UL 486A

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Wire Connectors and Soldering Lugs for Use With Copper Conductors

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UL Standard for Safety for Wire Connectors and Soldering Lugs for Use With Copper Conductors, UL 486A

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Revisions: This Standard contains revisions through and including May 23, 2001.

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The new and revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated December 18, 2000. The bulletin(s) is now obsolete and may be discarded.

The revisions dated May 23, 2001 include a reprinted title page (page1) for this Standard.

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New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if

the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

This Standard consists of pages dated as shown in the following checklist:

No Text on This Page

FEBRUARY 7, 1997 **ANSI/UL 486A-1998**
(Title Page Reprinted: May 23, 2001)

1

UL 486A

Standard For Wire Connectors and Soldering Lugs for Use With Copper Conductors

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Fourth Edition – June, 1969
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Ninth Edition

February 7, 1997

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated February 7, 1997 . These pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Approved as ANSI/UL 486A-1982, October 26, 1982
Approved as ANSI/UL 486A-1990, August 9, 1990
Approved as ANSI/UL 486A-1998, June 24, 1998

The Department of Defense (DoD) has adopted UL 486A on June 2, 1984 . The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. 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.

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FOREWORD

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

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

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

D. A product employing materials or having forms of construction 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.

INTRODUCTION

1 Scope

1.1 These requirements cover pressure wire connectors and soldering lugs for use with copper conductors according to the National Electrical Code, NFPA 70.

1.2 These requirements also cover ampere-rated connectors intended for use in appliances and equipment and that comply with the requirements specific to those appliances and equipment. Ampere-rated connectors are not intended for general use. Ampere-rated connectors are additionally evaluated for static temperature rise in the end-use application. Ampere-rated connectors shall be identified as such by the appropriate marking requirements. See 20.19.

1.3 These requirements cover terminal-type wire connectors designed for use with No. 30 AWG (0.05 mm^2) or larger copper conductors and splicing-type wire connectors intended for use with No. 4 AWG (21.2 mm^2) or larger copper conductors – see 1.5 – with currents not exceeding the capacity of the insulated conductors and not exceeding the maximum current rating, if provided, of the connector. For connectors intended for use with stranded conductors, the conductor strand configurations are Class B concentric and compressed, and Class C concentric. Other class and strand configurations may also be covered as indicated by marking.

1.3.1 These requirements also cover connectors of the types specified in 1.3 intended for use with metric conductors that have cross sectional area within the range of the rated AWG/kcmil conductors. For example, a connector rated for 6AWG – 250 kcmil may additionally be rated for 16 – 120 mm^2. See 6.1.9, 7.2.2.1, 20.24, and 20.25.

1.3.1 added May 22, 2000

1.4 These requirements also cover connectors additionally rated for No. 2 AWG (33.6 mm^2) and larger compact-stranded copper conductors. These connectors are identified in accordance with 20.9. See also 3.2 and the Exception to 7.2.5(c).

1.4 revised May 22, 2000

1.5 A splicing connector may have a conductor range that includes sizes smaller than No. 4 AWG (21.2 mm^2).

1.6 These requirements cover insulated connectors, insulating caps, and covers intended for use at 600 volts or less [1000 volts in a sign or lighting fixture (luminaire)] and uninsulated connectors for use in general use circuits rated 2000 volts nominal or less.

Exception: Uninsulated pressure wire connectors (both terminal and splicing type) that are compression tool applied may be used in circuits rated 35,000 volts or less. When connectors are used in such circuits, the stress-relief insulation prescribed by the manufacturers of shielded cables is to be provided when these connectors are installed.

1.7 These requirements do not cover connectors intended for direct burial, insulated connectors intended for use at voltage levels in excess of 600 volts [1000 volts in a sign or lighting fixture (luminaire)], manually applied screw-on connectors, binding-screw terminals, built-in terminal connectors on devices rated under 30 A and intended for outlet-box mounting or having provision for strain relief, or built-in terminal connectors on devices having integral cable clamps.

1.8 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

1.8 revised May 22, 2000

2 General

2.1 Units of measurement

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

2.1.1 revised May 22, 2000

2.2 Undated references

2.2.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

WIRE CONNECTORS

CONSTRUCTION

3 General

3.1 The construction of a connector intended for use with a stranded conductor shall be such that all strands of the conductor will be contained within the connector.

3.2 A connector rated and tested with compact-stranded copper conductors according to these requirements shall also accept all strands of a Class B concentric-stranded conductor of the same size. See also 1.4 and the Exception to 7.2.5 (c).

3.3 The clamping movement of a connector shall adapt it for use with conductors of different sizes without permanent removal or addition of parts, if such use is intended. Examples of clamping means 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; and

d) A nut threading onto a split bolt.

Any rearrangement or adjustment of a connector that is necessary to adapt it to various sizes of conductor shall be obvious unless the connector is marked as required by 20.8.

3.4 If the method of mounting an equipment terminal connector prevents retightening of the mounting means after conductors are installed, or after the connector is mounted in equipment, the construction of the mounting means – by inherent features or manufacturer's specifications– shall limit rotation of the connector around its mounting means to not more than 30 degrees.

3.5 There shall be no sharp edges or corners on the outer surface of a connector that would be likely to damage insulation that it may contact.

4 Materials

4.1 The main current-carrying part of a connector shall be of copper, a copper alloy, or other material investigated and found to be acceptable for the purpose.

4.2 A connector body of aluminum or aluminum alloy shall be:

a) Coated with an electrically conductive coating that will inhibit oxidation and corrosion;

b) Additionally subjected to the heat-cycling test with copper conductor according to the Standard for Wire Connectors for Use With Aluminum Conductors, UL 486B; and

c) Marked with a temperature rating according to UL 486B.

Exception No. 1: The saw-cut ends of a neutral bar need not be coated.

Exception No. 2: The top cap of a lay-in lug or connector not in contact with the wire need not be plated.

Exception No. 3: A stamped mounting hole in a connector which is intended to be secured by a bolt, nut, and washer need not be plated.

4.3 Tin is acceptable for the coating mentioned in 4.2. Other coatings may be used if found by investigation to be acceptable for the purpose.

4.4 A brass part of a connector shall be resistant to stress corrosion cracking.

4.5 A brass part containing not more than 15 percent zinc is considered to be resistant to stress corrosion cracking.

4.6 A brass part containing more than 15 percent zinc shall comply with 10-Day Moist Ammonia-Air Stress Cracking Test, Section 18.

4.7 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.

4.8 Insulation employed as a part of a connector shall be porcelain, cold-molded or phenolic composition, or other material that has been investigated and found to be acceptable. See 20.14.

4.8.1 The insulating material is able to have a flammability classification as determined by tests described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. See 20.26.

4.8.1 added May 23, 2001

4.9 Insulation consisting of natural or GR-S rubber or a thermoplastic material may be subjected to an investigation to determine if it is acceptable for the purpose.

4.10 Porcelain or cold-molded composition used as insulation shall additionally comply with Moisture Absorption Test, Section 19.

PERFORMANCE

5 General

5.1 A connector shall perform acceptably when separate sets of samples are subjected to the tests specified in Tables 5.1, 5.2, and 5.3.

Exception: Nos. 20 – 30 AWG (0.52 – 0.05 mm^2) conductors are not subjected to the secureness test.

Table 5.1
Test sequence for insulated connectors

Table 5.1 revised June 25, 1998

1	2	3[a]	4
Dielectric voltage-withstand	Secureness of insulation	Drop	Flexing
		Dielectric voltage-withstand after drop	

[a] Connectors intended for No. 2 AWG (33.6 mm^2) or larger conductor.

Table 5.2
Test sequence for all connectors intended for a single conductor

1[a]	2[b]
Secureness[c] Static heating Pullout	Secureness[c] Pullout

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

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

[c] Conductor size Nos. 30 – 20 AWG (0.05 – 0.52 mm^2) are not subject to a secureness test.

Table 5.3
Test sequence for all connectors intended for paralleling conductors

Static-heating sequence	Mechanical sequence
Static heating	Secureness
	Pullout

5.2 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.

5.3 With respect to 5.2, breaking of the conductor or any strand of a stranded conductor is to be determined by examination of the complete connector assembly while still intact after the secureness and pullout tests. If the conductor or a strand of a stranded conductor becomes visibly unattached, breakage is considered to have occurred.

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

5.5 The oven conditioning described in 13.2.2 and 13.2.3 and Table 13.3 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 wire connector insulation. However, discoloration of the connector insulation is acceptable.

6 Selection of Samples

6.1 General

6.1.1 Separate samples are to be used for the static-heating sequence, mechanical sequence and the dielectric voltage-withstand tests.

6.1.2 The basic sample set for the static-heating sequence and mechanical sequence is to consist of four connectors for each combination of connector and test conductor or conductors to be tested.

Exception No. 1: For testing a splicing connector or run and tap connector in which each conductor is secured by a separate means, the sample set is to consist of two connectors for each combination of connector and test conductor to be tested.

Exception No. 2: For a neutral bar, the basic sample set is to consist of a double set 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 provided in production.

6.1.3 The number of samples required for the dielectric voltage-withstand tests is specified in Dielectric Voltage-Withstand Test, Section 13.

6.1.4 For a line of connectors of similar design but of different sizes in which the largest connector, the smallest connector, and connectors of two representative intermediate sizes have been tested and found to be acceptable, tests are not required to be conducted on other intermediate sizes in the range.

Exception No. 1: For a line of connectors consisting of not more than five sizes, only the largest connector, the smallest connector, and one connector of a representative intermediate size need be tested.

Exception No. 2: For a line of connectors consisting of four or less sizes, only the largest connector and the smallest connector need be tested.

6.1.5 With reference to 6.1.4, in determining what constitutes a line of connectors of similar design, the following features are to be considered:

a) Shape of connector, shape of conductor opening, and shape of the conductor clamping screw;

b) Material of connector body;

c) Material of conductor clamping screw;

d) Number of clamping screws;

e) Torque corresponding to the conductor size of each connector in the line;

f) For connectors for use with a crimping tool, crimping die design and number of crimps; and

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

6.1.6 A connector that is intended to employ clamping screws made of either aluminum, brass, or steel is to be tested with clamping screws made of the materials specified in Table 6.1.

