UL 486E

STANDARD FOR SAFETY

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

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

Sixth Edition, Dated January 31, 2024

Summary of Topics

This new Sixth edition of ANSI/UL 486E dated January 31, 2024 includes the following changes in requirements:

– Addition to the Scope to address use of ferrules and adapters; 1.4

– Remove reference to a "Dielectric-Withstand Test"; 8.1.2 and 9.1.6.2

– Clarify that aluminum test conductors can be compact, compressed, or concentric stranding; 7.1.13

– Use of busbar during static heating test; 9.3.1.1

– Time stabilization clarification; 9.2.1 and 9.2.4

– Remove "number of strands" from marking requirement; 10.12

– Sizing and lubricating bushings during secureness test; 9.3.2.1 and Table 9.13

– Corrections to Table 8.3

– Testing with metric and non-standard size conductors; 1.3, 2.1.3, 3.2, 7.1.7, 7.1.10, 8.1.6, 8.1.7, 9.1.5.2, 9.1.5.3, 9.1.5.5, 9.1.5.6, 9.1.9.4, 10.4, 10.7, 10.8, 10.10, 10.26, 10.30, Table 7.5, Table 7.6, Table 8.3, Table 9.1, Table 9.2, Table 7.4, Table 9.3 – Table 9.6, Table 9.8, Table 9.13, Table 9.14, Section B4, and Annex E

– Testing with aluminum wire with AA-8000 alloy conductors; 7.2.2, 7.2.3, 7.3.1, Table 7.4, and Annex A

– Use of shear head bolts; 9.1.9.4, 9.1.9.5 and 9.1.9.6

– Insulating covers during stress corrosion tests; 9.6.1

– Addition of stranding table; 9.1.5.6 and Annex F

– Thermal testing with insulation colors other than black; 9.1.5.8, 9.1.5.9 and 9.1.5.10

– Alternate information means; 10.32

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated September 29, 2023 and December 15, 2023.

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UL 486E

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

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Sixth Edition

January 31, 2024

This ANSI/UL Standard for Safety consists of the Sixth Edition.

The most recent designation of ANSI/UL 486E as an American National Standard (ANSI) occurred on January 31, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time.Proposals should be submitted via a Proposal Request in the 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, 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 sizes, Classes 1, 2, 5, and 6, in the range of 0.5 – 1 000 mm^2, in addition to AWG/kcmil sizes, with AWG/kcmil ratings mandatory and metric wire ratings optional.

Note 1: Metric wire sizes are based on the IEC Standard for Conductors of Insulated Cables, IEC 60228.

Note 2: For example, an equipment wiring terminal rated for 6 AWG – 250 kcmil may be additionally rated for 16 – 120 mm^2. See Annex B for example.

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

1.4 Equipment wiring terminals covered by this Standard are also suitable for use with conductors that are prepared using ferrules evaluated in accordance with UL 486F, or wire connector adapters evaluated in accordance with UL 486A-486B, under the following conditions:

a) Ferrules and adapters are applied in accordance with their ratings and installation instructions.

b) The length of exposed conductive material maintains the strip lengths required by the connector manufacturer.

1.5 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.

1.6 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**

NFPA 70-2011, *National Electrical Code (NEC)*

* National Fire Protection Association

2.1.3 **IEC† Standards**

IEC 60228, *Conductors of Insulated Cables*

† International Electrotechnical Commission.

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.

3.2 For conductor sizes, AWG/kcmil conductor sizes are noted with their metric equivalents in parenthesis, followed by the closest metric conductor size covered by IEC 60228.

Note 1: Specifications for conductor sizes for both AWG/kcmil and metric are shown as follows: 12 – 3 AWG (3.31 – 26.7) / 4.0 – 25.0 mm^2.

Note 2: IEC 60228 covers conductors in the metric range of 0.5 – 2 500 mm^2. For requirements covering AWG/kcmil wire ranges outside this scope, the specification for the metric conductor will be limited to the conductor range covered by IEC 60228. Metric wire sizes larger than 1 000 mm^2 are not covered by this standard.

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

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

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° or less.

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 7.1 – Table 7.2 and in 7.5 – 7.6.

Table 7.1
Test Sequences for All Connectors

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

Note – Table 1 applies to equipment wiring terminals for non-parallel applications, in which case Table 7.2 would not be applicable. However, some equipment wiring terminals may have dual functionality, both parallel and non-parallel, in which case both Tables are applicable.

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

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

[c] The stress corrosion test, either moist ammonia or mercurous nitrate, need only be conducted for copper alloy parts not conforming to the copper requirements in 7.5 and 7.6.

Table 7.2
Test Sequences for All Equipment Wiring Terminals Intended for Parallel Conductors

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

Note – Table 2 applies to equipment wiring terminals for parallel applications, in which case Table 7.1 would not be applicable. However, some equipment wiring terminals may have dual functionality, both parallel and non-parallel, in which case both Tables are applicable.

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

[b] The stress corrosion test, either moist ammonia or mercurous nitrate, need only be conducted for copper alloy parts not conforming to the copper requirements in 7.5 and 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.

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 7.3 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.

Table 7.3
Conductor Materials to be Used in Test Sequences

Conductor for which connector is intended	Conductor used in test sequences
Copper[a]	Copper
Aluminum[a]	Aluminum
Copper to copper[b]	Copper
Copper-clad aluminum	Copper-clad aluminum
Aluminum to aluminum[b]	Aluminum
Copper-clad aluminum to Copper-clad aluminum[b]	Copper-clad aluminum
Copper to aluminum[b], intermixed	Copper to aluminum
Copper to copper-clad aluminum[b], intermixed	Copper to copper-clad aluminum

Notes –

1) If a equipment wiring terminal is rated for copper to copper, aluminum to aluminum, and copper to aluminum (intermixed), the mechanical sequence with copper to aluminum conductor may be omitted.

2) In all test sequences, aluminum conductor represents tests with copper-clad aluminum conductor.

[a] Single conductor in an opening.

[b] Two or more conductors in an opening.

7.1.7 Testing may be conducted using AWG/kcmil solid and stranded sized conductors or Class 1 (rigid solid) and Class 2 (rigid stranded) metric sized conductors as follows:

a) AWG/kcmil solid conductors is representative of Class 1 metric conductors.

b) Class 1 metric conductors is representative of AWG/kcmil solid conductors.

c) AWG/kcmil stranded conductors is representative of Class 2 metric conductors.

d) Class 2 metric conductors is representative of AWG/kcmil stranded conductors

Testing covers conductor sizes that are within the cross-sectional area envelope of the sizes tested, as determined by the circular mils of the conductor. See 9.1.5.5 – 9.1.5.7 for AWG/kcmil stranding classes.

See Annex E for conductor area, in circular mils, for conductor stranding, and for conductor diameters, of both AWG/kcmil and metric conductor sizes.

Note: See Annex B for example.

7.1.8 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 7.1 or Table 7.2. 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 7.1 or Table 7.2. 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 7.1 or Table 7.2.

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

7.1.10 An equipment wiring terminal rated for Class 5, Class 6, or both Class 5 and 6 metric conductors (flexible stranded) shall be subjected to all test sequences using the appropriate Class of flexible metric conductors based on the ratings specified by the manufacturer. See 9.1.5.7 for testing with specific stranding counts.

7.1.11 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.

7.1.12 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.

7.1.13 Tests conducted on an equipment wiring terminal with compact-stranded copper conductors shall represent tests with concentric and compressed stranded copper conductors of the same size. Tests conducted on a connector with compact, compressed, or concentric-stranded aluminum conductors shall represent tests with compact, concentric, and compressed stranded aluminum conductors of the same size. See Table 7.4.

Table 7.4
Conductor Materials

		AWG or kcmil (mm^2)	Test and control conductors shall be as follows:
Aluminum	Solid	12 (3.31) / 4.0 mm^2 and larger	Aluminum wire stock for use as an electrical conductor
	Stranded	12 – 3 (3.31 – 26.7) / 4.0 – 25.0 mm^2	AA-1350 or AA-8000 conductors. The stranding shall be Class B, SIW, or IEC Class 2 with compact, compressed or concentric stranding
		2 AWG – 1 000 (33.6 – 507) / 35 – 500 mm^2	AA-1350 or AA-8000 conductors. The stranding shall be Class B, SIW, or IEC Class 2 with compact, compressed or concentric stranding
		Larger than 1 000 (507) / 500 mm^2	AA-1350 or AA-8000 conductors. The stranding shall be Class B, SIW, or IEC Class

Table 7.4 Continued on Next Page

Table 7.4 Continued

		AWG or kcmil (mm^2)	Test and control conductors shall be as follows:
			2 with compact, compressed or concentric stranding
Copper	Solid	30 – 16 (0.05 – 1.31) / 0.5 – 1.5 mm^2	Soft annealed, tinned or untinned
		14 (2.08) / 2.5 mm^2 and larger	Soft annealed and untinned
	Stranded	30 – 16 (0.05 – 1.31) / 0.5 – 1.5 mm^2	Soft annealed, tinned or untinned
		14 (2.08) / 2.5 mm^2 and larger	Soft annealed, tinned or untinned. The stranding shall be concentric or compressed Class B, concentric Class C, or IEC Class 2.

7.1.14 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.

7.1.15 In regards to7.1.14, 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.

7.1.16 In regards to 7.1.14, equipment wiring terminals may be removed from the end use equipment if interference from molded parts, or the enclosure walls, or both, may occur.

7.1.17 In regards to 7.1.14, 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.

7.1.18 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 7.5, 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.

