UL 486E

STANDARD FOR SAFETY

Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors

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UL Standard for Safety for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E

Fifth Edition, Dated September 30, 2015

Summary of Topics

This revision to ANSI/UL 486E dated April 2, 2019 includes the following changes in requirements:

Conductor Insulation Type

The revised requirements are substantially in accordance with Proposal(s) on this subject dated February 8, 2019.

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.

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September 30, 2015

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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 https://csds.ul.com.

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1 Scope

1.1 This Standard applies to equipment wiring terminals for use with all alloys of copper, aluminum, or copper-clad aluminum conductors, in accordance with the National Electrical Code, ANSI/NFPA 70, as follows:

a) equipment wiring terminals intended to hold one or more conductor(s);

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

c) ampere-rated equipment wiring terminals;

d) horsepower rated equipment wiring terminals; and

e) wire range rated equipment wiring terminals.

1.2 These requirements apply to field wired equipment wiring terminals which are an integral part of the equipment, or are intended for use in specific equipment.

1.3 This Standard is intended for equipment wiring terminals 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; and

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

b) Copper-Clad Aluminum

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

2) 12 AWG (3.3 mm^2) to 2 000 kcmil (1 010 mm^2) stranded, Class B 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 for 2 AWG (33.6 mm^2) and larger.

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

Note: For example, an equipment wiring terminal 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.

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1.4 This Standard is intended for equipment wiring terminals suitable for currents not exceeding the ampacity of insulated conductors rated 75°C or 90°C in accordance with the rating of the equipment wiring terminal, if provided.

1.5 This Standard does not apply to:

a) insulated equipment wiring terminals; and

b) 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 **NFPA* Standard**

ANSI/NFPA 70-2011,

National Electrical Code (NEC)

*National Fire Protection Association

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.

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4 Definitions

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

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

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 equipment wiring terminal(s).

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

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

4.8 rated current (ampere rating) – current assigned to the equipment wiring terminal by the manufacturer.

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

4.10 temperature rise – denotes the difference of the temperature of the equipment wiring terminal, measured under load, and the ambient temperature.

4.11 unit container – the smallest container in which equipment wiring terminals are packaged.

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

5.6 CC – Copper-Clad Aluminum

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5.7 Cu – Copper

5.8 d – Days

5.9 f – Flexible

5.10 h – Hours

5.11 $HgNO_3$ – Mercurous nitrate

5.12 Hz – Hertz, cycles per second

5.13 in – Inch, Inches

5.14 kcmil – Thousand circular mil

5.15 m – Meter

5.16 mil – Thousandth of an inch

5.17 min – Minutes

5.18 ml – Milliliter

5.19 mm – Millimeter

5.20 mm^2 – Square millimeter

5.21 N – Newton - kilogram meter/sec^2

5.22 NH_4 – Ammonia

5.23 r – Rigid solid and rigid stranded

5.24 rpm – Revolutions per minute

5.25 s – Seconds

5.26 SAE – Society of Automotive Engineers

5.27 sol – Solid

5.28 str – Stranded

5.29 V – Volts

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6 Construction Requirements

6.1 General

6.1.1 The design and construction of an equipment wiring terminal intended for use with stranded conductors shall be such that all strands of the conductor shall be contained within the equipment wiring terminal.

6.1.2 An equipment wiring terminal 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 An equipment wiring terminal 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 equipment wiring terminal barrel (crimping) using a special tool;

d) a spring pressure terminal; and

e) an element for insulation-piercing or displacement.

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

6.1.5 There shall be no sharp edges or corners on the outer surface of an equipment wiring terminal that result in damage to insulation that the equipment wiring terminal contacts.

6.1.6 The construction of an equipment wiring terminal 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 equipment wiring terminal is investigated and found to meet the performance requirements of this Standard and is marked in accordance with 10.20.

6.1.7 If the method of mounting an equipment wiring terminal is such that the mounting means cannot be retightened after wires are installed, or after the equipment wiring terminal is mounted in equipment, the mounting means – by inherent features or manufacturer's specifications – shall limit rotation of the terminal around its mounting means to 30 degrees or less.

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6.2 Materials

6.2.1 The main current-carrying part of an equipment wiring terminal 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 The main current-carrying part of an equipment wiring terminal may be of plated steel or unplated steel of a corrosion resistant alloy if the equipment wiring terminal complies with the requirements for the end product.