Table 6.1
Material of clamping screw for tests

Screw material	Static-heating and mechanical sequences[a]		
	Steel	Brass	Aluminum
Aluminum, brass, or steel	X		X
Aluminum or steel	X		X
Brass or steel	X	X	
Brass or aluminum		X	X

[a] An X indicates that the test is to be conducted.

6.1.7 Sample sets are to be tested using both solid and stranded conductors for No. 30 – 10 AWG (0.05 – 5.3 mm^2) conductor sizes, and using stranded conductor for No. 8 AWG (8.4 mm^2) and larger conductor sizes unless the connector is marked according to 20.6, in which case the conductor used is to be of the type or types marked on the connector.

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

6.1.9 Testing using AWG/kcmil conductors are considered 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 7.2.2.1.

6.1.9 added May 22, 2000

6.2 Static-heating sequence

6.2.1 For the static-heating sequence – see Tables 5.2 and 5.3 – connectors with a conductor range are to be tested with the maximum size conductor. If more than one conductor is secured by a single clamping means, additional sample sets may be necessary. See 10.4.

Exception No. 1: For an ampere-rated connector not intended for paralleling of conductors, the static-heating test is not to be conducted with the larger sizes of conductors that exceed the size conductor that corresponds to the ampere rating of the connector as specified in Table 11.1, only the mechanical sequence tests are to be conducted. A connector sample set with the size conductor that corresponds to the ampere rating is to be subjected to the full static-heating sequence. For example, for a connector rated 200 amperes, No. 4/0 – 1/0 AWG (107.2 – 53.5 mm^2) the required tests are as follows:

Conductor size, AWG	(mm^2)	Copper conductor
4/0	(107.2)	Secureness and pull-out only
3/0	(85)	Full sequence (310 amperes)

Exception No. 2: For an ampere-rated connector intended for paralleling conductors, the static-heating test is not to be conducted with the larger sizes of conductors that exceed the size of the conductor or conductors that correspond to the ampere rating of the connector – only the mechanical sequence tests are to be conducted. Static-heating tests are to be conducted with the parallel conductor combinations that equal the assigned ampere rating using Table 11.1. When using Table 11.1 for parallel conductors, the ampere rating assigned to the connector is to be divided by the number of conductors. For ampere ratings that fall in between the values specified, the next larger conductor size is to be used. The values of test current in the static-heating test for the single-conductor range are to be Selected from Table 11.1. The values of test current in the static-heating test for the parallel-conductor range are to be selected from Table 11.2. If the number of conductors is less than the number of conductor openings, the conductors are to 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-wire ranges, the conductor sizes and values of test current in the static-heating test for single conductor ranges are to be selected from Table 11.1 using the conductor size that corresponds to the ampere rating of the connector. For example, for a connector rated 400 amperes with two conductor openings and a conductor range of 700 kcmil – No. 2/0 AWG (355 – 67.4 mm^2), the required tests are as follows:

Conductor range based on ampere rating for static-heating test selection

Ampere rating	Type of conductor	Conductor range
400	Copper	Single conductor, 700 kcmil – 2/0 AWG Two conductors, 3/0 AWG – 2/0 AWG

Static-heating tests for copper wire

Number of conductors	Conductor size, AWG or kcmil	Test current, amperes
1	600	690[a]
2	3/0	400[b]
[a] Selected from Table 11.1. [b] Selected from Table 11.2.		

6.2.1 revised May 22, 2000

6.3 Mechanical sequence

6.3.1 For the mechanical sequence – see Tables 5.2 and 5.3 – connectors with a conductor range are to 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 sample sets may be necessary. See 10.4.

7 Preparation of Samples

7.1 General

7.1.1 To determine if a connector complies with the performance requirements, representative samples of the connector are to be assembled to conductors of the proper type, length, and size and in the manner that would be used in service.

7.1.2 A connector intended for assembly by means of a specific tool, is to be assembled in the intended manner with the specific tool.

7.1.3 If a connector is intended to be assembled to a conductor by means of more than one type of specific tool, the connector shall perform acceptably in the tests when any of the specific tools is employed in the assembly operation.

7.1.4 With reference to 7.1.3, in selecting tools for assembly of a connector to a conductor, the following features are to 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.

7.1.5 If specific instructions for assembling the connector to the conductor are furnished with the connector by the manufacturer, such instructions are to be followed in the preparation of the samples.

7.1.6 A tangless terminal connector – collar or meter-socket construction - is to be mounted for test purposes on a tang representative of the intended use, according to the manufacturer's assembly instructions and specifications for the tang material, plating, and cross-sectional dimensions. The length of the tang is not to exceed twice the length of the connector body. Individual tangs with a mounting hole in the end opposite the connector are to be used. If a specified mounting means includes auxiliary anti-rotation means, such means is not to increase the thermal mass or heat-radiating capabilities of the assembly.

Exception: A terminal connector integral with a fuse clip or meter-socket jaw or the like or intended for connection to a bus having a low conductivity because of material or cross-sectional area is to have the tang sized to prevent excessive heating of the tang. However, the test tang should not be so large that it operates cooler than the bodies of the connectors, as determined by the thermocouples placed on the tangs and connector bodies.

7.2 Test conductor

7.2.1 All test conductors are to be new – previously unused – and as specified in Table 7.1. See 6.1.7.

Exception: Conductors may be previously used:

a) With the concurrence of all parties concerned; and

b) If the conductors have not attained a temperature of over 120°C (248°F) in previous tests.

Used conductor ends shall be cut off and the resulting new ends of the conductor re-stripped in accordance with 7.3.1 – 7.3.4.

Figure 7.1
Method for mounting tangless connectors

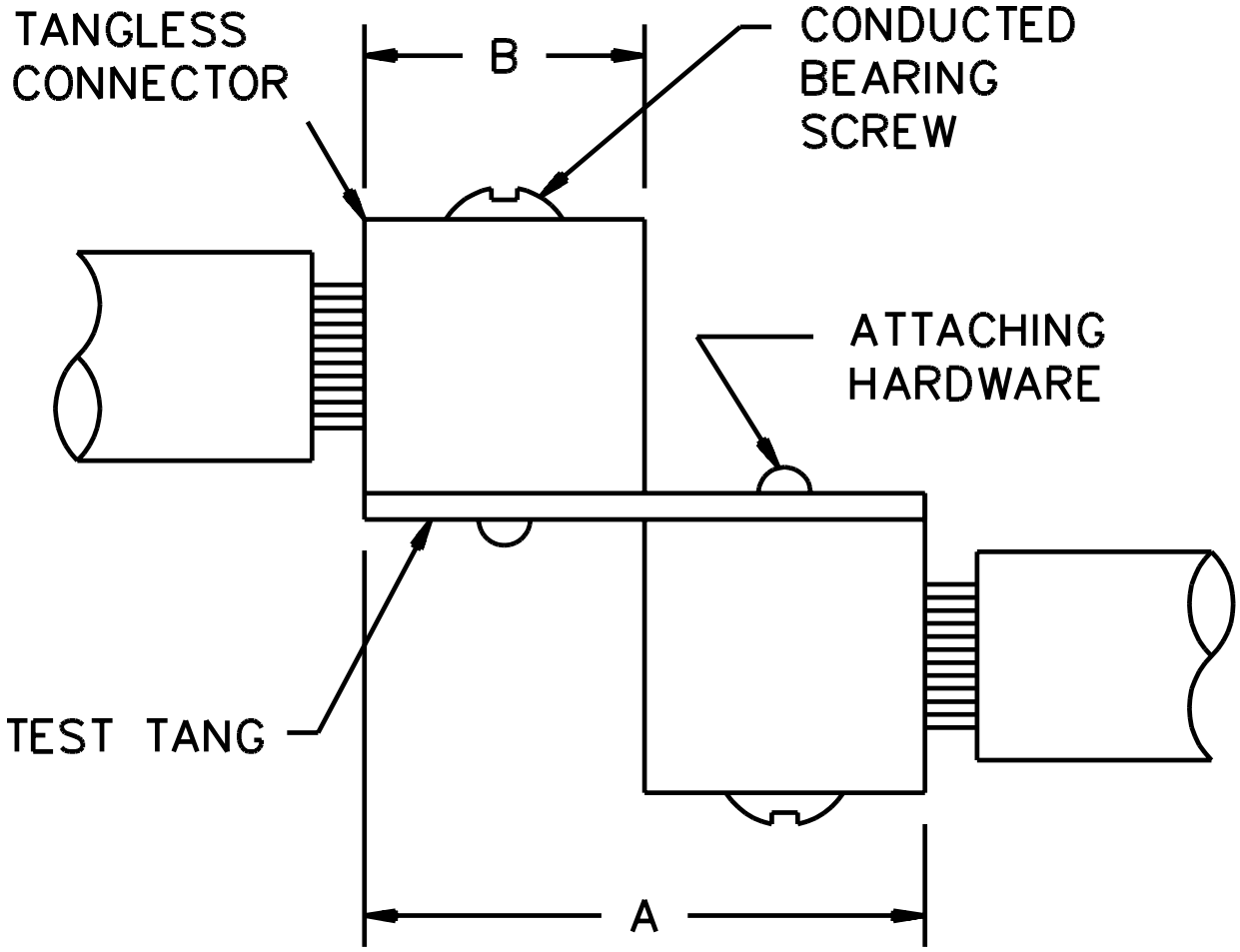


Table 7.1
Conductor for test

Size of conductor to which connector is to be assembled, AWG or kcmil (mm^2)		Number of strands, if stranded conductor	
		Copper	
		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
1 – 4/0	(42.4 – 107.2)	19	37
250 – 500	(127 – 253)	37	61
600 – 1000	(304 – 508)	61	91
1250 – 1500	(635 – 759)	91	127
1750 – 2000	(886 – 1016)	127	271

[a] Number of strands may vary.

7.2.2 A connector may be acceptable for copper wire other than Class B or Class C stranding if the connector is subjected to all test sequences using the other stranding. See 20.5.

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

7.2.2.1 added May 22, 2000

7.2.3 Insulation is to be black, Type THHN, THW, USE, or XHHW for No. 14 AWG (2.1 mm^2) and larger. Numbers 22 – 16 AWG (0.32 – 1.3 mm^2) are to be insulated with black thermoplastic insulation at least 0.030 inch (0.76 mm) thick. Numbers 30 – 24 AWG (0.05 – 0.20 mm^2) conductors are to be insulated with black thermoplastic insulation at least 0.010 inches (0.25 mm) thick.