Table 7.5
Test Current for Connectors Intended for a Single Conductor, A

Conductor size			Copper							Aluminum and copper-clad aluminum							On (and off) times for current-cycling hours[f]
			As-signed maximum ampere rating[b]	Static-heating[a,c,g]		Current-cycling connector temperature rating[a]				As-signed maximum ampere rating[b]	Static-heating[a,c,g]		Current-cycling connector temperature rating[a]				
AWG or kcmil	(mm²)	mm² [h]				75 °C[d,g]		90 °C[e,g]					75 °C[d,g]		90 °C[e,g]		
30	(0.05)	–	0.5		3		3.5		4	–		–		–		–	1
28	(0.08)	–	0.8		3.5		4		5	–		–		–		–	1
26	(0.13)	–	1		5.5		6		8	–		–		–		–	1
24	(0.20)	–	2		7		8		10	–		–		–		–	1
22	(0.32)	–	3		9		12		13	–		–		–		–	1
–	–	0.5	4.8		11.7		15.6		16.6								1
20	(0.52)	–	5		12		16		17	–		–		–		–	1
–	–	0.75	6.5		15.8		18.3		22.4								1
18	(0.82)	–	7		17		19		24	–		–		–		–	1
–	–	1	8		17.4		19.4		26.6								1
16	(1.31)	–	10		18		20		31	–		–		–		–	1
–	–	1.5	11.2		21		23.2		33.2								1
14	(2.08)	–	15	[20]	30	[22]	33	[27]	40	–		–		–		–	1
–	–	2.5	16.7	[21.7]	31.7	[24]	35	[31.4]	44.8								1
12	(3.31)	–	20	[25]	35	[28]	39	[40]	54	15	[20]	30	[22]	33	[29]	43	1
–	–	4	23.5	[30.3]	40.3	[34]	45	[47]	61.4	18.5	[23.5]	33.5	[26.2]	37.2	[35]	49	1
10	(5.26)	–	30	[40]	50	[45]	56	[60]	75	25	[30]	40	[34]	45	[46]	60	1
–	–	6	34.7		54.7		61.7		81	28.5		43.6		48.6		64	1
8	(8.37)	–	50		70		80		100	40		55		60		77	1
–	–	10	55		78.3		88.3		110	43.3		61.6		68.3		85.3	1
6	(13.3)	–	65		95		105		131	50		75		85		102	1
–	–	16	71.8		105		117		146	55.1		83.5		93.5		115	1
4	(21.2)	–	85		125		140		175	65		100		110		140	1
–	–	25	105		132		149		185	68.4		105		115		147	1

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Table 7.5 Continued

Conductor size			Copper				Aluminum and copper-clad aluminum				On (and off) times for current-cycling hours[f]
			As-signed maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]		As-signed maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]		
AWG or kcmil	(mm^2)	mm^2 [h]			75 °C[d,g]	90 °C[e,g]			75 °C[d,g]	90 °C[e,g]	
3	(26.7)	–	100	145	165	205	75	115	125	160	1
2	(33.6)	–	115	170	190	240	90	135	150	190	1
–	–	35	117	174	195	246	91.6	138	154	194	1
1	(42.4)	–	130	195	220	275	100	155	175	215	1
–	–	50	144	219	244	306	114	172	192	239	1
1/0	(53.5)	–	150	230	255	320	120	180	200	250	1
2/0	(67.4)	–	175	265	300	370	135	210	230	295	1
–	–	70	179	272	307	380	138	214	236	301	1
3/0	(85.0)	–	200	310	345	435	155	240	270	335	1
–	–	95	214	333	372	467	166	258	290	360	1
4/0	(107)	–	230	360	405	505	180	280	315	390	1-1/2
–	–	120	246	389	431	544	196	303	338	423	1-1/2
250	(127)	–	255	405	445	565	205	315	350	440	1-1/2
–	–	150	283	442	496	620	228	347	387	486	1-1/2
300	(152)	–	285	445	500	625	230	350	390	490	1-1/2
350	(177)	–	310	505	555	708	250	395	435	555	1-1/2
–	–	185	318	517	570	726	256	404	446	567	1-1/2
400	(203)	–	335	545	605	765	270	425	470	595	1-1/2
–	–	240	368	601	668	843	300	470	522	658	2
500	(253)	–	380	620	690	870	310	485	540	680	2
–	–	300	417	685	768	960	338	536	595	754	2
600	(304)	–	420	690	775	968	340	540	600	760	2
700	(355)	–	460	755	850	1 055	375	595	675	835	2
750	(380)	–	475	785	885	1 100	385	620	700	870	2
–	–	400	487	809	913	1 132	393	640	720	898	2

Table 7.5 Continued on Next Page

Table 7.5 Continued

Conductor size			Copper				Aluminum and copper-clad aluminum				On (and off) times for current-cycling hours[f]
			As-signed maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]		As-signed maximum ampere rating[b]	Static-heating[a,c,g]	Current-cycling connector temperature rating[a]		
AWG or kcmil	(mm^2)	mm^2 [h]			75 °C[d,g]	90 °C[e,g]			75 °C[d,g]	90 °C[e,g]	
800	(405)	–	490	815	920	1 140	395	645	725	905	2
900	(456)	–	520	870	980	1 220	425	700	785	980	2
–	–	500	542	926	1 036	1 298	442	743	832	1 040	2
1 000	(507)	–	545	935	1 045	1 310	445	750	840	1 050	2
–	–	630	589	1 062	1 182	1 486	484	853	947	1 192	3
1 250	(633)	–	590	1 065	1 185	1 490	485	855	950	1 195	3
1 500	(760)	–	625	1 175	1 320	1 645	520	950	1 065	1 330	3
–	–	800	633	1 208	1 356	1 691	528	981	1 100	1 374	3
1 750	(887)	–	650	1 280	1 435	1 790	545	1 050	1 175	1 470	3
–	–	1 000	664	1 376	1 531	1 928	559	1 142	1 271	1 599	3
2 000	(1010)	–	665	1 385	1 540	1 940	560	1 150	1 280	1 610	3

Note – Conductor sizes between values provided in the table may be used for testing and rating connectors. Test currents shall be determined by interpolation of adjacent conductors based on the conductors area. See Table E.1 for conductor area.

[a] See 7.2, 8.2, and 9.2.

[b] Values are for 75 °C, not more than three conductors in raceway or cable ampacities, National Electrical Code, NFPA 70.

[c] Values for 14 AWG (2.08 mm^2) and larger are for 75 °C single conductor in free air ampacities, National Electrical Code, NFPA 70, Table 3 of the Canadian Electrical Code, C22.1, and Table 310-16 of the Standard for Electrical Installations, NOM-001-SEDE.

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

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

[f] See 9.2.5.

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

[h] Values in the mm^2 column represent the common sizes for metric conductors, as specified in IEC 60228. Corresponding ampacities and test currents are determined by interpolation of the values for AWG/kcmil conductors, as permitted in NFPA 70, Section 310.15(A).

7.2.2 The current-cycling test shall be completed without any equipment wiring terminal exceeding the following temperature rise for any recorded cycle.

a) Tests conducted with aluminum wire with AA-1350 alloy conductors shall not exceed a 125 °C temperature rise above the ambient temperature.

b) Tests conducted with aluminum wire with AA-8000 alloy conductors shall not exceed a 115 °C temperature rise above the ambient temperature.

c) Tests conducted with copper wire shall not exceed a 125 °C temperature rise above the ambient temperature.

7.2.3 The stability factor "S_i" (see 7.2.4) shall not exceed the following for the equipment wiring terminal temperature measurements taken at approximately 25, 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles.

a) Tests conducted with aluminum wire with AA-1350 alloy conductors shall not exceed a stability factor of ±10.

b) Tests conducted with aluminum wire with AA-8000 alloy conductors shall not exceed a stability factor of ±8.

c) Tests conducted with copper wire shall not exceed a stability factor of ±10.

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

$$S_i = d_i - D$$

$$D = \left[\frac{(d1 + d2 + \ldots + d11)}{11} \right]$$

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 di 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.

7.3 Static-heating sequence

7.3.1 The specimen sets shall carry continuously the value of 60 Hz test current specified in Table 7.5 or Table 7.6 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.

Note 3: When testing with aluminum conductors, testing may be conducted with either AA-1350 or AA-8000 conductors, with the same allowed temperature rise.

Table 7.6
Static Test Currents for Connectors Intended for Paralleling Conductors, A

Conductor sizes			Number and material of conductors					
			Two		Three		Four	
AWG or kcmil	(mm^2)	mm^2	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
1/0	(53.5)	–	300	240	450	360	480	384
2/0	(67.4)	–	350	270	525	405	560	432
–	–	70	357	276	536	414	572	441
3/0	(85.0)	–	400	310	600	465	640	496
–	–	95	427	333	641	499	684	532
4/0	(107)	–	460	360	690	540	736	576
–	–	120	504	393	755	589	942	735
250	(127)	–	527	410	790	615	1 053	820
–	–	150	575	451	862	678	1 150	903
300	(152)	–	579	455	868	683	1 158	910
350	(177)	–	657	514	985	770	1 314	1 028
–	–	185	673	526	1 009	788	1 346	1 052
400	(203)	–	709	553	1 063	829	1 418	1 106
–	–	240	781	611	1 171	916	1 562	1 221
500	(253)	–	806	631	1 209	946	1 612	1 262
–	–	300	1 017	796	1 527	1 194	2 034	1 592
600	(304)	–	1 035	810	1 554	1 215	2 070	1 620
700	(355)	–	1 133	893	1 699	1 339	2 266	1 786
750	(380)	–	1 178	930	1 767	1 395	2 356	1 860
–	–	400	1 214	960	1 821	1 441	2 428	1 921
800	(405)	–	1 223	968	1 834	1 452	2 446	1 936
900	(456)	–	1 305	1 050	1 958	1 575	2 610	2 100
–	–	500	1 390	1 115	2 084	1 672	2 779	2 229
1 000	(507)	–	1 403	1 125	2 104	1 688	2 806	2 250
–	–	630	1 593	1 378	2 390	1 918	3 187	2 558
1 250	(633)	–	1 598	1 383	2 397	1 924	3 196	2 566
1 500	(760)	–	1 763	1 425	2 644	2 138	3 526	2 850
–	–	800	1 812	1 472	2 596	2 209	3 625	2 944
1 750	(887)	–	1 920	1 575	2 880	2 363	3 840	3 150
–	–	1000	2 065	1 713	3 098	2 570	4 130	3 426
2 000	(1 010)	–	2 078	1 725	3 117	2 588	4 156	3 450
NOTES –								

Table 7.6 Continued on Next Page

Table 7.6 Continued

Conductor sizes			Number and material of conductors					
			Two		Three		Four	
AWG or kcmil	(mm^2)	mm^2	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum

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

2) The currents for conductor sizes 250 kcmil (127 mm2) and larger are in accordance with the NEC, NFPA 70 , Sections 392.90(A)(2(a) and 392.80(A)(2)(b) for Table 310.17 (free air ampacities), 75 °C column, multiplied by the number of conductors and de-rated as follows:

250 – 500 kcmil (127 – 253 mm^2) – adjusted to 65 percent

600 kcmil (304 mm^2) and larger – adjusted to 75 percent

3) Any number of conductors other than tabulated shall be adjusted in accordance with NEC, NFPA 70, Table 310.15(C)(1).

4) Values in the mm^2 column represent the common sizes for metric conductors, as specified in IEC 60228. Corresponding test currents are determined by interpolation of the values for AWG/kcmil conductors, as permitted in NFPA 70, Section 310.15(A).