6.2.3 An equipment wiring terminal intended for use with aluminum conductor(s) or an equipment wiring terminal 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) the wire-securing (barrel) portion of an equipment wiring terminal that is shipped prefilled with an oxide-inhibiting compound;

b) the top cap of a lay-in equipment wiring terminal not in contact with the wire; and

c) the stamped mounting hole in an equipment wiring terminal 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.

6.2.4 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.

6.2.5 In regards to 6.2.4, an equipment wiring terminal intended for use in an appliance or equipment that complies with the requirements for such appliance or equipment may be plated steel or unplated steel of a corrosion-resistant alloy.

7 Test Requirements

7.1 General

7.1.1 An equipment wiring terminal shall meet the test requirements when separate sets of specimens are subjected to the applicable tests for the design of the equipment wiring terminal as specified in Table 1 through Table 2 and in 7.5 through 7.6.

7.1.2 With reference to 7.1.1, an equipment wiring terminal of copper or copper alloy need not be subjected to the current-cycling sequence using copper conductor, unless the equipment wiring terminal 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.

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7.1.4 With reference to 7.1.1, for other than a tool-applied crimp type equipment wiring terminal, the current-cycling test using a copper conductor need not be performed when the equipment wiring terminal 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 B 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 3 for the one or more conductor material combinations for which the equipment wiring terminal is intended. The stress corrosion tests shall be permitted to be conducted using either copper or aluminum conductor. When an equipment wiring terminal is rated for copper-to-copper, aluminum-to-aluminum, and copper-to-aluminum (intermixed), the mechanical sequence with copper-to-aluminum conductors may be omitted.

7.1.7 For an equipment wiring terminal intended to be used with aluminum, copper-clad aluminum, and copper wire (marked ″AL-CU″ on the equipment wiring terminal or the end use equipment), sample sets with aluminum wire and copper wire are to be subjected to the test sequence in Table 1 or Table 2. For an equipment wiring terminal intended to be used with copper-clad aluminum wire and copper wire (marked ″CC-CU″ on the equipment wiring terminal or the end use equipment), sample sets with copper-clad aluminum wire and copper wire are to be subjected to the test sequence in Table 1 or Table 2. For a terminal intended to be used with copper wire only, sample sets with copper wire are to be subjected to the test sequence in Table 1 or Table 2.

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

7.1.9 An equipment wiring terminal rated for Class 5 and 6 metric conductors (flexible stranded) shall be subjected to all test sequences using flexible metric conductors.

7.1.10 For an equipment wiring terminal intended to be used with aluminum and copper conductor, specimens with aluminum conductor and copper conductor shall be subjected to the current-cycling, static-heating sequence, and mechanical sequence tests.

7.1.11 For an aluminum-bodied equipment wiring terminal 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.

7.1.12 Tests conducted on an equipment wiring terminal with compact-stranded conductors shall represent tests with concentric and compressed stranded conductors of the same size.

7.1.13 The mechanical sequence and static sequence tests are to be conducted on the equipment wiring terminals in the end use equipment of which they are an integral part. The static heating test of the static sequence tests may be conducted on a sample not subjected to the Secureness Test. See 7.3.2.

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7.1.14 In regards to 7.1.13, with the concurrence of those concerned, all test sequences may be conducted on samples prepared in accordance with 9.1.8 if such preparation is representative of the final use of the equipment wiring terminals in the end use equipment. See 9.1.8.8 for additional requirements for tangless type equipment wiring terminals.

7.1.15 In regards to 7.1.13, equipment wiring terminals may be removed from the end use equipment if interference from molded parts, or the enclosure walls, or both, may occur.

7.1.16 In regards to 7.1.13, equipment wiring terminals that are intended for use in specific end use equipment but are not integral to the end use equipment may be tested in free air outside the end use equipment.

7.1.17 The current-cycling tests are to be conducted on equipment wiring terminals that have been assembled utilizing the enclosure in the end use equipment or a reasonable facsimile and then removed and tested in open air.

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 4, other than as noted in 9.2.1 and 9.2.4, while carrying the current specified for the equipment wiring terminal temperature rating and conductor size being tested.