Exception: Insulation colored other than black may be used if agreeable to those concerned.

7.2.4 A separator is to be located between the conductor and the insulation of a stranded conductor unless examination of the conductor shows that the insulation has not penetrated beyond the first strand layer during the manufacturing process.

7.2.5 The test conductors are to be as follows. See also 7.2.3, 7.2.4, and Table 7.1:

a) Solid and Stranded – Nos. 30 – 16 AWG (0.05 – 1.3 mm^2), soft annealed, tinned or untinned.

b) Solid – No. 14 AWG (2.1 mm^2) and larger, soft annealed, and untinned.

c) Stranded – No. 14 AWG – 2000 kcmil (2.1 – 1016 mm^2), soft annealed, and untinned. The stranding is to be concentric or compressed Class B or concentric Class C.

Exception: Connectors additionally rated for No. 2 AWG (33.6 mm^2) and larger compact-stranded copper conductors shall be tested with compact-stranded Class B copper conductors. See also 3.2 and 20.9.

7.2.5 revised May 22, 2000

7.2.6 The length measured from the conductor entry face of the test connector to the face of the connector at the other end of the test conductor for the static-heating test shall be as specified in Table 7.2.

Table 7.2
Test conductor length

Table 7.2 revised June 25, 1998

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

[a] The conductor length for the secureness test in the static-heating sequence shall not be less than that specified in 10.3 – 10.6.

7.3 Conductor stripping

7.3.1 A conductor is to be stripped immediately prior to installation for a distance that is proper for insertion into the connector – see 7.3.2 – 7.3.4 – and is to be assembled in the connector in the intended manner. Care is to be taken in stripping a conductor to avoid cutting, nicking, scraping, or otherwise damaging the conductor. Care is also to be exercised in removing all foreign materials, such as insulation and separators, from the stripped ends but the conductor is not to be brushed or abraded.

7.3.2 For an insulated or uninsulated connector marked with a nominal strip length according to 20.11 (c) and Table 20.1, the static-heating-sequence tests are to be conducted with conductors stripped to the minimum tolerance specified in Table 7.3. The dielectric voltage-withstand test on an insulated connector is to be conducted with the conductors stripped to the marked nominal strip length.

Table 7.3
Strip-length tolerances for conductors

Conductor size		Tolerance	
AWG or kcmil	(mm^2)	Inch	(mm)
30 – 14	(0.05 – 2.1)	±1/32	(0.8)
12 – 10	(3.3 – 5.3)	±3/64	(1.2)
8 – 250	(8.4 – 127)	±1/16	(1.6)
300 – 2000	(152 – 1016)	±1/8	(3.2)

7.3.3 For an insulated connector marked with a maximum conductor strip length and a minimum conductor strip length according to 20.11(c) and Table 20.1, the static-heating-sequence tests are to be conducted with the conductors stripped to the minimum length specified by the manufacturer, and the dielectric voltage-withstand test is to be conducted with the conductors stripped to the maximum length specified by the manufacturer. For an uninsulated connector marked with a minimum conductor strip length, the static-heating-sequence tests are to be conducted with the conductors stripped to the minimum length.

7.3.4 If the conductor strip length is not marked on a connector, the insulation on the test conductor is to 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 is to be positioned so that 1/4 – 1/2 inch (6.4 – 12.7 mm) of bare conductor is exposed between the conductor-entry face of the connector and the beginning of the insulation. If the conductor can project through the wire connector without interference, the conductor is to be installed to project a maximum of 1/4 inch (6.4 mm).

7.4 Tightening torque

7.4.1 The connection between the conductor and the connector is to be made before the start of the first test on any sample set. No additional tightening is to be done during the testing program.

7.4.2 A connector of the type described in 3.4 is to be mounted to a test bus according to the manufacturer's minimum specifications. During application of the tightening torque, the connector assembly is to be free to turn about its mounting means except as restricted by the construction of the connector or the specified mounting means. Subsequent turning of the connector about its mounting means is to be avoided except as may occur due to test procedures such as those for the secureness test. The mounting means is not to be retightened during the testing program. See 7.1.6.

7.4.3 The specified torque is to be applied by:

a) Tightening the fastening until the specified value of torque is attained; and

b) Maintaining this value, with a static torque reading, for 5 seconds.

7.4.4 The tightening torque values specified in Tables 7.4, 7.5, or 7.6 apply to all connectors employing tightening nuts or bolts of the types prescribed in the tables. The values in Table 7.4 are based on the size of the test conductor installed, while the torque values specified in Tables 7.5 and 7.6 are independent of the test conductor installed except that Table 7.5 is limited to use with connectors intended for No. 8 AWG (8.4 mm^2) or smaller conductors. When more than one conductor is secured by the same tightening means, the torque value in Table 7.4 is to be applied based on the largest conductor installed.

Exception: The manufacturer shall assign a value of tightening torque determined appropriate for the design of the connector and according to the requirements for the product in which the connector is intended to be used. The static-heating sequence tests, mechanical sequence test, and dielectric voltage-withstand test samples are to be prepared using this value of torque. See 20.17 for marking requirements.

7.4.4 revised June 25, 1998

Table 7.4
Tightening torque for screws

Test conductor size installed in connector		Tightening torque, pound-inches (N·m)			
		Slotted head No. 10 and larger[a]		Hexagonal head-external drive socket wrench	
AWG or kcmil	(mm^2)	Slot width – 0.047 inch (1.2 mm) or less and	Slot width – over 0.047 inch (1.2 mm) or slot	Split-bolt connectors	Other connectors
30 – 10	(0.05 – 5.3)	20 (2.3)	35 (4.0)	80 (9.0)	75 (8.5)
8	(8.4)	25 (2.8)	40 (4.5)	80 (9.0)	75 (8.5)
6 – 4	(13.3 – 21.2)	35 (4.0)	45 (5.1)	165 (18.6)	110 (12.4)
3	(26.7)	35 (4.0)	50 (5.6)	275 (31.1)	150 (16.9)
2	(33.6)	40 (4.5)	50 (5.6)	275 (31.1)	150 (16.9)
1	(42.4)	–	50 (5.6)	275 (31.1)	150 (16.9)
1/0 – 2/0	(53.5 – 67.4)	–	50 (5.6)	385 (43.5)	180 (20.3)
3/0 – 4/0	(85.0 – 107.2)	–	50 (5.6)	500 (56.5)	250 (28.2)
250 – 350	(127 – 177)	–	50 (5.6)	650 (73.4)	325 (36.7)
400	(203)	–	50 (5.6)	825 (93.2)	325 (36.7)
500	(253)	–	50 (5.6)	825 (93.2)	375 (42.4)
600 – 750	(304 – 380)	–	50 (5.6)	1000 (113.0)	375 (42.4)
800 – 1000	(406 – 508)	–	50 (5.6)	1100 (124.3)	500 (56.5)
1250 – 2000	(635 – 1016)	–	–	1100 (124.3)	600 (67.8)

Note – Connectors having clamping screws with multiple tightening means (for example, a slotted, hexagonal head screw) are to be tested using both values of torque.

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

Table 7.5
Tightening torque for slotted head screws smaller than No. 10 intended for use with No. 8 AWG or smaller conductors

Slot length of screw		Tightening torque, pound-inches (N·m)			
		Slot width of screw, inch (mm)[a]			
		Smaller than 0.047 (1.2)		0.047 (1.2) and larger	
Inch	(mm)[b]				
Less than 5/32	(4)	7	(0.79)	9	(1.0)
5/32	(4)	7	(0.79)	12	(1.4)
3/16	(4.8)	7	(0.79)	12	(1.4)
7/32	(5.6)	7	(0.79)	12	(1.4)
1/4	(6.4)	9	(1.0)	12	(1.4)
9/32	(7.1)			15	(1.7)
Above 9/32	(7.1)			20	(2.3)

[a] Slot width is the nominal design value.

[b] For slot lengths of intermediate values, select torques pertaining to next shorter slot length. Also see note to Table 7.4 for screws with multiple tightening means. Slot length is to be measured at the bottom of the slot

Table 7.6
Tightening torque for recessed allen head screws

Socket size across flats		Tightening torque	
Inch	(mm)[a]	Pound-inches	(N·m)
1/8	(3.2)	45	(5.1)
5/32	(4.0)	100	(11.4)
3/16	(4.8)	120	(13.8)
7/32	(5.6)	150	(17.0)
1/4	(6.4)	200	(22.6)
5/16	(7.9)	275	(31.1)
3/8	(9.5)	375	(42.4)
1/2	(12.7)	500	(56.5)
9/16	(14.3)	600	(67.8)

[a] See note to Table 7.4 for screws with multiple tightening means.

7.4.5 For the static-heating sequence tests, each conductor that has been terminated or is intended to be terminated in a test connector is to have the free end terminated in a tool-applied compression connector or a pressure screw-type wire connector. The wire connector is not to be larger than that needed for the conductor size involved.

8 Temperature Measurements

8.1 Temperatures are to be measured by thermocouples having conductors not larger than No. 24 AWG (0.21 mm^2) and not smaller than No. 30 AWG (0.05 mm^2).

8.2 When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of No. 30 AWG (0.05 mm^2) iron and constantan conductor and a potentiometer-type instrument; and such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

8.3 The thermocouples and related instruments are to be accurate and calibrated according to good laboratory practice. The thermocouple conductor is to conform with the requirements listed in the table of Initial Calibration Tolerances for Thermocouples in Temperature Measurement Thermocouples, ANSI/ISA MC96.1-1982.

8.3 revised May 22, 2000

8.4 A thermocouple on a wire connector is to be positioned to sense the highest temperatures generated by the connector. In general, the thermocouple sensing bead is to be located on one of the conductor entry sides of the connector and closest to the conductor/connector contact surface. A thermocouple is to 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.