5) Conductor sizes between values provided in the table may be used for testing and rating connectors. Test currents shall be determined by interpolation of adjacent conductors based on the conductors area. See Table E.1 for conductor area.

7.3.2 For equipment wiring terminals which are tested as part of the end use equipment, see 7.1.14, 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.

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 8.1 for the minimum number of specimens for test.

Table 8.1
Minimum Number of Specimens for Test

Clause	Test	Number of specimens
9.2	Current-cycling	4 of each combination of connector and test conductor(s) to be tested
9.3	Static-heating sequence	4 of each combination of connector and test conductor(s) to be tested
9.4	Mechanical sequence	4 of each combination of connector and test conductor(s) to be tested
9.5 or 9.6	Stress corrosion	3

8.1.2 Separate specimen sets shall be used for current-cycling, mechanical sequence, static-heating sequence, and the other tests as applicable. See Table 7.1 and Table 7.2.

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.

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) / 0.5 – 6 mm^2 conductor sizes, and using stranded conductor for 8 AWG (8.4 mm^2) / 10 mm^2 and larger unless the connector 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) / 2.5 – 6 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) / 2.5 – 6 mm^2

8.1.8 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 8.2.

Table 8.2
Material of Clamping Screws for Tests

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

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

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

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

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.

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 7.5. 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 7.5, and the current shall be selected in accordance with Table 8.3. 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.

Table 8.3
Cycling Test Currents for 75 °C and 90 °C Connectors Intended for Paralleling Conductors, A

Conductor size,			Number and material of conductors											
			Two				Three				Four			
			Copper		Aluminum and copper-clad aluminum		Copper		Aluminum and copper-clad aluminum		Copper		Aluminum and copper-clad aluminum	
AWG or kcmil	(mm^2)	mm^2	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C
1/0	(53.5)	–	336	420	269	336	504	630	403	504	538	672	431	538
2/0	(67.4)	–	392	490	302	378	588	735	454	567	628	784	484	605
–	–	70	400	500	309	386	600	751	464	579	641	801	495	618
3/0	(85.0)	–	448	560	347	434	672	840	521	651	717	896	556	695
–	–	95	478	598	372	466	718	897	559	699	766	957	596	745
4/0	(107)	–	515	644	403	504	773	966	605	756	824	1 030	645	806
–	–	120	564	705	440	550	846	1 057	660	824	1 055	1 320	824	1 028
250	(127)	–	590	738	460	574	885	1 106	689	861	1 180	1 476	920	1 148
–	–	150	644	805	506	632	965	1 206	759	948	1 289	1 610	1 012	1 264
300	(152)	–	649	811	510	637	972	1 215	765	956	1 298	1 622	1 020	1 274

Table 8.3 Continued on Next Page

Table 8.3 Continued

Conductor size,			Number and material of conductors											
			Two				Three				Four			
			Copper		Aluminum and copper-clad aluminum		Copper		Aluminum and copper-clad aluminum		Copper		Aluminum and copper-clad aluminum	
AWG or kcmil	(mm^2)	mm^2	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C	75 °C	90 °C
350	(177)	–	736	920	576	720	1 103	1 379	862	1 078	1 472	1 840	1 132	1 440
–	–	185	754	942	520	736	1 130	1 413	882	1 104	1 508	1 885	1 165	1 473
400	(203)	–	794	993	620	771	1 191	1 488	928	1 161	1 588	1 986	1 240	1 548
–	–	240	875	1 094	684	854	1 312	1 640	1 026	1 282	1 749	2 187	1 369	1 709
500	(253)	–	903	1 129	707	883	1 354	1 693	1 060	1 324	1 806	2 258	1 414	1 766
–	–	300	1 140	1 425	891	1 124	1 396	2 138	1 337	1 687	2 280	2 850	1 784	2 249
600	(304)	–	1 160	1 450	907	1 145	1 400	2 176	1 361	1 718	2 320	2 900	1 815	2 290
700	(355)	–	1 269	1 587	1 000	1 250	1 903	2 379	1 500	1 875	2 538	3 174	2 000	2 500
750	(380)	–	1 320	1 650	1 041	1 302	1 979	2 474	1 562	1 953	2 640	3 300	2 082	2 604
–	–	400	1 360	1 700	1 075	1 344	2 039	2 549	1 613	2 017	2 720	3 401	2 151	2 689
800	(405)	–	1 370	1 713	1 084	1 355	2 054	2 568	1 626	2 033	2 740	3 426	2 168	2 710
900	(456)	–	1 462	1 828	1 176	1 470	2 193	2 741	1 764	2 205	2 924	3 656	2 352	2 940
–	–	500	1 557	1 946	1 248	1 561	2 334	2 918	1 874	2 341	3 114	3 892	2 497	3 121
1 000	(507)	–	1 572	1 965	1 260	1 575	2 356	2 946	1 891	2 363	3 144	3 930	2 520	3 150
–	–	630	1 785	2 232	1 433	1 791	2 676	3 346	2 149	2 686	3 570	4 463	2 866	3 581
1 250	(633)	–	1 790	2 238	1 437	1 796	2 684	3 356	2 155	2 694	3 580	4 476	2 874	3 592
1 500	(760)	–	1 975	2 469	1 596	1 995	2 961	3 701	2 395	2 993	3 950	4 938	3 192	3 990
–	–	800	2 030	2 538	1 649	2 061	3 044	3 805	2 474	3 092	4 060	5 076	3 298	4 122
1 750	(887)	–	2 150	2 688	1 764	2 205	3 226	4 032	2 647	3 308	4 300	5 376	3 528	4 410
–	–	1 000	2 314	2 892	1 918	2 398	3 469	4 337	2 879	3 597	4 627	5 784	3 837	4 796
2 000	(1 010)	–	2 328	2 910	1 932	2 415	3 491	4 364	2 899	3 623	4 656	5 820	3 864	4 830

NOTES –

1) Current values in the 75 °C column are approximately 112 percent of the static-heating test currents from Table 8.3.

2) Current values in the 90 °C column are approximately 140 percent of the static-heating test currents from Table 8.3.

3) Conductor sizes between values provided in the table may be used for testing and rating connectors. Test currents shall be determined by interpolation of adjacent conductors based on the conductors area. Reference Table E.1 for conductor area.

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 7.3, 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.

8.3 Static-heating sequence

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

8.3.2 For an ampere-rated equipment wiring terminal not intended for paralleling conductors, the static-heating sequence shall not be conducted with the larger size(s) of conductor that exceed the size conductor that corresponds to the ampere rating of the conductor as determined from Table 7.5; only the mechanical sequence tests shall be conducted. An equipment wiring terminal specimen set with the size conductor that corresponds to the ampere rating shall be subjected to the full static-heating sequence.

Note: See Annex B for example.

8.3.3 For an ampere-rated equipment wiring terminal intended for paralleling conductors, specimens shall be tested with the parallel conductor combinations that equal the assigned ampere rating as determined from Table 7.5. The ampere rating assigned to the equipment wiring terminal shall be divided by the number of conductors. For ampere ratings that fall between two consecutive values, the next larger conductor size shall be used. The values of test current in the static-heating test for the parallel-conductor range shall be selected from Table 7.6. If the number of conductors is less than the number of conductor openings, the conductors shall be positioned in the equipment wiring terminal so that the test current is concentrated in the smallest cross-sectional area of the equipment wiring terminal in the current path. If the equipment wiring terminal also has single conductor ranges, the conductor sizes and values of test current in the static-heating tests for the single conductor ranges shall be selected from Table 7.5 using the conductor size that corresponds to the ampere rating of the equipment wiring terminal.

Note: See Annex B for example.

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

8.4 Mechanical sequence

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

8.5 Stress corrosion/moist ammonia (NH_4)

8.5.1 The number of specimens as identified in Table 8.1 shall be subjected to the stress corrosion/moist ammonia (NH_4) test described in 9.5.

8.6 Stress corrosion/mercurous nitrate ($HgNO_3$)

8.6.1 The number of specimens as identified in Table 8.1 shall be subjected to the stress corrosion/mercurous nitrate ($HgNO_3$) test described in 9.6.

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

9 Test Methods

9.1 General

9.1.1 Temperature measurement

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

9.1.2 Ambient temperature measurement

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

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

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

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

9.1.3 Control conductor temperature measurement

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

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

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

a) A small flap shall be cut into the conductor insulation and rolled back to expose the conductor. When using uninsulated conductors, this step shall be skipped.

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

c) The flap of insulation shall be repositioned and secured by a tightly wrapped, double layer of black thermoplastic tape extending not more than 12.7 mm (1/2 in) on each side of the flap, or by another similar means of holding the test conductor insulation in place. When using uninsulated conductors, no insulation flap shall be used. A double layer of black thermoplastic tape shall be wrapped directly over the thermocouple bead.

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

a) A 25.4 mm (1 in) minimum length of insulation over the full circumference of the conductor shall be removed. When using uninsulated conductors, this step shall be skipped.

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

c) One conductor strand shall be pried out of the stranding just enough to insert the end of a soft copper ribbon measuring 6.4 mm (1/4 in) wide x 0.13 mm (0.005 in) thick to a length that overlaps approximately 3.2 mm (1/8 in) as illustrated in Figure 9.1. The conductor strand shall then be lightly tapped back down on the copper ribbon.

