulated connectors	
10.16	Voltage	A, B
10.42	Flammability	A, B
10.21, 10.22, 10.23	Maximum operating temperature limit of insulation	A, B, D
10.32, 10.33	Separable insulating cover	B, D
	– Manufacturer's name	
	– Catalog number or equivalent	

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Clause	Subject[a]	Location Options[a,b]
	– Voltage – Maximum operating temperature limit	
	Unit container and information sheet	
10.31	Unit container / information sheet – Manufacturer's name – Catalog number or equivalent	B
10.37, 10.38	Identifying number	B

[a] These are a brief summary of marking requirements. For complete details, see the specific clause.

[b] Marking locations are coded as follows:

A. On the connector.

B. On the unit container or information sheet within the unit container. Markings are not to be divided between unit container and information sheet, see 10.36.

C. On or with the tool.

D. On the insulator.

E. May be on the unit container or on an information sheet packed in the unit container for a connector used with 6 AWG (13.3 mm^2) or smaller conductors.

[c] For small devices, may be replaced with an identifying symbol. See 10.3.

Superseded requirements for
the Standard for
Wire Connectors

UL 486A-486B, First Edition

The requirements shown are the current requirements that have been superseded by requirements in revisions issued for this Standard. To retain the current requirements, do not discard the following requirements until the future effective dates are reached.

7.1.2 With reference to 7.1.1, a connector of copper or copper alloy need not be subjected to the current-cycling sequence using copper conductor.

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