8.5 Thermocouples to measure the ambient temperature for a connector sample set under test are to be installed on 2 inch (50.8 mm) square by 1/4-inch (6.4-mm) thick sections of unplated copper bus bar. For vertically mounted connectors, one bus bar is to be located 2 feet (610 mm) in front and one bus bar 2 feet in back of the sample set and control conductor; if several sample sets of connectors are included, bus bar sections are to be located 2 feet in front, 2 feet in back and 2 feet on each side of the test assembly. For horizontally mounted connectors in an assembly of one or more sample sets of connectors, bus bar sections are to be located 2 feet in front, 2 feet in back and 2 feet on each side of the test assembly. For test assemblies employing an insulating backboard as mentioned in the exception to 9.1.5, no bus bar section is to be mounted behind the test assembly. All bus bars are to be mounted in a vertical plane at the same elevation as the wire connectors being tested. All measurements are to be made to the centerline of the nearest connector or conductor. If all thermocouples employed are the same length, they may be connected in parallel to provide an average ambient temperature.

8.6 An alternate method of locating the thermocouple for a horizontal test assembly is to place one bus bar at the center of a loop formed by the sample sets and control conductors.

8.7 A test sample is considered to have attained a stable temperature during the static-heating test – see 11.3 – when three readings taken at not less than 10-minute intervals show no more than a 2°C (3.6°F) variation between any two of the readings.

9 Sample Test Assembly

9.1 General

9.1.1 Sample sets are to be connected in series and to a current source that is maintained at or above the required value by regulation or frequent adjustment. Tang-type connectors are to be bolted back-to-back and the connectors mounted on the free end of the conductors – see 7.4.5 – are to be bolted together or to lengths of bus bar using the hardware specified in 9.2.1.

9.1.2 For a connector intended for paralleling of conductors, the initial current through the conductors, is to be balanced so that the current in any conductor is not more than 125 percent of the current in a parallel conductor.

Exception: The current need not be balanced if agreeable to those concerned.

9.1.3 The bus bar lengths mentioned in 9.1.1 are to be the minimum required to provide contact area for the connectors mounted on the free end of the conductors – see 7.4.5 – while maintaining the center-to-center sample spacings specified in 9.1.4. The cross-section dimensions of the bus bar are to be:

a) Sufficient to prevent a test-current density in excess on 1000 amperes per square inch for copper or 800 amperes per square inch for copper-clad aluminum or aluminum bus bar; or

b) As specified in Table 9.1, Bus bar cross-section dimensions.

9.1.3 revised June 25, 1998

Table 9.1
Bus bar cross-section dimensions

Table 9.1 revised June 25, 1998

Range of test current, amperes	Maximum cross-section of bus bar, inches[a] (mm)	
	Copper	Copper-clad aluminum or aluminum
226 – 400	1/4 x 1-1/2 (6.35 x 38.1)	1/4 x 2 (6.35 x 50.8)
401 – 600	1/4 x 2 (6.35 x 50.8)	1/4 x 3 (6.35 x 76.2)

[a] For SI units 1 inch = 25.4 mm.

9.1.4 Individual connector/conductor samples are to be separated by at least 18 inches (457 mm) when measured center-to-center.

Exception No. 1: The spacing may be reduced with the concurrence of those concerned.

Exception No. 2: The spacing may be reduced to a minimum of 6 inches (152 mm) if a thermal barrier is used between assemblies. The thermal barrier is to extend at least 6 inches in a vertical direction and 1 inch (25.4 mm) in a horizontal direction beyond the extremities of the connector.

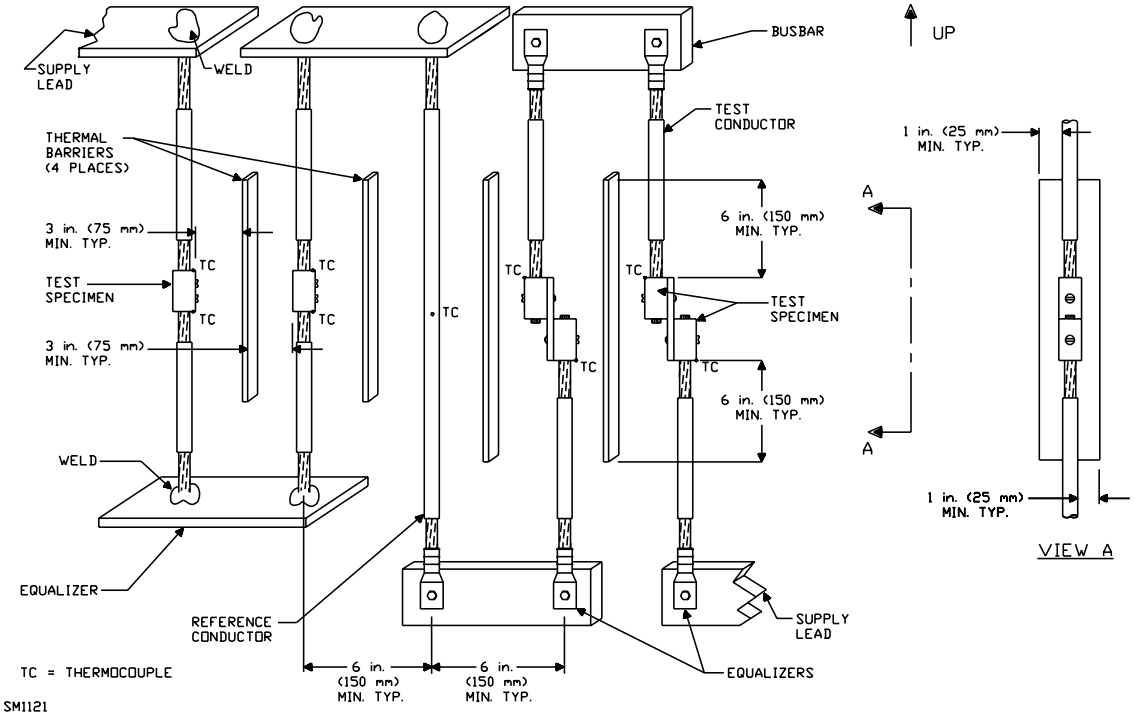
9.1.5 The temperature measurement location for the connector samples is to be located a minimum of 24 inches (610 mm) from the building floor, ceiling, and walls.

Exception: The spacing need not be maintained if a solid insulating backboard separates the test samples from the building floor, ceiling, or walls. The samples are to be spaced at least 4 inches (102 mm) from the insulating backboard.

9.1.6 Test assemblies are to 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 bus bars supported in turn by nonmetallic blocks. The method used is to be such that test connections are not disturbed during handling of the samples and to reduce the transmission of tensile loads to the test connectors through test or supply conductors. See Figure 9.1 for an example of a vertical arrangement.

9.1.7 Test assemblies are to be located in a substantially vibration and draft-free location where the average ambient air temperature can be maintained in the range of 15 – 35°C (59 – 95°F). The ambient temperature is to be kept within ±4.0°C (±7.2°F) at all times during the test unless a greater variation in temperature is agreeable to those concerned.

Figure 9.1
Vertical arrangement of sample for heat-cycling test



9.2 Parts for securement

9.2.1 The following hardware is to be used to make the connections specified in 9.1.1. Once the initial assembly is completed, there is to be no subsequent retightening.

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

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

c) A nut is to be plated steel, have Class 2B UNC threads, and a hexagonal configuration.

d) Clean, dry, nonlubricated screws, bolts, and nuts are to be used. The assembled hardware is to be torqued to the values in Table 9.2.

Exception No. 1: When the manufacturer's installation instructions – see 20.15 – specify that a dished washer is to be used, the hardware is to be as follows:

a) One plated or stainless steel dished washer per securing bolt is to be used;

b) Bolts or nuts are to be tightened until the crown of the washer is no longer discernible;

c) A flat washer as specified in 9.2.1(b) is to be used on the side of the tang-to-tang or tang-to-bus connection opposite the dished washer; and

d) The design of the dished washer is to be such that the force required to flatten the washer is as specified for the corresponding bolt size in Table 9.3.

Exception No. 2: Tests on a connector may be conducted using:

a) Hardware other than mentioned;

b) Dished or other washers having different characteristics; or

c) Part securement torque values if the manufacturer's installation instructions – see 20.15 – specify all necessary hardware.

9.2.1 revised June 25, 1998

Table 9.2
Torque value

Table 9.2 revised June 25, 1998

Screw or bolt, size	Tightening torque	
	Pound-feet	(N·m)
No. 8	1.5	(2)
No. 10	2.0	(3)
1/4 inch or less	6	(8)
5/16 inch	11	(15)
3/8 inch	19	(26)
7/16 inch	30	(41)
1/2 inch	40	(54)
9/16, 5/8 inch, or larger	55	(75)

Table 9.3
Bolt diameter

Table 9.3 revised June 25, 1998

Bolt diameter, inch (mm)	Minimum force, pounds (N)	
1/4 (6.35)	800	(3560)
5/16 (7.94)	1000	(4450)
3/8 (9.53)	1400	(6230)
7/16, 1/2 (11.11, 12.7)	2700	(12015)
9/16, 5/8 or larger (14.29, 15.88)	3400	(15130)

10 Secureness

10.1 The joint between a connector and the conductor of a sample set shall be intact after being subjected to the test described in 10.3 – 10.6 for 30 minutes. For the secureness tests on a connector intended for paralleling conductors, the tests are to be conducted on only one conductor entry hole if all conductor entry holes are identical in construction.

Exception: A secureness test on sizes Nos. 30 – 20 AWG (0.05 – 0.52 mm^2) is not required.

10.2 Samples are to be selected as prescribed in Sections 6 and 7.

10.3 A terminal connector is to be fastened to a conductor that is at least 3 inches (76.2 mm) longer than the height specified in Table 10.1, and is to be rigidly secured in a vertical position simulating actual service conditions. The free end of the conductor is to be passed through a bushing of the size specified in Table 10.1. The bushing is to 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 10.1. The circle is to have a diameter of 3 inches, and its center is to 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 is to be within 1/2 inch (12.7 mm) of the distance specified in the column titled Height in Table 10.1. The bushing is to be lubricated so that there is no binding, twisting, or rotation of the insulated conductor. A weight as specified in Table 10.1 is to be suspended from the free end of the conductor.