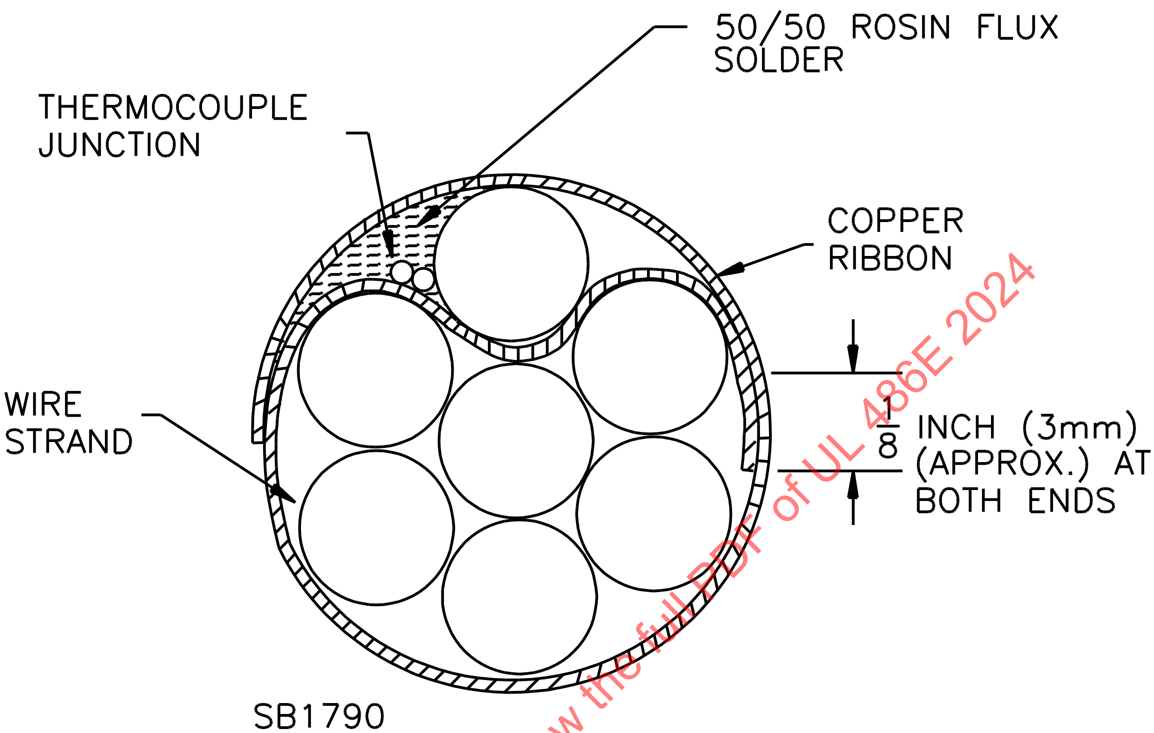
d) The copper ribbon shall be wrapped partially around the conductor strands back to the one strand that has been pried out.

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

f) The section of insulation removed as described in (a) shall be attached with the slit side directly opposite the thermocouple junction. Thin-walled heat shrinkable 125 °C tubing or a tightly wrapped, double layer of black thermoplastic tape extending not more than 12.7 mm (1/2 in) on each end of the section of insulation shall be used to hold it in place. When using uninsulated conductors, no insulation flap shall be used. A double layer of black thermoplastic tape wrapped directly over the copper ribbon or heat shrink tubing shall be used.

Figure 9.1

Method for Attaching Thermocouples to Stranded Aluminum Control Conductors Used for Current-Cycling Tests



9.1.4 Specimen temperature measurement

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

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

9.1.5 Test and control conductors

9.1.5.1 All test specimen conductors and control conductors shall comply with the requirements in Table 9.1, Table 9.2, Table 7.4, and Table 9.3, see 9.1.5.4. All test specimen conductors and control conductors shall be new (previously unused) or, with the concurrence of those concerned, shall be previously used conductors that have not attained a temperature of over 120 °C. For previously used conductors, used conductor ends shall be cut off and the resulting new ends of the conductor re-stripped in accordance with 9.1.6.

Table 9.1
Conductor Stranding for AWG or kcmil Conductors

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

[a] Number of strands vary.

[b] Aluminum 14 AWG (2.1 mm^2) is not available.

Table 9.2
Conductor Stranding for Class 2 mm^2 Conductors

Size of conductor to which connector is to be assembled		Circular		Circular compacted	
mm^2	(AWG or kcmil)	Cu	Al	Cu	Al
0.5 – 1.0	(20 – 18)	7	–	–	–
1.5 – 6	(16 – 10)	7	–	6	–
10 – 16	(8 – 6)	7	7	6	6
25 – 35	(4 – 2)	7	7	6	6
50	(1 – 1/0)	19	19	6	6
70	(2/0)	19	19	12	12
95	(3/0 – 4/0)	19	19	15	15
120 – 150	(250 – 300)	37	37	18	15
185	(350 – 400)	37	37	30	30
240	(500)	37	37	34	30
300	(600)	61	61	34	30
400 – 500	(700 – 1 000)	61	61	53	53
630	(1 250)	91	91	53	53
800 – 1 000	(1 500 – 2 000)	91	91	53	53

Note: Stranding requirements from the IEC Standard for Conductors of Insulated Cables, IEC 60228.

Table 9.3
Conductor Insulation[a]

		AWG or kcmil (mm^2)	Type of insulation[b]
Aluminum	Solid	12 (3.31) / 4 mm^2 and larger	THHN THW USE XHHW PE or XLPE thermoset insulation
	Stranded	All sizes	USE PE or XLPE thermoset insulation
Copper	Solid and stranded	30 – 24 (0.05 – 0.20)	Thermoplastic at least 0.254 (0.010 in) thick
		22 – 16 (0.32 – 1.31) / 0.5 – 1.5 mm^2	Thermoplastic at least 0.762 mm (0.030 in) thick
		14 (2.08) / 4 mm^2 and larger	THHN THW USE XHHW

[a] Table 11 is not applicable when testing with uninsulated conductors.

[b] Type of insulation is not specified when testing with a connector assembly that does not rely on the conductor insulation.

9.1.5.2 IEC 60228 indicates that aluminum conductors shall consist of aluminum or aluminum alloy. When testing with aluminum metric wire, alloy of the aluminum conductor shall be confirmed to be either AA-1350 or AA-8000.

9.1.5.3 When testing with copper metric wire, any conductor complying with IEC 60228 shall be considered acceptable.

9.1.5.4 With reference to 9.1.5.1, a connector may be tested with uninsulated conductors or conductors with any type of insulation when the connector assembly does not rely on the conductor insulation, i.e. insulation piercing connector. When using uninsulated conductors, Table 9.3 shall not be applied.

9.1.5.5 Equipment wiring terminals additionally rated for 2 AWG (33.6 mm^2) / 35 mm^2 and larger compact-stranded copper conductors shall be tested with compact-stranded Class B or IEC Class 2 compact copper conductors. See also 6.1.2 and 10.12.

9.1.5.6 An equipment wiring terminal for flexible copper wire other than Class B, Class C, or IEC Class 2 stranding shall be subjected to all test sequences using the other stranding. Testing with stranded wire with the maximum stranding count and minimum stranding count for a specific size of wire is considered to represent wire of that specific size with stranding counts between the tested ranges. Refer to Annex F for Conductor Stranding.

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

9.1.5.8 When performing the Current-Cycling and Static-Heating Tests, the insulation for conductors shall be black or, if a comparison measurement is made in accordance with 9.1.5.9 and an adjustment factor is included in the temperature rise limit, insulation color other than black shall be allowed.

9.1.5.9 Performing the Current-Cycling and Static-Heating Tests with a conductor having an insulation color other than black shall be permitted if a temperature comparison is conducted, using a control conductor and a conductor with the color to be used during the test (referred to as a "comparison conductor"). The comparison set-up shall be performed with the control and comparison conductor and equalizer size and length (if applicable) complying with the requirements for a control conductor and equalizer used during the Current-Cycling Test. The current used during the temperature comparison shall be the same used during the Static-Heating Test. If higher temperature rises are measured on the control conductor, the difference in temperature rises (temperature rise of control conductor, minus the temperature rise of comparison conductor) shall be considered an adjustment factor and deducted from the allowed temperature rise in the Current-Cycling and Static-Heating Tests.

9.1.5.10 For the purposes of the temperature comparison in 9.1.5.9, the control conductor shall be provided with black insulation or without insulation, and the comparison conductor shall be provided with insulation of the color being used during the test. The conductors shall comply with 9.1.5, except as follows: The control and comparison conductor may be compact, compressed, or concentric stranding, and when using aluminum conductors, either AA-1350 or AA-8000 alloy, so long as the control and comparison use the same stranding configuration, class, and material.

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

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

9.1.5.12 The length measured from the conductor entry face of the test equipment wiring terminal to the equalizer for the current-cycling test or to the face of the equipment wiring terminal at the other end of the test conductor for the mechanical or static-heating test shall be as specified in Table 9.4.

Table 9.4
Test Conductor Length

Conductor size		Minimum conductor length[a]	
AWG or kcmil (mm^2)	mm^2	mm	(in)
30 – 8 (0.05 – 8.4)	0.5 – 10	203	(8)
6 – 3 (13.3 – 26.7)	16 – 25	305	(12)
2 – 500 (33.6 – 253)	35 – 240	457	(18)
Larger than 500 (Larger than 253)	Larger than 240	660	(26)

[a] The conductor length for the secureness test in the mechanical or static-heating sequence shall not be less than that specified in 9.3.2.1 – 9.3.2.3.

9.1.5.13 The length of control conductors used in the current-cycling tests shall be a minimum of twice the length of the test conductors used with the equipment wiring terminal specimens.

9.1.5.14 The length of control conductors used in the current-cycling tests shall be a minimum of twice the length of the test conductors used with the equipment wiring terminal specimens.

9.1.6 Conductor stripping

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

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

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

9.1.6.2 For an equipment wiring terminal marked with a nominal strip length according to footnote (a) of Table 9.5, all tests shall be performed with conductors stripped to the nominal value minus the tolerance specified in Table 9.6.

9.1.6.3 For an equipment wiring terminal marked with a minimum conductor strip length, all tests shall be conducted with conductors stripped to the minimum length.

9.1.6.4 If the strip length is not provided in accordance with footnotes (b) and (c) of Table 9.5, the insulation of the test conductor shall be stripped to allow the conductor to make contact with the full available length of the equipment wiring terminal collar or barrel that contains the securing means. The conductor shall be positioned so that 6.4 – 12.7 mm (1/4 – 1/2 in) of bare conductor is exposed between the conductor-entry face of the equipment wiring terminal and the beginning of the insulation. If the conductor projects through the equipment wiring terminal without interference, the conductor shall be installed to project a maximum of 6.4 mm (1/4 in).

Table 9.5
Wire Strip Length

Connector type	Required wire strip length marking	
	Maximum strip length	Minimum strip length
Non-insulated	–	X[a,b,c]
Note: An X indicates marking is required.		
[a] Strip length shall be specified as a single – nominal – value if tested as specified in 9.1.6.2.		
[b] Strip length marking shall be optional if the connector is provided with an open end opposite the conductor insertion end through which the end of the conductor is visible after it is connected.		
[c] Strip length marking shall be optional if the connector is provided with an inspection hole opposite the conductor insertion end through which the end of the conductor is visible after it is connected.		