7.2.2 The current-cycling test shall be completed without any equipment wiring terminal 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 the equipment wiring terminal 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:

$$S_i = d_i - D$$

$$D = [d1 + d2 + ... + d11)/11]$$

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 equipment wiring terminal temperature. The value for d_i is a positive number when the equipment wiring terminal temperature is more than that of the control conductor and a negative number when the equipment wiring terminal temperature is less than that of the control conductor. The average of the 11 temperature deviations is then determined. See Annex C for example.

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7.3 Static-heating sequence

7.3.1 The specimen sets shall carry continuously the value of 60 Hz test current specified in Table 4 or Table 5 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 equipment wiring terminal may exceed 50°C when the equipment wiring terminal, as used in the intended end use equipment application, does not exceed the maximum allowable temperature rise permitted for the end-use equipment application.

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

7.3.2 For equipment wiring terminals which are tested as part of the end use equipment, see 7.1.13, the samples shall carry the rated current of the end use equipment without exceeding the temperature limits for that particular equipment.

7.3.3 The joint between an equipment wiring terminal and the conductor shall be intact after being subjected for 15 min to the secureness test described in 9.3.2.

7.3.4 The joint between an equipment wiring terminal 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.

7.3.5 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 equipment wiring terminal. Breaking of the conductor or any strand of a stranded conductor shall be determined by examination of the complete equipment wiring terminal 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 an equipment wiring terminal and the conductor of a specimen set shall be intact after being subjected for 15 min to the secureness test described in 9.3.2.

7.4.2 The joint between an equipment wiring terminal 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 equipment wiring terminal. Breaking of the conductor or any strand of a stranded conductor shall be determined by examination of the complete equipment wiring terminal 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.

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7.5 Stress corrosion/moist ammonia (NH_4)

7.5.1 A copper alloy part of an equipment wiring terminal shall be resistant to stress corrosion cracking.

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

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

7.5.3 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 9.5.

7.6 Stress corrosion/mercurous nitrate ($HgNO_3$)

7.6.1 A copper alloy part of an equipment wiring terminal shall be resistant to stress corrosion cracking.

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

7.6.2 A brass part containing less than 80 percent copper shall not crack when subjected to the stress corrosion/mercurous nitrate ($HgNO_3$) test in 9.6.

8 Sampling Requirements

8.1 General

8.1.1 See Table 6 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 1 and Table 2.

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

8.1.4 For a line of equipment wiring terminals 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.

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8.1.5 A line of equipment wiring terminals of similar design is determined by the following features:

a) shape of equipment wiring terminal, shape of conductor opening, and shape and number of clamping screws;

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

c) torque corresponding to the wire size of each equipment wiring terminal;

d) crimping die design and number of crimps for equipment wiring terminals using crimping tools; and

e) for a tangless type equipment wiring terminal, the material and plating of the associated tang to be used with the equipment wiring terminal.

8.1.6 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 equipment wiring terminal.

8.1.7 If the conductor range of an equipment wiring terminal 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).

8.1.8 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 7.1.9.

8.1.9 An equipment wiring terminal 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 7.

8.2 Current-cycling

8.2.1 For an equipment wiring terminal without an assigned ampere rating, specimens shall be tested using the maximum size conductor or conductors. For an equipment wiring terminal 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 an equipment wiring terminal that is intended for a range of conductor sizes and for copper conductor in addition to 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. Also see 7.1.4.

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

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8.2.2 For an equipment wiring terminal 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 equipment wiring terminal temperature rating as indicated in Table 4. If the assigned maximum ampere rating of an equipment wiring terminal 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 an equipment wiring terminal intended for paralleling conductors, the conductor sizes shall be selected in accordance with Table 4, and the current shall be selected in accordance with Table 8. For an equipment wiring terminal that is intended for a range of conductor sizes and for copper conductors in addition to 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.

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

8.2.3 For an equipment wiring terminal 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 an equipment wiring terminal that is intended for a range of conductor sizes and for copper conductors in addition to 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.

Note: The current used in the tests with 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 3, if the equipment wiring terminal is intended for the intermixing of conductors of different materials, the current cycling tests shall be conducted using the following conductor material:

a) maximum size copper with maximum size aluminum;

b) maximum size copper with minimum size aluminum;

c) minimum size copper with minimum size aluminum; and

d) maximum size copper in combination with a minimum size 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.

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