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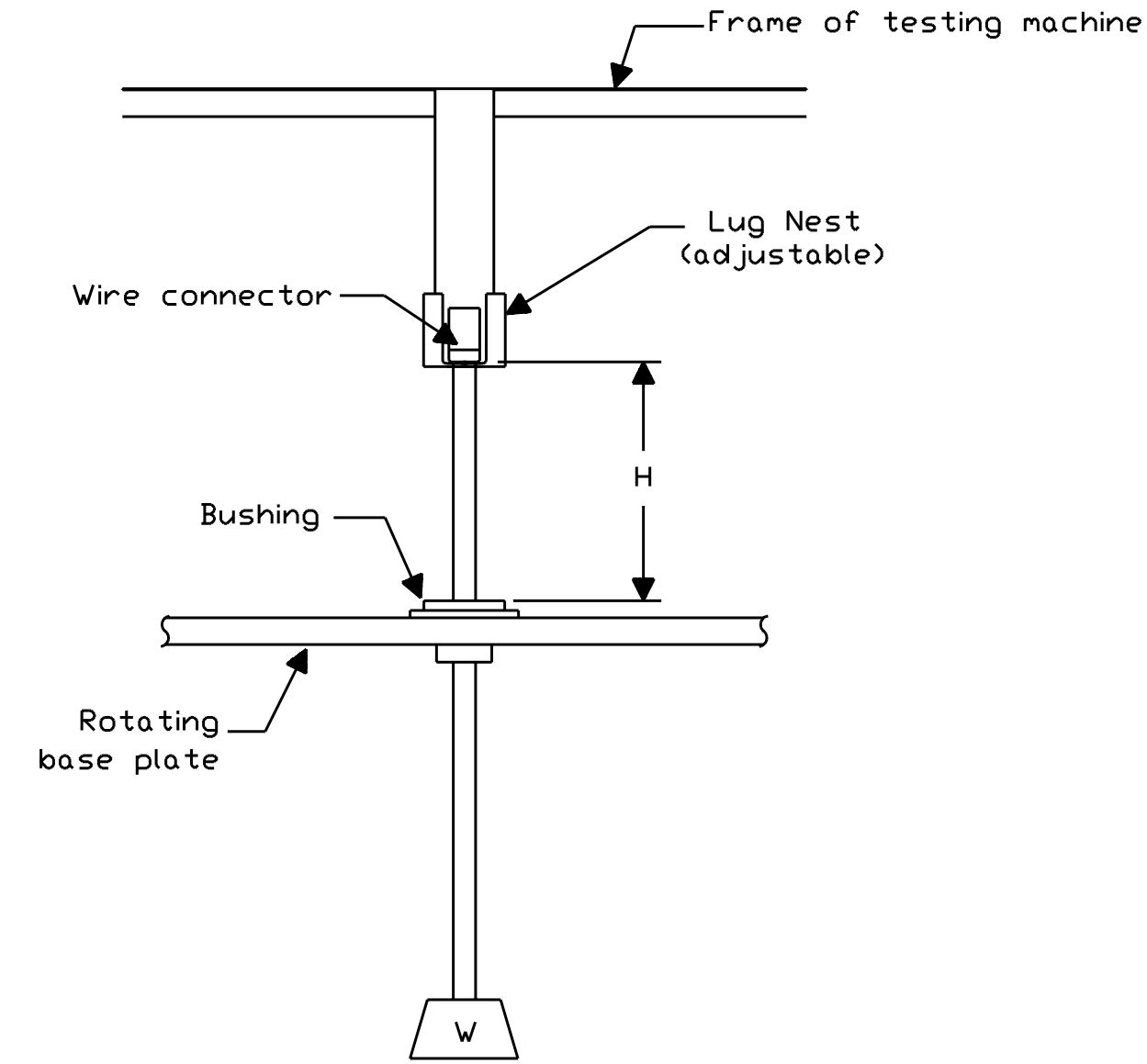
Table 10.1
Test values

Size of conductor		Diameter of bushing hole		Height		Weight	
AWG or kcmil	(mm^2)	Inches[a]	(mm)	Inches	(mm)	Pounds	(kg)
18 – 16	(0.82 – 1.3)	1/4	(6.4)	10-1/4	(260)	2	(0.9)
14	(2.1)	3/8	(9.5)	11	(279)	3	(1.4)
12 – 10	(3.3 – 5.3)	3/8	(9.5)	11	(279)	5	(2.3)
8	(8.4)	3/8	(9.5)	11	(279)	8	(3.6)
6	(13.3)	1/2	(12.7)	11-3/4	(298)	18	(8.2)
4	(21.2)	1/2	(12.7)	11-3/4	(298)	30	(13.6)
3 – 2	(26.7 – 33.6)	9/16	(14.3)	12-1/2	(318)	30	(13.6)
1 – 1/0	(42.4 – 53.5)	5/8	(15.9)	13-1/2	(343)	50	(22.7)
2/0	(67.4)	3/4	(19.1)	14-1/2	(368)	50	(22.7)
3/0 – 4/0	(85.0 – 107.2)	3/4	(19.1)	14-1/2	(368)	60	(27.2)
250	(127)	7/8	(22.2)	16	(406)	60	(27.2)
300	(152)	7/8	(22.2)	16	(406)	80	(36.3)
350 – 400	(177 – 203)	1	(25.4)	17	(432)	80	(36.3)
500 – 600	(253 – 304)	1-1/8	(28.6)	18-1/4	(464)	100	(45.4)
700	(354)	1-1/4	(31.8)	19-1/2	(495)	100	(45.4)
750	(380)	1-1/4	(31.8)	19-1/2	(495)	110	(50.0)
800 – 900	(406 – 456)	1-3/8	(34.9)	21-1/4	(540)	110	(50.0)
1000	(508)	1-1/2	(38.1)	22-1/2	(572)	110	(50.0)
1250	(635)	1-3/4	(44.5)	26	(660)	155	(70.3)
1500	(759)	2	(50.8)	28	(711)	180	(81.7)
1750	(886)	2-1/8	(54.0)	30	(762)	205	(93.0)
2000	(1016)	2-1/8	(54.0)	30	(762)	240	(108.9)

[a] If a hole with the diameter given is not adequate to accommodate the conductor without binding, a bushing having a hole of slightly larger diameter may be used.

Figure 10.1
Secureness test setup

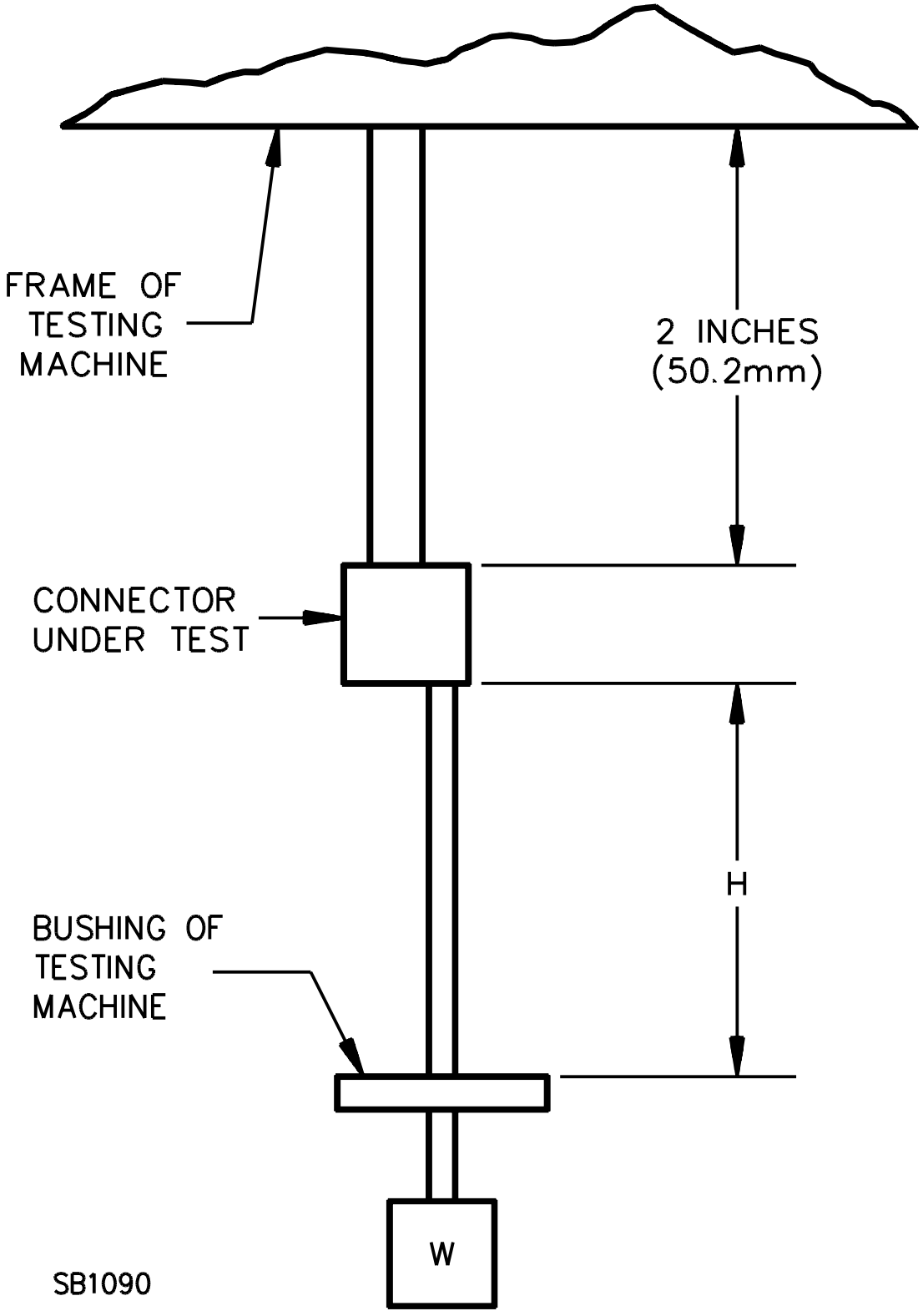


10.4 If a wire connector is intended to secure more than one conductor at a time by a single clamping means, only one conductor in each combination is to be tested for secureness. If the conductors in the combination are of different sizes, separate sample sets are to be used for testing each size of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

10.5 For the test of a splicing connector in which the conductors lie parallel to or in line with each other, the set-up is to be as illustrated in Figure 10.2. If the connector is secured to conductors of different sizes, the weight is to be attached to the smallest conductor and the entire assembly of connector, conductors, and weight is to be suspended by means of the largest conductor. The values of the weight W and the height of H are to be selected from Table 10.1 according to the size of the conductor to which the weight is attached. Terminal connectors or other means that will distribute the stress uniformly among the strands of the conductor are to be employed for attaching the weight and for securing the assembly to the frame of the testing machine. The testing machine is to be operated as described in 10.3.