Table 9.6
Strip-Length Tolerances for Conductors

Conductor size		Tolerance	
AWG or kcmil (mm^2)	mm^2	mm	(in)
30 – 14 (0.05 – 2.1)	0.5 – 2.5	±0.8	(±1/32)
12 – 10 (3.3 – 5.3)	4 – 6	±1.2	(±3/64)
8 – 250 (8.4 – 127)	10 – 120	±1.6	(±1/16)
300 – 2 000 (152 – 1 016)	150 – 1 000	±3.2	(±1/8)

9.1.7 Equalizer

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

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

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

9.1.7.2 An equalizer shall be constructed using:

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

b) A tool-applied compression connector; or

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

9.1.7.3 The end of the conductor that projects through the equalizer shall be welded into a homogeneous mass with the bus [see9.1.7.2(a)] or the connector [see 9.1.7.2(c)]. For a equipment wiring terminal intended for paralleling conductors, the hole spacing pattern in the equalizer shall be identical to the hole spacing pattern in the equipment wiring terminal. A wire connector used as an equalizer shall not be larger than that needed for the conductor size involved, and an equalizer bus shall not be larger than the applicable bus size indicated in Table 9.7. For test currents over those in Table 9.7, the size of the equalizer shall be based on 1.55 A/mm^2 (1 000 A/in^2) of cross-section for a copper bus equalizer and 1.16 A/mm^2 (750 A/in^2) of cross-section for an aluminum bus equalizer.

Table 9.7
Busbar Dimensions

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

9.1.8 Preparation of specimens

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

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

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

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

a) Profile, width, and depth of the equipment wiring terminal;

b) Material of equipment wiring terminal body;

c) Crimping die geometry;

d) The number of crimps; and

e) Similarity of crimp forces.

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

9.1.8.6 A tangless type equipment wiring terminal (e.g., collar or meter-socket construction) shall be mounted for test purposes on a tang representative of the intended use; see 9.1.8.8. The length of the tang shall not exceed twice the length of the equipment wiring terminal body. For the static-heating sequence and mechanical sequence, individual tangs with a mounting hole in the end opposite the equipment wiring terminal shall be used. For the current-cycling test, one tang with equipment wiring terminals mounted as illustrated in Figure 9.2 shall be used. If the specified mounting means includes auxiliary antirotation means, such means shall not increase the thermal mass or heat-radiating capabilities of the assembly.

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

9.1.8.8 For a tangless type equipment wiring terminal (see Figure 9.2), the following information shall be provided:

a) Material of tang;

b) Plating on tang;

c) Minimum cross-section of tang;

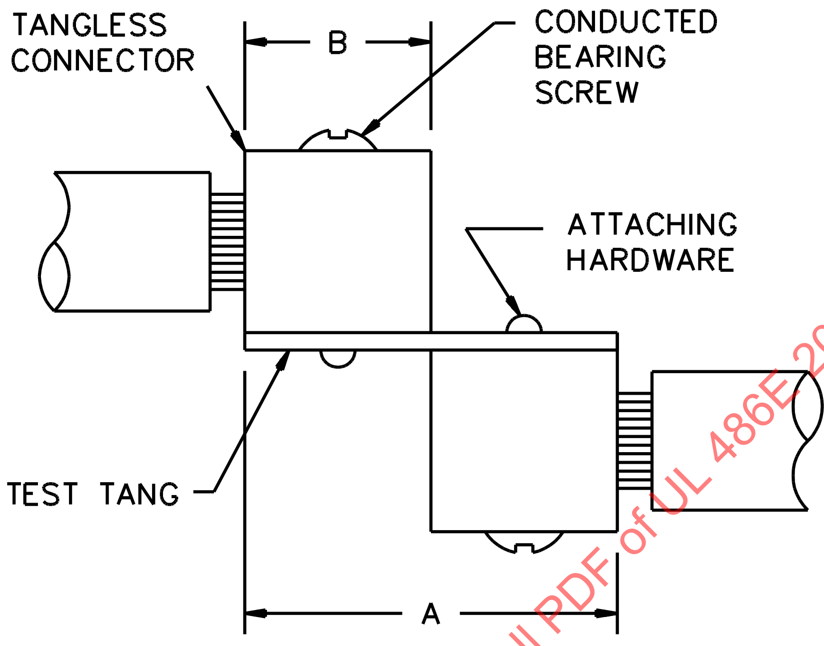
d) Material of mounting screw;

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

f) Torque to be used to secure the equipment wiring terminal to the tang.

Figure 9.2

Method for Mounting Tangless Type Equipment Wiring Terminals



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9.1.8.9 When preparing assemblies using uninsulated conductors, a cable tie or similar means shall be used in close proximity to the wire opening to prevent splaying or spreading of the uninsulated conductor. This restriction shall be applied to the conductor end prior to any torqueing or crimping and shall remain in place during the remainder of the test.

Note: The use of a cable tie or similar means is intended to maintain the relative positioning of the individual conductor strands with similar constraints that might occur if insulated conductors had been used, where the conductor insulation acts in the same capacity.

9.1.9 Tightening torque

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

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

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

9.1.9.4 Except as allowed in 9.1.9.5 and 9.1.9.6, the tightening torque values specified in Table 9.8, Table 9.9, or Table 9.10 shall apply to all equipment wiring terminals employing conductor clamping nuts or bolts of the types described in the tables. The values in Table 9.8 are based on the size of the installed test conductor, while the torque values specified in Table 9.9 and Table 9.10 are independent of the installed test conductor. Table 9.9 is limited for use with equipment wiring terminals intended for 8 AWG (8.4 mm^2) / 10 mm^2 or smaller conductors. If more than one conductor is secured under the same clamping nut or bolt, the torque value in Table 9.8 shall be applied based on the largest conductor installed. Specimens prepared for the current-cycling test shall be tightened using the values of torque shown in column A. All other tests shall have the specimens prepared using the values in column B.

9.1.9.5 When a tightening torque value is assigned, the current-cycling test specimens shall be prepared using 90 percent of the assigned torque value. All other tests shall have the specimens prepared using the assigned value of torque. See 10.22 for marking requirements.

9.1.9.6 For equipment wiring terminals with shear bolt style clamping means, all tests shall have the specimens prepared with the shear bolt tightened to the point of shearing.

9.1.9.7 Equipment wiring terminals having clamping screws with multiple tightening means (for example, a combination slotted, hexagonal head screw) shall be tested using the multiple values of torque as specified in Table 9.8, Table 9.9, and Table 9.10.

Table 9.8
Tightening Torque for Screws

Test conductor size installed in connector			Tightening torque, N·m (lbf-in)															
			Slotted head No. 10 and larger[a]								Hexagonal head – external drive socket wrench							
			Slot width – 1.2 mm (0.047 in) or less and slot length – 6.4 mm (1/4 in) or less				Slot width – over 1.2 mm (0.047 in) or slot length – over 6.4 mm (1/4 in)				Split-bolt connectors				Other connectors			
AWG or kcmil	(mm^2)	mm^2	A		B		A		B		A		B		A		B	
30 – 10	(0.05 – 5.3)	0.5 – 6	1.7	(15)	2.3	(20)	2.8	(25)	4.0	(35)	7.3	(65)	9.0	(80)	6.8	(60)	8.5	(75)
8	(8.4)	10	2.3	(20)	2.8	(25)	3.4	(30)	4.5	(40)	7.3	(65)	9.0	(80)	6.8	(60)	8.5	(75)
6 – 4	(13.2 – 21.2)	16	2.8	(25)	4.0	(35)	4.0	(35)	5.1	(45)	15.3	(135)	18.6	(165)	10.2	(90)	12.4	(110)
3	(26.7)	25	2.8	(25)	4.0	(35)	4.5	(40)	5.6	(50)	25.4	(225)	31.1	(275)	14.1	(125)	16.9	(150)
2	(33.6)	35	3.4	(30)	4.5	(40)	4.5	(40)	5.6	(50)	25.4	(225)	31.1	(275)	14.1	(125)	16.9	(150)
1	(42.4)	–	–		–		4.5	(40)	5.6	(50)	25.4	(225)	31.1	(275)	14.1	(125)	16.9	(150)
1/0 – 2/0	(53.5 – 67.4)	50 – 70	–		–		4.5	(40)	5.6	(50)	35.6	(315)	43.5	(385)	16.9	(150)	20.3	(180)
3/0 – 4/0	(85.0 – 107.2)	95	–		–		4.5	(40)	5.6	(50)	45.2	(400)	56.5	(500)	22.6	(200)	28.2	(250)
250 – 350	(127 – 177)	120 – 185	–		–		4.5	(40)	5.6	(50)	62.1	(550)	73.4	(650)	28.2	(250)	36.7	(325)
400	(203)	–	–		–		4.5	(40)	5.6	(50)	76.3	(675)	93.2	(825)	28.2	(250)	36.7	(325)
500	(253)	240	–		–		4.5	(40)	5.6	(50)	76.3	(675)	93.2	(825)	33.9	(300)	42.4	(375)
600 – 750	(304 – 380)	300 – 400	–		–		4.5	(40)	5.6	(50)	90.4	(800)	113.0	(1000)	33.9	(300)	42.4	(375)
800 – 1000	(406 – 508)	450 – 500	–		–		4.5	(40)	5.6	(50)	111.7	(900)	124.3	(1100)	45.2	(400)	56.5	(500)
1250 – 2000	(635 – 1010)	630 – 1 000	–		–		–		–		111.7	(900)	124.3	(1100)	56.5	(500)	67.8	(600)

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

Table 9.9
Tightening Torque for Slotted Head Screws Smaller than No. 10 Intended for Use With 8 AWG (8.4 mm²) or Smaller Conductors

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

[a] For slot lengths of intermediate values, select torques pertaining to next shorter slot lengths. Also, see 9.1.9.7 for screws with multiple tightening means. Slot length shall be measured at the bottom of the slot.

[b] Slot width is the nominal design value.

Table 9.10
Tightening Torque for Screws With Recessed Allen or Square Drives

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

[a] See 9.1.9.7 for screws with multiple tightening means.

9.1.10 Test assembly

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

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

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

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

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

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

e) The assembled hardware shall be torqued to the values in Table 9.11.

Table 9.11
Tightening Torque for Connecting Hardware

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

9.1.10.3 When the installation instructions (see 10.21) specify that a dished washer shall be used, the design of the dished washer shall be such that the force needed to flatten the washer is as specified for the corresponding bolt size in Table 9.12. The hardware shall be as follows:

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

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

c) Tests on an equipment wiring terminal shall be conducted using other hardware, part securement torque values, and dished or other washers having different characteristics, if the installation instructions specify all necessary hardware and torque. See 10.21.

Table 9.12
Flattening Force

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

9.1.10.4 The lengths of the busbars mentioned in 9.1.10.1 shall be the minimum necessary to provide sufficient contact area for the equalizers while maintaining the center-to-center specimen spacing specified in 9.1.10.5. The cross-section dimensions of the bar shall be sufficient to prohibit a test-current density in excess of 1.55 A /mm^2 (1 000 A /in^2) for copper or 1.24 A /mm^2 (800 A /in^2) for aluminum bus. See Table 9.7.

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

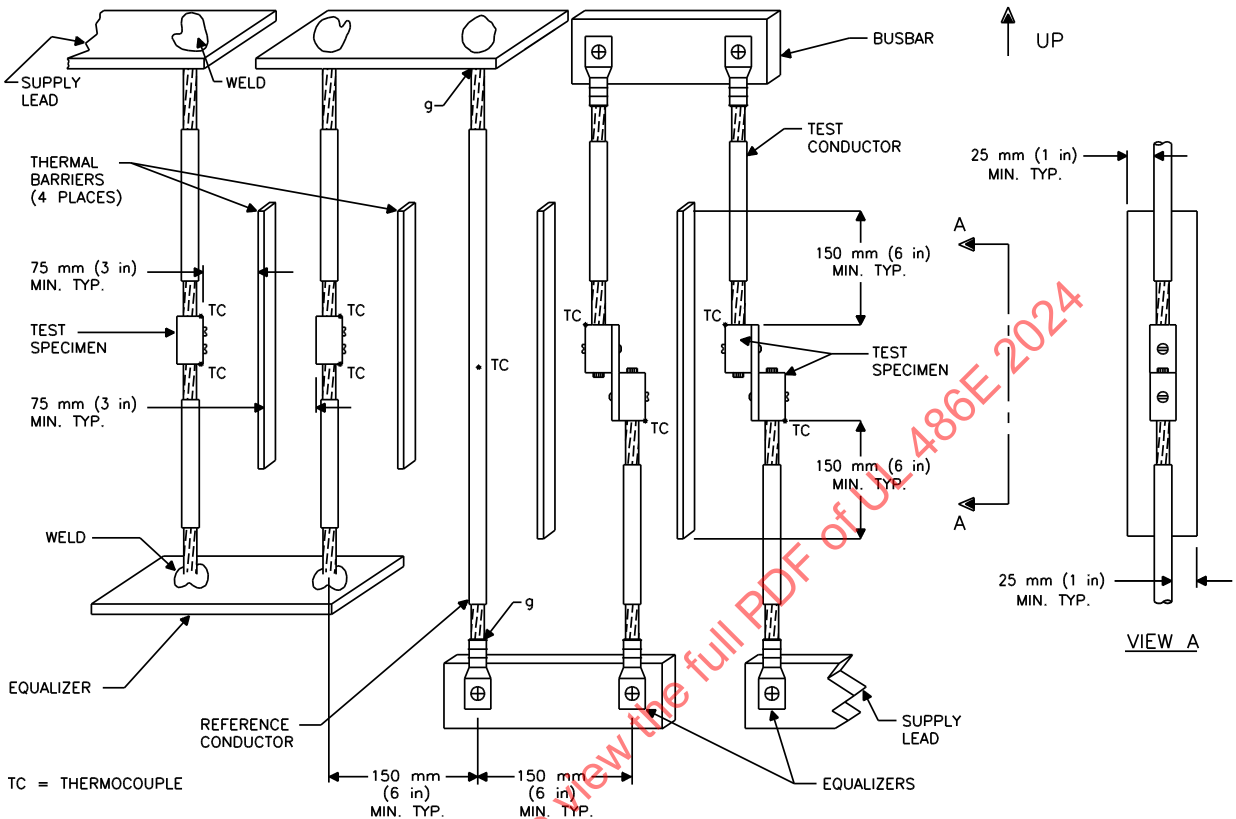
9.1.10.6 With reference to 9.1.10.5, the spacing may be reduced with the concurrence of those concerned.

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

9.1.10.8 Test assemblies and the control conductor shall be suspended vertically or horizontally in free air by the use of loose-fitting, nonmetallic tie straps around the conductors or by suspension from the equalizers supported in turn by nonmetallic blocks. The method used shall reduce the disturbance of the test connections during handling of the specimens and reduce the transmission of tensile loads to the test equipment wiring terminals through test or supply conductors. See Figure 9.3 for an example of a vertical arrangement.

Figure 9.3

Vertical Arrangement of Specimen for Current-Cycling Test



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

a) MATERIAL OF TANG;

b) PLATING ON TANG;

c) MINIMUM CROSS–SECTION OF TANG;

d) MATERIAL OF MOUNTING SCREW;

e) USE OF A WASHER, TYPE AND SIZE;

f) TORQUE TO BE USED TO SECURE THE CONNECTOR TO THE TANG.

g) EQUALIZERS ON BOTH ENDS TO BE THE SAME TYPE (EITHER WELDED OR COMPRESSION).

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

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

9.2 Current-cycling

9.2.1 For an equipment wiring terminal intended for paralleling conductors, the current-on time shall be the time it takes for the equipment wiring terminal to reach stable temperatures. The current-off time shall be the time it takes to reach room temperature. Forced-air cooling may be employed to reduce the current-off time with the concurrence of those concerned. These times shall be determined in the first 25 cycles of operation as follows:

a) For all iterations of the first 25 cycles of operation, the time to stabilization shall be recorded.

b) The time to stabilization during each cycle of the first 25 cycles, for both the current-on time and current-off time, shall be the time necessary for the test specimen to attain a stable temperature as demonstrated by three readings at 10 min intervals showing no more than a 2 °C variation between any two of the readings.

c) The current-on time for the remaining 475 cycles shall be the longest interval of time to stabilization measured during the first 25 cycles of operation.

d) The current-off time for the remaining 475 cycles shall be determined by selecting the cycle with the longest interval of time for current-off time stabilization measured during the first 25 cycles of operation. The current-off time for the remaining 475 cycles shall be the first of the three readings from this longest interval of time.

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

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

9.2.4 The current-off times may be reduced after the first 25 cycles of testing to the maximum time it takes any equipment wiring terminal to reach a stable temperature during the current-off period. Forced-air cooling may be employed to reduce the current-off time with the concurrence of those concerned. This current-off period shall be determined as follows:

a) For all iterations of the first 25 cycles of operation, the time to stabilization for the current-off time shall be recorded.

b) The time to current-off time stabilization during each cycle of the first 25 cycles shall be the time necessary for the test specimen to attain a stable temperature as demonstrated by three readings at 10 min intervals showing no more than a 2 °C variation between any two of the readings.

c) The current-off time for the remaining 475 cycles shall be determined by selecting the cycle with the longest interval of time for current-off time stabilization measured during the first 25 cycles of operation. The current-off time for the remaining 475 cycles shall be the first of the three readings from this longest interval of time.

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

9.3 Static-heating sequence

9.3.1 Static-heating test

9.3.1.1 Specimens shall be selected and prepared as described in Clause 8 and 9.1.8, except that equalizers shall not be used as it is necessary to insert the open end of the conductor through a bushing for the secureness test. A busbar sized in accordance with 9.1.7.3 may be used to facilitate connection between test conductors.

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

9.3.2 Secureness test

9.3.2.1 An equipment wiring terminal shall be fastened to a length of conductor not less than 76 mm (3 in) longer than the height specified in Table 9.13, and shall be rigidly secured in a vertical position simulating actual service conditions. The free end of the conductor shall be passed through a bushing of the size specified in Table 9.13. The bushing shall be attached to an arm driven by a motor at a rate of approximately 9 rpm and in such a manner that the center of the bushing describes a circle in a horizontal plane. See Figure 9.4. The circle shall have a diameter of 76 mm (3 in), and its center shall be vertically below the center of the conductor opening in the equipment wiring terminal. The distance between the upper side of the bushing and the mouth of the equipment wiring terminal shall be within 12.7 mm (1/2 in) of height specified in Table 9.13. The bushing may either be lubricated or have a hole of a slightly larger diameter than specified in Table 9.13 so there is no binding, twisting, or rotation of the conductor. A mass as specified in Table 9.13 shall be suspended from the free end of the conductor.

Table 9.13
Secureness Test Values

Size of conductor		Diameter of bushing hole[a]		Height		Mass			
						Copper		Aluminum/Copper-clad aluminum	
AWG or kcmil	(mm^2) mm^2	mm	(in)	mm	(in)	kg	(lb)	kg	(lb)
18	(0.82)	6.4	(1/4)	260[b]	(10-1/4)[b]	0.45	(1)	–	–
	1.0	6.4	(1/4)	260	(10-1/4)	0.45	(1)	–	–
16	(1.3)	6.4	(1/4)	260[b]	(10-1/4)[b]	0.45	(1)	–	–
	1.5	6.4	(1/4)	260	(10-1/4)	0.45	(1)		
14	(2.1)	9.5	(3/8)	279[b]	(11)[b]	0.68	(1.5)	–	–
	2.5	9.5	(3/8)	279	(11)	0.9	(2)	–	–
12	(3.3)	9.5	(3/8)	279[b]	(11)[b]	0.9	(2)	0.7	(1.5)
	4	9.5	(3/8)	279[b]	(11)[b]	0.9	(2)	0.7	(1.5)
10	(5.3)	9.5	(3/8)	279[b]	(11)[b]	1.4	(3)	0.7	(1.5)
	6	9.5	(3/8)	279[b]	(11)[b]	1.5	(3.3)	0.9	(2)
8	(8.4)	9.5	(3/8)	279[b]	(11)[b]	2.0	(4.5)	1.4	(3)
	10	9.5	(3/8)	279[b]	(11)[b]	2.3	(5.1)	2.2	(4.9)