10.6 A splicing connector in which the conductors do not lie parallel to or in line with each other is to 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 is to be supported by a U-shaped yoke, the arms of which grasp the through conductor on each side of the connector approximately 2 inches (50.8 mm) from the ends of the connector. The depth of the yoke is to be approximately 3 inches (76.2 mm). The yoke is to be secured firmly to the frame of the testing machine so that the tap conductor hangs vertically. The weight, which is to be suspended from the free end of the tap conductor after it has passed through the bushing of the testing machine, is to be as specified in Table 10.1 according to the size of the tap conductor. The tap conductor is to be at least 3 inches longer than the height specified in Table 10.1, corresponding to the size of the tap conductor. The testing machine is to be operated as described in 10.3.

Figure 10.2
Splicing-connector test arrangement



11 Static-Heating Test

11.1 The sample sets previously subjected to the secureness test shall be subjected to a static-heating test.

11.2 The test assembly and securing hardware are to be as described in Sample Test Assembly, Section 9.

11.3 The sample sets are to continuously carry the value of test current specified in Table 11.1 or 11.2 for the conductor size tested until stable temperatures are reached – see 8.7. The temperature shall not rise more than 50°C (90°F) above ambient temperature.

Exception: The temperature rise on an ampere-rated connector may exceed 50°C if when the connector is used in the intended equipment application, the temperature rise on the connector does not exceed the maximum temperature rise permitted in the end-use application or the temperature rating of the connector.

Table 11.1
Test current for connectors intended for a single conductor, amperes

Conductor size		Assigned maximum ampere rating[a]	Static-heating test current[b,c]
AWG or kcmil	(mm^2)		
30	(0.05)	–	3
28	(0.08)	–	3.5
26	(0.13)	–	3.5
24	(0.20)	–	7
22	(0.324)	–	9
20	(0.519)	–	12
18	(0.823)	–	17
16	(1.31)	–	18
14	(2.08)	15	[20]30
12	(3.31)	20	[25]35
10	(5.261)	30	[40]50
8	(8.367)	50	70
6	(13.30)	65	95
4	(21.15)	85	125
3	(26.67)	100	145
2	(33.62)	115	170
1	(42.41)	130	195
1/0	(53.49)	150	230
2/0	(67.43)	175	265
3/0	(85.01)	200	310
4/0	(107.2)	230	360
250	(127)	255	405
300	(152)	285	445
350	(177)	310	505
400	(203)	335	545
500	(253)	380	620
600	(304)	420	690
700	(355)	460	755
750	(380)	475	785
800	(405)	490	815
900	(456)	520	870
1000	(507)	545	935
1250	(633)	590	1065
1500	(760)	625	1175
1750	(887)	650	1280
2000	(1016)	665	1385

Note – See 6.2.1 and 11.1.

[a] Values are ampacities for 75°C (167°F), not more than 3 conductors in raceway or cable, National Electrical Code, ANSI/NFPA No. 70-1996 for sizes No. 14 AWG – 2000 kcmil, except that for Nos. 14 – 10 AWG the values are load-current ratings.

[b] Values are ampacities for 75°C single conductor in free air, National Electrical Code, ANSI/NFPA No. 70-1996 for size No. 14 AWG – 2000 kcmil.

[c] Values in brackets are applicable to connectors with assigned ampere ratings.

Table 11.2
Test currents for connectors intended for paralleling of copper conductors, amperes

Conductor size		Number of conductors		
AWG or kcmil	(mm^2)	2	3	4
1/0	(53.49)	300	450	480
2/0	(67.43)	350	525	560
3/0	(85.01)	400	600	640
4/0	(107.2)	460	690	736
250	(127)	527	790	1053
300	(152)	579	868	1158
350	(177)	657	985	1314
400	(203)	709	1063	1418
500	(253)	806	1209	1612
600	(304)	1035	1554	2070
700	(355)	1133	1699	2266
750	(380)	1178	1767	2356
800	(405)	1223	1834	2446
900	(456)	1305	1958	2610
1000	(507)	1403	2104	2806
1250	(633)	1598	2397	3196
1500	(760)	1763	2644	3526
1750	(887)	1920	2880	3840
2000	(1016)	2078	3117	4156

NOTES

1 The current for conductor sizes 1/0 – 4/0 AWG are based on the National Electrical Code (NEC), NFPA 70-1996, Table 310-16, 75°C column, multiplied by the number of conductors and de-rated by 80 percent.

2 The current for conductor sizes 250 kcmil and larger are in accordance with the NEC, NFPA 70-1996, Sections 318 -11(b)(1) and 318-11(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 – de-rated by 65 percent

600 kcmil 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 70-1996, Table 310-16, note 8.

12 Pullout Test

12.1 The connectors subjected to the static-heating test or secureness test shall be subjected to a direct pull of the value specified in Table 12.1 for 1 minute. For a connector intended to secure more than one conductor at a time by a single clamping means, only those wires that have been subjected to the secureness test in accordance with 10.4 are to be subjected to the pullout test. In accordance with the Exception to 5.1 and 10.1, Nos. 30 – 20 AWG (0.05 – 0.52 mm^2) conductors need not be subjected to the secureness test prior to the pullout test. The connector is acceptable if it does not become separated from the conductor or conductors after completion of the test.

12.2 For an insulated connector in which the insulation is assembled to the connector during installation, the test is to be conducted with the insulation in place if it is always supplied with the connector by the manufacturer. Otherwise the test is to be conducted without the insulation assembled to the connector. Breakage or tearing of the insulation of an insulated connector is acceptable in the pullout test. The pull is to be exerted by means of a tension-testing machine or the equivalent, so that there will be no sudden application of force or jerking during the test. See Secureness, Section 10.

Table 12.1
Test values for pullout test

Size of conductor		Pullout force	
AWG or kcmil	(mm^2)	Pounds	(N)
30	(0.05)	1-1/2	(6.7)
28	(0.08)	2	(8.9)
26	(0.13)	3	(13.4)
24	(0.20)	5	(22.3)
22	(0.324)	8	(35.6)
20	(0.519)	13	(57.9)
18	(0.823)	20	(89.0)
16	(1.31)	30	(133.5)
14	(2.08)	50	(222.5)
12	(3.31)	70	(311.5)
10	(5.261)	80	(356.0)
8	(8.367)	90	(400.5)
6	(13.30)	100	(445.0)
4	(21.15)	140	(623.0)
3	(26.67)	160	(712.0)
2	(33.62)	180	(801.0)
1	(42.41)	200	(890.0)
1/0	(53.49)	250	(1112.5)
2/0	(67.43)	300	(1235.0)
3/0	(85.01)	350	(1557.5)
4/0	(107.2)	450	(2202.5)
250	(127)	500	(2225.0)
300	(156)	550	(2447.5)
350	(177)	600	(2670.0)
400	(203)	650	(2892.5)
500	(253)	800	(3560.0)
600	(304)	900	(4005.0)
700 – 2000	(355) – (1016)	1000	(4450.0)

13 Dielectric Voltage-Withstand Test

13.1 General

13.1.1 No sample is to be subjected to more than one dielectric voltage-withstand test.

Exception: If agreeable to those concerned, samples may be subjected to more than one test. Samples tested in Test A, Insulation Puncture, may be used for Test B, Flashover.

13.1.2 For a connector intended to secure combinations of conductors of different total cross-sectional area, or single conductors of different AWG sizes, the entire specified series of tests is to be repeated. For one series, samples of the connector are to be secured to the combination of conductors of the smallest cross-sectional area, or the smallest conductor, if only one conductor is intended to be secured; and for the second series, the samples are to be secured to the combination of largest total cross-sectional area, or the largest conductor, if only one conductor is intended to be secured.

13.1.3 A connector is unacceptable if any sample performs unacceptably in any specified test.

13.1.4 An insulated wire connector shall withstand the dielectric voltage-withstand tests indicated in Table 13.1.

Table 13.1
Dielectric voltage-withstand test sequence

Connector construction		Required tests[a]
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:	
	i) No. 10 AWG (5.3 mm^2) or smaller conductors	A, C
	ii) Nos. 8 – 4/0 AWG (8.4 – 107.2 mm^2) conductors	A
2)	Insulated connectors not covered in Item 1.	A, B

[a] A – Test A is described in 13.2 and Tables 13.2 and 13.3.
B – Test B is described in 13.3 and Table 13.4.
C – Test C is described in 13.4.

13.2 Test A, insulation puncture

13.2.1 The tests to be conducted and the number of samples for each test are to be as specified in Table 13.2. The test potential is to be 2200 volts for a connector rated 300 volts and is to be 3400 volts for a connector rated 600 volts – 1000 volts for signs and lighting fixtures (luminaires). Each sample is to be connected to a conductor or conductors in the intended manner, and the test potential is to be applied for 1 minute between the conductor or conductors and an outer electrode. Each sample is to be embedded in No. 7-1/2 conductive shot that is to serve as the outer electrode; except that for a connector employing a separable cap that is applied after assembly of the connector to the conductor and has openings that cannot be effectively closed to prevent entry of the shot, metal foil, closely applied to the outer surface of the insulation, may be used as the outer electrode. Only that portion of the outer insulating surface that covers live parts is to be covered with the outer electrode. A connector that has openings that would allow the entrance of shot, there by possibly resulting in flashover, is to have those openings closed with tape, petrolatum, epoxy, silicone, rubber, or other acceptable material; and the exposed tang of a terminal connector is to be similarly treated. The supplementary insulating material is not to be applied so as to supplement the connector insulation where it covers live parts. Puncture of the conductor insulation during this test is not acceptable. If flashover between the electrode and a normally insulated live part occurs, the supplementary insulation is to be repaired and the test is to be repeated.

Exception: A smaller than No. 7-1/2 (higher size number) shot may be used with concurrence of those concerned.

13.2.1 revised May 22, 2000

13.2.2 With reference to note b to Table 13.2, samples previously assembled to conductors are to be conditioned in an air-circulating oven, according to Table 13.3.