Table 9.13 Continued on Next Page

Table 9.13 Continued

Size of conductor		Diameter of bushing hole[a]		Height		Mass			
						Copper		Aluminum/Copper-clad aluminum	
AWG or kcmil	(mm²) mm²	mm	(in)	mm	(in)	kg	(lb)	kg	(lb)
6	(13.3)	12.7	(1/2)	298[b]	(11-3/4)[b]	2.9	(6.5)	4.0	(9)
	16	12.7	(1/2)	298[b]	(11-3/4)[b]	3.4	(7.5)	4.2	(9.3)
4	(21.2)	12.7	(1/2)	298[b]	(11-3/4)[b]	4.5	(10)	4.5	(10)
	25	12.7	(1/2)	298	(11-3/4)	5.5	(12)	5.5	(12)
3	(26.7)	14.3	(9/16)	318	(12-1/2)	5.9	(13)	5.9	(13)
2	(33.6)	14.3	(9/16)	318	(12-1/2)	6.8	(15)	6.8	(15)
	35	14.3	(9/16)	318	(12-1/2)	7.1	(16)	7.1	(16)
1	(42.4)	15.8	(5/8)	343	(13-1/2)	8.6	(19)	8.6	(19)
	50	15.8	(5/8)	343	(13-1/2)	9.2	(20)	9.2	(20)
1/0	(53.5)	15.8	(5/8)	343	(13-1/2)	9.5	(21)	9.5	(21)
2/0	(67.4)	19.1	(3/4)	368	(14-1/2)	10.4	(23)	10.4	(23)
	70	19.1	(3/4)	368	(14-1/2)	11	(24)	11	(24)
3/0	(85.0)	19.1	(3/4)	368	(14-1/2)	14.0	(31)	13.6	(30)
	95	19.1	(3/4)	368	(14-1/2)	14	(31)	13.6	(30)
4/0	(107)	19.1	(3/4)	368	(14-1/2)	14.0	(31)	13.6	(30)
	120	22.2	(7/8)	406	(16)	14.0	(31)	13.6	(30)
250	(127)	22.2	(7/8)	406	(16)	14.0	(31)	13.6	(30)
	150	22.2	(7/8)	406	(16)	14.8	(33)	15.0	(33)
300	(156)	22.2	(7/8)	406	(16)	15.0	(33)	15.4	(34)
350	(177)	25.4	(1)	432	(17)	16.8	(37)	17.2	(38)
	185	25.4	(1)	432	(17)	16.8	(37)	17.2	(38)
400	(203)	25.4	(1)	432	(17)	16.8	(37)	17.2	(38)
	240	28.6	(1-1/8)	432	(17)	19.2	(42)	19.6	(43)
500	(253)	28.6	(1-1/8)	464	(18-1/4)	20.0	(44)	20.4	(45)
	300	28.6	(1-1/8)	464	(18-1/4)	20.0	(44)	20.4	(45)
600	(304)	28.6	(1-1/8)	464	(18-1/4)	20.0	(44)	20.4	(45)
	350	31.8	(1-1/4)	495	(19-1/2)	22.5	(50)	21.7	(48)
700	(354)	31.8	(1-1/4)	495	(19-1/2)	22.7	(50)	21.8	(48)
750	(380)	31.8	(1-1/4)	495	(19-1/2)	22.7	(50)	24.5	(54)
	400	34.9	(1-3/8)	540	(21-1/4)	24.5	(54)	24.5	(54)
800	(406)	34.9	(1-3/8)	540	(21-1/4)	25.0	(55)	24.5	(54)
900	(456)	34.9	(1-3/8)	540	(21-1/4)	25.0	(55)	25.0	(55)
	500	38.1	(1-1/2)	565	(22-1/4)	25.0	(55)	25.0	(55)
1 000	(508)	38.1	(1-1/2)	565	(22-1/4)	25.0	(55)	25.0	(55)
	630	44.5	(1-3/4)	660	(26)	33.6	(74)	336	(74)
1 250	(635)	44.5	(1-3/4)	660	(26)	34.0	(75)	34.0	(75)
1 500	(759)	50.8	(2)	711	(28)	41.0	(90)	41.0	(90)

Table 9.13 Continued on Next Page

Table 9.13 Continued

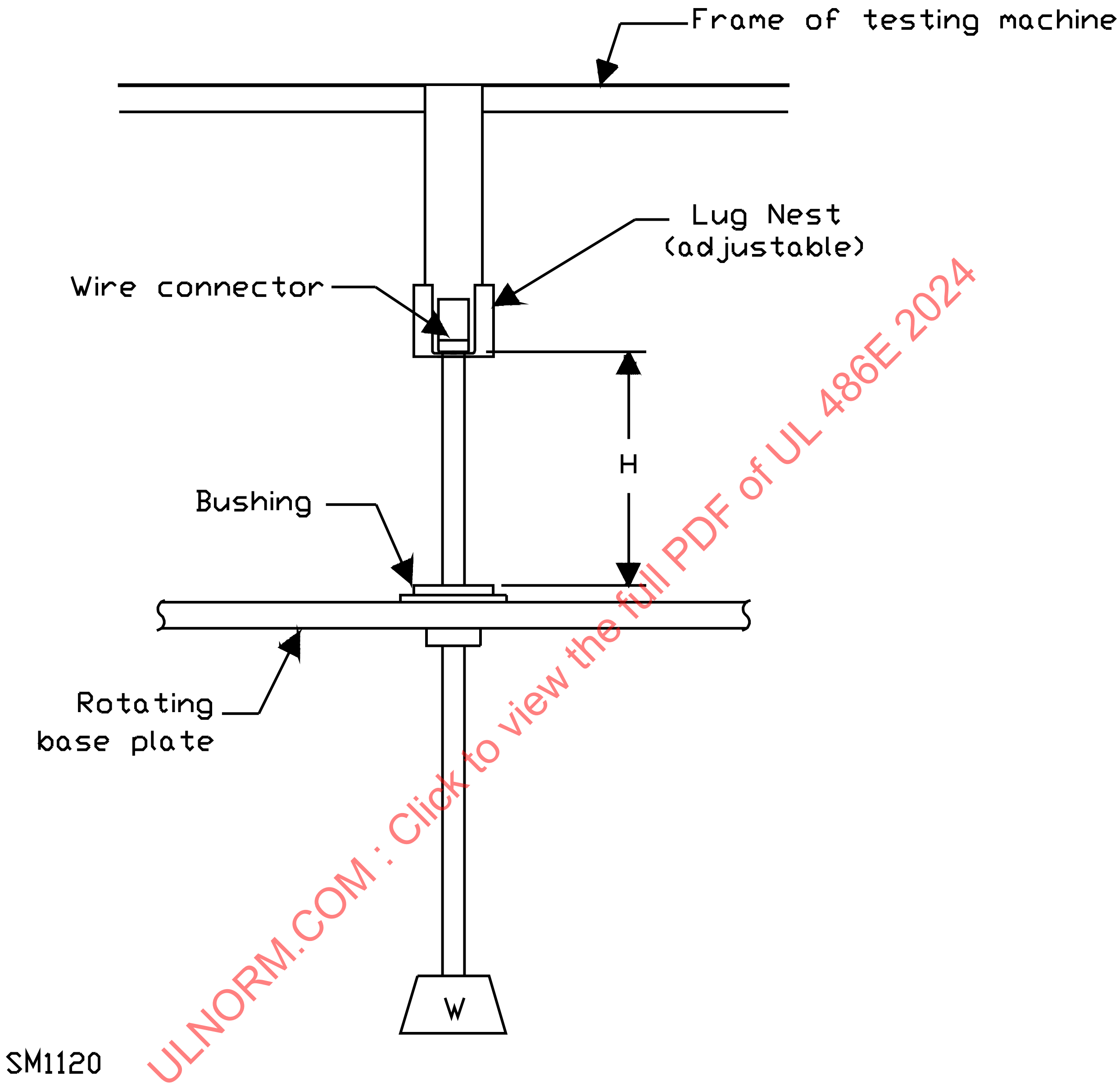
Size of conductor		Diameter of bushing hole[a]		Height		Mass			
						Copper		Aluminum/Copper-clad aluminum	
AWG or kcmil	(mm^2) mm^2	mm	(in)	mm	(in)	kg	(lb)	kg	(lb)
	800	54.0	(2-1/8)	762	(30)	42.3	(93)	42.3	(93)
1 750	(886)	54.0	(2-1/8)	762	(30)	45.0	(99)	45.0	(100)
	1 000	54.0	(2-1/8)	762	(30)	53.8	(119)	54.2	(119)
2 000	(1 010)	54.0	(2-1/8)	762	(30)	54.0	(119)	54.4	(120)

[a] A slightly larger diameter bushing or lubrication may be used to ensure there is no binding, twisting, or rotation of the conductor. See 9.3.2.1.

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

Figure 9.4

Secureness Test Setup



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

9.3.2.3 For an equipment wiring terminal intended for paralleling conductors, the test shall be performed on four specimens of entry hole if all conductor entry holes are identical in construction. If entry holes are not identical, then the test shall be repeated using four different entry holes to represent the different constructions.

9.3.3 Repeated static-heating test

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

9.3.3.2 With reference to 9.3.3.1, an equipment wiring terminal designed for paralleling conductors need not be subjected to this test.

9.3.4 Pullout test

9.3.4.1 The same equipment wiring terminals and entry holes subjected to the secureness test shall be subjected to a direct pull of the applicable value specified in Table 9.14. For an equipment wiring terminal intended to secure more than one conductor at a time by a single clamping means, only those conductors that have been subjected to the secureness test shall be subjected to the pullout test.

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

Table 9.14
Pullout Test Values

Size of conductor		Pullout force, N (lb)			
AWG or kcmil	(mm^2) mm^2	Copper		Aluminum/Copper-clad aluminum	
30	(0.05)	2.2	(1-1/2)	–	–
28	(0.08)	4.5	(1)	–	–
26	(0.13)	8.9	(2)	–	–
24	(0.20)	13.4	(3)	–	–
22	(0.32)	20	(4.5)	–	–
	0.5	29	(6.5)		
20	(0.52)	30	(6.75)	–	–
	0.75	30	(6.75)		
18	(0.82)	30	(6.75)	–	–
	1.0	34	(7.64)		
16	(1.3)	40	(9)	–	–
	1.5	42.5	(9.5)		
14	(2.1)	50	(11.5)	–	–
	2.5	53	(11.9)		

Table 9.14 Continued on Next Page

Table 9.14 Continued

Size of conductor		Pullout force, N (lb)			
AWG or kcmil	(mm^2) mm^2	Copper		Aluminum/Copper-clad aluminum	
12	(3.3)	60	(13.5)	44	(10)
	4	67	(15.1)	44	(10)
10	(5.3)	80	(18.0)	44	(10)
	6	82	(18.4)	44	(10)
8	(8.4)	90	(20.5)	44	(10)
	10	91	(20.5)	70	(15.7)
6	(13.3)	94	(21)	124	(28)
	16	107	(24.1)	136	(30.6)
4	(21.2)	133	(30)	160	(36)
	25	149	(33.5)	179	(40.2)
3	(26.7)	156	(35)	187	(42)
2	(33.6)	186	(42)	222	(50)
	35	194	(43.6)	230	(51.7)
1	(42.4)	236	(53)	271	(61)
	50	270	(60.7)	305	(68.6)
1/0	(53.5)	285	(64)	320	(72)
2/0	(67.4)	285	(64)	347	(78)
	70	295	(66.3)	360	(80.9)
3/0	(85.0)	351	(79)	432	(97)
	95	386	(86.8)	470	(106)
4/0	(107)	427	(96)	516	(116)
	120	427	(96)	516	(116)
250	(127)	427	(96)	516	(116)
	150	438	(98.5)	516	(116)
300	(156)	441	(99)	516	(116)
350	(177)	503	(113)	574	(129)
	185	503	(113)	574	(129)
400	(203)	503	(113)	574	(129)
	240	559	(126)	656	(148)
500	(253)	578	(130)	685	(154)
	300	578	(130)	685	(154)
600	(304)	578	(130)	685	(154)
	350	638	(143)	785	(177)
700	(355)	645	(145)	796	(179)
750	(380)	690	(155)	796	(179)
	400	690	(155)	796	(179)
800	(405)	690	(155)	796	(179)
900	(456)	702	(158)	805	(181)