13.2.3 With reference to note c to Table 13.2, the samples not previously assembled to conductors are to be conditioned for 168 hours in an air-circulating oven at 100°C (212°F). Connectors employing extended covers or sleeves may have the wires pre-inserted, but not crimped, prior to the oven aging. The samples are then to be allowed to cool to room temperature. Nylon samples are then to be conditioned for 24 hours at a relative humidity of 85 ±5 percent at 30 ±2°C (86 ±4°F). The samples are then to be assembled (or crimped) to conductors in the intended manner.

Table 13.2
Required tests and samples

Insulating material	Number of samples[a]
Thermosetting – for example; porcelain, cold-molded melamine, phenolic, or urea compound:	
Test as received only	6
Thermoplastic– for example; vinyl or nylon:	
Test as received	6
Test after oven conditioning, with samples assembled to conductors before such conditioning[b]	6
Test after oven conditioning, with samples assembled to conductors after such conditioning[c]	6

[a] See 13.1.2.
[b] See 13.2.2 and Table 13.3.
[c] See 13.2.3.

13.3 Test B, flashover

13.3.1 Six samples are to be tested in the as received condition. See 13.1.2. Each sample is to be wired as intended. The 1-minute value of test potential specified in Table 13.4 is to be applied for that interval, and the potential is then to be rapidly and steadily increased to some value higher than the maximum value specified in Table 13.4 – but breakdown at a value higher than the specified maximum is not unacceptable – and is to be immediately removed. The potential is to be applied between a conductor secured by the connector and an outer electrode. A connector having insulation in the form of a cap is to be embedded in No. 7-1/2 conductive shot that is to serve as the outer electrode. Any other connector is to have the surface immediately adjacent to the conductor opening covered with metal foil to serve as the outer electrode. To reduce the likelihood of flashover to the exposed tang of a terminal connector or the likelihood of insulation puncture, the outer surface of the connector insulation and the exposed tang may be supplemented with tape, petrolatum, epoxy, silicone, rubber, or other acceptable insulating material so that it does not interfere with the position of the outer electrode immediately adjacent to the conductor opening. If flashover from the outer electrode to a normally insulated live part of the connector or insulation puncture occurs, the test is to be repeated. Flashover between the conductor and the outer electrode is not acceptable.

Exception No. 1: At the manufacturer's option, after being held at the required test potential for 1 minute, the potential may be reduced to 0 volts and then rapidly and steadily increased to the higher potential.

Exception No. 2: A smaller than No. 7-1/2 (higher size number) shot may be used with concurrence of those concerned.

13.3.1 revised May 22, 2000

Table 13.3
Oven-conditioning specifications

Rated temperature of connector		Oven temperature			
		168 hour test		Optional 1440 hour test	
°C	°F	°C	°F	°C	°F
75	167	113	235	81	178
90	194	121	250	97	207
105	221	136	277	113	235
125	257	158	316	133	271
150	302	180	356	158	316

Table 13.4
Test voltage

Connector rating, volts	Test potential, volts	
	1-Minute	Maximum
300	2200	4000
600 (1000 in signs and fixtures)	3400	8000

No Text on This Page

13.4 Test C, flashover

13.4.1 Six samples are to be tested in the as received condition. See 13.1.2. The test potential is to be 1600 volts for a connector rated 300 volts, 3000 volts for a connector rated 600 volts – 1000 volts in signs and lighting fixtures (luminaires) – and is to be applied for 1 minute. Each sample, not assembled to a conductor or conductors, is to be placed on a flat metal plate in a position most likely to result in breakdown to the open end when the test potential is applied between the metal plate and all insulated metal parts of the connector. A breakdown – flashover – is not acceptable.

14 Secureness-of-Insulation Test

14.1 For other than a connector as described in 14.2, the insulation of a connector shall not be damaged and shall not become detached from the body of the connector when a pull of 20 pounds (89.0 N) for a connector employing a No. 30 – 18 AWG (0.05 – 0.84 mm^2) conductor, or 30 pounds (133.5 N) for any other connector, is applied for 1 minute between the insulation and the connector.

14.2 Connector insulation in the form of a tubular sleeve and intended for use with No. 10 AWG (5.3 mm^2) or smaller conductors shall not be damaged and shall not become detached from the body of the connector when a pull is applied for 1 minute between the insulation and the connector as described in 14.3.

14.3 The test is to consist of applying:

a) A 1-pound (4.5 N) pull on an unassembled as-received sample and on an unassembled sample after oven conditioning according to Table 13.3; and

b) A 5-pound (22.3 N) pull on an assembled as-received sample, on a sample that has been assembled to a conductor before oven conditioning according to Table 13.3, and on a sample that has been assembled to the conductor after oven conditioning at 100°C (212°F) according to 13.2.3.

For connectors that are assembled to conductors as specified in (b), only the maximum and minimum size conductors for which the connector is rated are to be used.

14.4 With reference to the requirements in 14.1 and 14.2, a temporary distortion of flexible insulating material during the test is considered acceptable. Tearing or breaking of the insulation is acceptable if the results of a repeated dielectric voltage-withstand test are acceptable. The variety of designs of connectors is such that it is not practicable to specify in detail how the pull is to be applied; the arrangement is to be such that the tendency for the insulation to be damaged or to be separated from the body is greatest.

14.5 A connector having flexible insulation that is assembled to the body of the connector after the latter is assembled to a conductor or conductors is not to be subjected to the test required by 14.1 until after the insulation has regained its normal shape after being assembled to the connector.

15 Drop Test

15.1 A latch or a lock employed on the cover of an insulated splicing connector intended for use with a No. 2 AWG (33.6 mm^2) or larger conductor shall not open or break when the connector is subjected to the drop test described in 15.2.

15.2 The drop test is to consist of dropping the insulation covers and connectors onto a maple board from a height of 3 feet (914 mm). Six samples are to be assembled with the combination of conductors of the smallest total cross-sectional area for which the connector is intended, and six samples are to be assembled with the combination of conductors of the largest total cross-sectional area. The connectors are to be assembled so that 3 inches (76.2 mm) of the conductor extends from the ends of the insulating cover. The test is to be conducted on insulating covers that have been oven-conditioned according to Table 13.3, on as-received samples, and on samples that have been subjected to minus 10°C (14°F) for 2 hours. The assemblies that have been subjected to minus 10°C (14°F) for 2 hours are to be subjected to the drop test as soon as possible after removal from the cold box. Each assembly is to be dropped four times so that an impact occurs at the top, bottom, sides, and edges, except that the samples subjected to minus 10°C (14°F) are to 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 samples. Cracks are acceptable if the assemblies comply with the requirement in Dielectric Voltage-Withstand After Drop Test, Section 16.

15.2 revised May 22, 2000

16 Dielectric Voltage-Withstand After Drop Test

16.1 An insulating splicing connector that has been subjected to the drop test described in 15.1 and 15.2 shall comply with the requirements described in Dielectric Voltage-Withstand Test, Section 13. Breakdown through a crack is considered equivalent to insulation puncture.

17 Flexing Test

17.1 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 described in 17.2.

17.2 The flexing test is to be conducted on insulating covers in the as received condition, after oven conditioning according to Table 13.3, and after conditioning at minus 10°C (14°F) for 2 hours. The samples conditioned at minus 10°C (14°F) are to be allowed to attain room temperature after removal from the cold box before the flexing test is conducted. Six samples are to be tested for each condition. The samples are to be prepared as described in 15.2 except that only a conductor of the maximum cross-sectional area is to be used. The insulating cover is to be completely opened and closed 20 times. If flexible extensions are provided around the conductors, the conductors are also to be flexed 20 times. Distortion of the flexible extensions is acceptable if, after 24 hours, they return to their original shape and position.

18 10-Day Moist Ammonia-Air Stress Cracking Test

18.1 After being subjected to the conditions described in 18.2 – 18.4, a brass part containing more than 15 percent zinc shall not show evidence of cracking when examined using 25X magnification.

18.2 Each test sample is to be subjected to the physical stresses normally imposed on or within a part as the result of assembly. Such stresses are to be applied to the sample prior to and maintained during the test. Samples shall be assembled to a 6-inch (152-mm) length of the maximum rated size conductor and torqued to the value specified in 7.4.4.

18.3 Three samples are to be degreased and then continuously exposed in a set position for ten days to a moist ammonia-air mixture maintained in a glass chamber approximately 12 by 12 by 12 inches (305 by 305 by 305 mm) having a glass cover.

18.4 Approximately 600 ml of aqueous ammonia having a specific gravity of 0.94 is to be maintained at the bottom of the glass chamber below the samples. The samples are to be positioned 1-1/2 inches (38.1 mm) above the aqueous ammonia solution and supported by an inert tray. The moist ammonia-air mixture in the chamber is to be maintained at atmospheric pressure and a temperature of 34 ±2°C (93 ±4°F).

19 Moisture Absorption Test

19.1 Porcelain or cold-molded composition used as insulation on connectors shall not absorb more than 3 percent of its weight when tested as described in 19.2.

19.2 Samples used for the Moisture Absorption Test are to be clean and dry. The insulation on the connector is to be broken, weighed, and then submerged in distilled water at room temperature for 24 hours. After removal from the water the broken insulation is to be dried with a soft cloth to remove all surface water and immediately reweighed.

MARKING

20 Details

20.1 For the purpose of the marking requirements, containers, are defined as follows:

a) Unit Container – The smallest container in which connectors are packaged.

b) Packaging Container – The container in which the unit containers are packaged.

20.2 A connector shall be plainly marked with the:

a) Manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified – hereinafter referred to as the manufacturer's name;

b) A distinctive catalog number or the equivalent; and

c) The conductor size or ranges of sizes.

Exception: In lieu of the markings in (b) or (c), or both, a connector that is for use only with conductors smaller than No. 8 AWG (8.4 mm^2) may be marked with a single identifying symbol. This symbol may consist of 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 (a), (b), and (c).

20.3 A type designation is intended primarily to identify a particular design, which may include various features covered by different catalog numbers.

20.4 A connector, a unit container, or an information sheet packed in the unit container shall be plainly marked with ″CU.″

20.5 A connector, a unit container, or an information sheet packed in the unit container for a connector tested with conductors other than Class B or Class C stranding – see 7.2.2 – shall also be marked with the conductor class or classes and the number of strands.

20.6 A connector tested with a solid or stranded conductor other than as specified in 6.1.7 shall be marked ″Solid″ or ″Stranded″ or with both markings as appropriate. See 20.7.

20.7 The ″Solid″ and ″Stranded″ markings mentioned in the requirement in 20.6:

a) May be abbreviated ″Sol.″ and ″Str.″ respectively, to fit in a restricted area on the connector; or

b) May be printed on the unit container or on an information sheet packed in the unit container, only if there is not adequate space on the connector for either the complete or the abbreviated marking.

20.8 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 the connector.

20.9 Connectors additionally rated for No. 2 AWG (33.6 mm^2) and larger compact-stranded copper conductors shall have the connector, the unit container, or an information sheet packed in the unit container marked ″For compact-stranded copper conductors ″ or the equivalent.

20.9 revised May 22, 2000

20.10 A required conductor-size marking, on a connector intended for assembly to a conductor or conductors by means of a specific tool, may consist of a single symbol if the significance of the symbol, in terms of a conductor size or sizes, is clearly marked on the tool.

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

a) USE OF A SPECIFIC TOOL REQUIRED– If a connector is intended to be assembled to a conductor or conductors 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, on the unit container in which the connector is packed, or on an information sheet packed within the unit container. 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 REQUIRED– 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 (b)(1), (b)(2), or (b)(3).

c) CONDUCTOR STRIP LENGTH – Strip length marking as specified in Table 20.1 shall appear:

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

2) On the connector;

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 in which the connector is packed, on an information sheet packed in the unit container, or on the carrying case provided for permanent storage of the tool. See 7.3.1.

Table 20.1
Required wire strip length marking

Connector type	Maximum strip length[a]	Minimum strip length[a]
Insulated	X[b,c]	X[b,c,d]
Noninsulated	–	X[b,c,d]

[a] An X indicates marking is required.
[b] Strip length may be specified as a single – nominal – value if tested as specified in 7.3.2.
[c] Strip length marking 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.
[d] Strip length marking is 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.

20.12 A specific tool and a removable part of such a tool, such as a pressing die, shall be permanently marked with an identification that can be used for the selection and the proper use of the tool. See 20.11.

20.13 An insulated connector shall be marked with the applicable voltage rating for which it has been found acceptable. The marked voltage rating shall be: ″300 volts maximum,″ ″600 volts maximum,″ or ″600 volts maximum, building wiring: 1000 volts maximum, signs and lighting fixtures (luminaires),″or equivalent wording. The word ″luminaires″ is optional.

Exception: The marking may be on the unit container or on an information sheet packed in the unit container.

Revised 20.13 effective August 25, 1997

20.14 An insulated connector shall be marked with the maximum operating temperature limit of 75°C (167°F) or 90°C (194°F).

Exception No. 1: The marking may be on the unit container or on an information sheet packed in the unit container.

Exception No. 2: 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 (°F)." See Table 20.2.

20.15 Installation instructions specifying the proper assembly procedures for securing hardware shall be provided for connectors tested according to 7.1.6 and the Exceptions to 9.2.1. The marking shall be on the unit container in which the connector is packaged or on an information sheet packed in the unit container.

Table 20.2
Acceptable temperature of insulation

Material	Temperature	
	°C	°F
Thermoplastic[a]	75	167
	90	194
	105	221
	150	302
Phenolic[b]	150	302
Urea[c]	100	212
Melamine[d]	130	266
Melamine[e]	150	302

[a] To be assigned by the manufacturer.
[b] Composition may be filled or unfilled.
[c] Unless the compound has been found by test to be acceptable for used 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.

20.16 A blank tang connector (no mounting hole) shall be provided with installation instructions specifying the minimum mounting hole size or range and the mounting hole location or, the connector tang is to be welded. 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.

20.17 If the manufacturer assigns a value of tightening torque as described in the Exception to 7.4.4, the assigned value shall be marked where readily visible on the connector.

Exception: The marking may be on the unit container or on an information sheet packed in the unit container.

20.18 A connector with an assigned ampere rating shall be marked with the assigned ampere rating; for example, ″100 A.″

Exception: For a connector intended for conductor sizes No. 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.

20.19 Ampere-rated connectors shall be marked according to 20.2. See 20.18.

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

a) Manufacturer's name; and

b) A distinctive catalog number of the connector or the equivalent if the marking is provided as specified in 20.22.

20.21 A cover of an insulated splicing connector shall be marked with the:

a) Manufacturer's name;

b) A distinctive catalog number or the equivalent;

c) The voltage rating – see 20.13; and

d) The operating-temperature limit – see 20.14.

Exception: The voltage rating in (c), and operating temperature limit in (d), may be marked on the unit container if such container is also marked as specified in (a) and (b).

20.22 The information in a marking shall not be divided between a unit container and an information sheet. If any of the required markings specified in 20.7(b); 20.11; and the exceptions to 20.13, 20.14, 20.17 and 20.18, are placed on the unit container or on the information sheet packed in the unit container rather than on the connector, then all such markings as specified in the paragraph in their entirety shall be so placed.

Exception: 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 20.23.

20.23 With respect to 20.22, the information sheet shall be marked with the manufacturer's name, an identifying number, the catalog number of the connector to which it pertains or equivalent, and with all the necessary information required by 20.7(b), 20.11, 20.13, 20.14, and 20.26. The information sheet – one for each unit container – shall be packed in the packaging container.

20.23 revised May 23, 2001

20.24 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.

20.24 added May 22, 2000

20.25 A connector rated for use with 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.

20.25 added May 22, 2000

20.26 In addition to the required markings, the manufacturer is able to mark the flammability classification of the insulating material on the connector, smallest unit container, or on an information sheet placed in the smallest unit container. See 4.8.1.

20.26 added May 23, 2001

SOLDERING LUGS

CONSTRUCTION

21 General

21.1 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 21.1, according to the maximum size of conductor that the lug is intended to accommodate.

21.2 A lug of other than wrought copper shall be subjected to an appropriate investigation that usually will include tests for comparing its performance with that of a wrought-copper lug.

21.3 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 21.1.

22 Materials

22.1 A soldering lug shall be made of copper, brass, bronze, or other material that has been shown by investigation to be acceptable for the purpose.

MARKING

23 General

23.1 A soldering lug shall be plainly marked with the name or trademark of the manufacturer.

Table 21.1
Lug dimensions

Size of conductor		Diameter of conductor hole		Depth of conductor hole		Wall thickness		Contact area	
AWG or kcmil	(mm^2)	Inches	(mm)	Inches	(mm)	Inches	(mm)	$Inches^2$	(mm^2)
10	(5.26)	0.143	(3.6)	0.34	(8.64)	0.045	(1.14)	0.117	(75.5)
8	(8.4)	0.164	(4.1)	0.24	(6.1)	0.032	(0.81)	0.175	(113)
6	(13.3)	0.232	(5.8)	0.35	(8.9)	0.032	(0.81)	0.250	(161)
5	(16.9)	0.232	(5.8)	0.35	(8.9)	0.032	(0.81)	0.275	(178)
4	(21.2)	0.253	(6.4)	0.38	(9.6)	0.032	(0.81)	0.350	(226)
3	(26.7)	0.300	(7.6)	0.45	(11.4)	0.040	(1.02)	0.400	(258)
2	(33.6)	0.336	(8.5)	0.50	(12.7)	0.040	(1.02)	0.450	(290)
1	(42.4)	0.375	(9.5)	0.56	(14.2)	0.040	(1.02)	0.500	(323)
1/0	(53.5)	0.398	(10.1)	0.60	(15.2)	0.051	(1.30)	0.625	(403)
2/0	(67.4)	0.450	(11.4)	0.67	(17.0)	0.051	(1.30)	0.750	(484)
3/0	(85.0)	0.500	(12.7)	0.75	(19.1)	0.051	(1.30)	0.875	(565)
4/0	(107.2)	0.559	(14.2)	0.84	(21.3)	0.062	(1.57)	1.125	(726)
250	(127)	0.650	(16.5)	0.97	(24.6)	0.062	(1.57)	1.250	(806)
300	(152)	0.700	17.8)	1.05	(26.7)	0.062	(1.57)	1.375	(887)
350	(177)	0.750	(18.8)	1.11	(28.2)	0.062	(1.57)	1.500	(968)
400	(203)	0.775	(19.7)	1.16	(29.5)	0.072	(1.83)	1.625	(1048)
500	(253)	0.830	(21.1)	1.24	(31.5)	0.072	(1.83)	2.000	(1290)
600	(304)	0.920	(23.4)	1.33	(33.8)	0.090	(2.29)	2.250	(1451)
700	(354)	1.050	(26.7)	1.57	(39.9)	0.096	(2.44)	2.500	(1613)
800	(406)	1.080	(27.4)	1.62	(41.1)	0.096	(2.44)	2.750	(1774)
900	(456)	1.125	(28.6)	1.68	(42.7)	0.096	(2.44)	3.000	(1965)
1000	(508)	1.209	(30.7)	1.81	(46.0)	0.110	(2.79)	3.250	(2096)
1100	(558)	1.320	(33.5)	1.98	(50.3)	0.110	(2.79)	3.450	(2225)
1200	(609)	1.375	(34.9)	2.06	(52.3)	0.110	(2.79)	3.650	(2354)
1300	(660)	1.440	(36.6)	2.16	(54.9)	0.145	(3.68)	3.850	(2483)
1400	(708)	1.460	(37.1)	2.19	(55.6)	0.145	(3.68)	4.050	(2612)
1500	(759)	1.460	(37.1)	2.19	(55.6)	0.145	(3.68)	4.250	(2741)
1600	(812)	1.620	(41.1)	2.43	(61.7)	0.145	(3.68)	4.450	(2870)
1700	(862)	1.660	(42.2)	2.49	(63.2)	0.145	(3.68)	4.650	(2999)
1800	(912)	1.660	(42.2)	2.49	(63.2)	0.156	(3.96)	4.850	(3128)
1900	(964)	1.660	(42.2)	2.49	(63.2)	0.156	(3.96)	5.050	(3257)
2000	(1016)	1.660	(42.2)	2.49	(63.2)	0.156	(3.96)	5.250	(3386)