Table 9.14 Continued on Next Page

Table 9.14 Continued

Size of conductor		Pullout force, N (lb)			
AWG or kcmil	(mm^2) mm^2	Copper		Aluminum/Copper-clad aluminum	
	500	768	(173)	874	(197)
1000	(507)	778	(175)	885	(199)
	630	961	(216)	1 111	(250)
1250	(633)	965	(217)	1 116	(251)
1500	(760)	1 174	(264)	1 343	(302)
	800	1 233	(277)	1 404	(316)
1750	(877)	1 347	(303)	1 521	(342)
	1 000	1 508	(316)	1 686	(379)
2000	(1010)	1 521	(342)	1 699	(382)

9.4 Mechanical sequence

9.4.1 Secureness test

9.4.1.1 The test procedure described in 9.3.2 shall be conducted.

9.4.2 Pullout test

9.4.2.1 The test procedure described in 9.3.4 shall be conducted.

9.5 Stress corrosion/moist ammonia (NH_4)

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

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

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

9.6 Stress corrosion/mercurous nitrate ($HgNO_3$)

9.6.1 Specimens shall be immersed in an aqueous solution of 100 g of mercurous nitrate and 13 ml of nitric acid (specific gravity of 1.42) per liter for 15 min. Insulation that covers the copper alloy under test shall not be included as part of the test specimens. Evidence of cracking shall be determined with normal or corrected vision without magnification.

10 Marking, Labeling, and Packaging

10.1 Required marking locations shall be in accordance with 10.3 – 10.31. Refer to Annex D as a guide for marking locations.

10.2 The requirements in 10.3 – 10.31 are applicable to equipment wiring terminals which are not an integral part of the equipment. For marking of equipment wiring terminals which are an integral part of the equipment, refer to the appropriate equipment standard.

10.3 A equipment wiring terminal shall be legibly marked with:

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

b) A distinctive catalog number or the equivalent; and

c) The conductor size or ranges of sizes.

10.4 In lieu of the markings in 10.3 (b) or (c), or both, an equipment wiring terminal that is for use only with conductors smaller than 8 AWG (8.4 mm^2) / 10 mm^2 shall be marked with a single identifying symbol. This symbol may be an individual catalog number, a type designation, a size designation, such as 12, or an equivalently significant symbol. Each unit container containing equipment wiring terminals so identified or an information sheet packed in the unit container shall be marked with the information specified in 10.3 (a), (b), and (c). A type designation is intended primarily to identify a particular design, which may include various features covered by different catalog numbers.

10.5 With reference to 10.3(c), the conductor-size marking on an equipment wiring terminal intended for assembly to a conductor(s) by means of a specific tool may be a symbol or color, provided that its significance, in terms of a conductor size or sizes, is clearly marked on the tool (die).

10.6 An equipment wiring terminal intended for copper conductor only shall be legibly marked with ″CU″ on:

a) The equipment wiring terminal;

b) Its unit container; or

c) An information sheet packed in the unit container.

10.7 An equipment wiring terminal rated for use with aluminum conductor only shall be legibly marked with the letters ″AL″. In lieu of the marking on the equipment wiring terminal, for equipment wiring terminals used with 6 AWG (13.3 mm^2) / 16 mm^2 or smaller conductors, the letters ″AL″ may be marked on the unit container or on an information sheet packed in the unit container.

10.8 An equipment wiring terminal intended for use with aluminum and copper conductor shall be legibly marked ″AL-CU″ or ″CU-AL″. An equipment wiring terminal intended for use with aluminum or copper-clad aluminum and copper wire shall be plainly marked ″AL-CU″ or ″CU-AL.″ An equipment wiring terminal intended for use with copper-clad aluminum and copper wire shall be plainly marked ″CC-CU″ or ″CU-CC.″ In lieu of the marking on the equipment wiring terminal, for equipment wiring terminals used with 6 AWG (13.3 mm^2) / 16 mm^2 or smaller conductors, the letters ″AL-CU″ , ″CU-AL″, ″CC-CU″ or ″CU-CC" may be printed on the unit container or on an information sheet packed in the unit container.

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

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

a) The maximum wire size for both copper and aluminum is the same; and

b) The minimum aluminum wire size for both copper and aluminum is the same or the minimum copper wire size is smaller than 12 AWG (3.31 mm^2) / 4 mm^2.

Note: It is understood that the minimum available aluminum conductor size is 12 AWG (3.31 mm^2) / 4 mm^2, even though a wire range may include smaller copper wire sizes. For example: a wire range of 1/0 – 14 AWG (53.5 – 2.08 mm^2) / 50 – 2.5 mm^2 is interpreted as 1/0 – 14 AWG (53.5 – 2.08 mm^2) 50 – 2.5 mm^2 copper conductors and 1/0 – 12 AWG (53.5 – 3.31 mm^2) 50 – 4 mm^2 aluminum conductors.

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

a) The equipment wiring terminal;

b) Its unit container; or

c) An information sheet packed in the unit container.

10.12 An equipment wiring terminal, a unit container, or an information sheet packed in the unit container for an equipment wiring terminal tested with conductors other than Class B or Class C stranding (see 9.1.5.5) shall also be marked with the conductor class or classes.

10.13 An equipment wiring terminal tested with a solid or stranded conductor other than as specified in 8.1.6 shall be marked ″Solid″ or ″Stranded″ or with both markings as applicable. See 10.14.

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

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

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

10.15 A procedure that must be followed for proper assembly of an equipment wiring terminal to a conductor shall be provided as follows:

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

1) Catalog or type designation;

2) Color coding;

3) Die index number; or

4) Other equivalent means.

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

1) On the unit container in which the equipment wiring terminal 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 equipment wiring terminal.

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

c) **CONDUCTOR STRIP LENGTH** – Strip length marking as specified in Table 9.5 shall appear:

1) On the equipment wiring terminal;

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

3) On an insulating cover; or

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

i) The equipment wiring terminal requires the use of a specific tool for its application; and

ii) The strip length applies to all equipment wiring terminals with which the tool is used.

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

10.16 Copper-bodied equipment wiring terminals intended for copper conductors only are rated 90 °C and are not required to be marked with an equipment wiring terminal temperature rating.

10.17 An aluminum-bodied equipment wiring terminal intended for copper conductors only (see 7.1.12) shall be marked with an equipment wiring terminal temperature rating in accordance with 10.18 (e.g., CU75, CU7, CU90, or CU9).

10.18 An equipment wiring terminal rated for AL or AL-CU shall be marked with the equipment wiring terminal temperature rating, 75 °C or 90 °C, as tested in the current-cycling test. In lieu of the marking on the equipment wiring terminal, for equipment wiring terminals used with 6 AWG (13.3 mm^2) or smaller conductors, the temperature rating shall be printed on the unit container or on an information sheet packed in the unit container.

10.19 With reference to 10.18, a 7 may be used to represent a 75 °C marking and a 9 may be used to represent a 90 °C marking. For an equipment wiring terminal marked for use with only aluminum, the single digit shall follow the letters; for example, ″AL7.″ The 7 or 9 shall be incorporated in place of the dash in a marking such as ″AL-CU″ or ″CU-AL″; for example, ″AL7CU″ or ″CU7AL.″

10.20 An equipment wiring terminal intended for intermixing between conductor types shall be additionally marked ″(intermixed – dry locations)″ immediately following the marking in 10.18 or 10.19; for example, AL7CU (intermixed – dry locations). See 6.1.6.

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

10.22 If the equipment wiring terminal has an assigned tightening torque value, as described in 9.1.9.5, the assigned value shall be marked where readily visible on:

a) The equipment wiring terminal;

b) The unit container; or

c) An information sheet packed in the unit container.

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

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

a) The manufacturer's name; and

b) A distinctive catalog number of the equipment wiring terminal or the equivalent if the marking is provided as specified in 10.27.

10.25 An equipment wiring terminal 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 equipment wiring terminal, unit container, or information sheet within the unit container.

10.26 An equipment wiring terminal rated for use with metric conductors shall be marked in close proximity to the metric wire range marking with the following, as applicable:

a) "Class 1" or "Rigid Solid";

b) "Class 2" or "Rigid Stranded";

c) "Class 1 and 2," "Rigid Solid and Stranded," or the letter "r" for rigid solid and rigid stranded;

d) "Class 5";

e) "Class 6"; or

f) "Class 5 and 6," "Flexible," or the letter "f" for flexible.

A connector rated for rigid, solid, rigid stranded, and both Class 5 and 6 flexible conductors need not be marked. "Solid" and "Stranded" may be abbreviated as "Sol" and "Str" respectively.

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

10.28 With reference to 10.27, a unit container of ten or fewer equipment wiring terminals may be marked with a reference to an identifying number on an information sheet as described in 10.30.

10.29 The information sheet mentioned in 10.27 shall be marked with the manufacturer's name, an identifying number as mentioned in 10.28, the catalog number of the equipment wiring terminal to which it pertains or equivalent, and all the necessary information required by 10.14(b), 10.15, 10.18, 10.22, and 10.23. The information sheet, one for each unit container, shall be packed in the packaging container.

10.30 Equipment wiring terminals additionally rated for 2 AWG (33.6 mm^2) / 35 mm^2 and larger compact copper shall be marked ″For compact-stranded copper conductors″ or the equivalent on the equipment wiring terminal, unit container, or an information sheet packed in the unit container.

10.31 A unit container shall be marked with the following, ″These equipment wiring terminals may only be used with specific equipment for which it has been found acceptable.″

10.32 As an alternative, any markings permitted to be printed on the unit container or on an information sheet packed in the unit container may be provided online if marked with the webpage URL, a QR code, or other markings providing the necessary information.

ANNEX A (Informative) – INFORMATIVE REFERENCES

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

ASTM* Standards

ASTM B8-99, *Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*

ASTM B154-95, *Standard Test for Method for Mercurous Nitrate Test for Copper and Copper Alloys*

ASTM B172-95, *Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors*

ASTM B173-95, *Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors*

ASTM B174-95, *Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors*

ASTM B230/B230M-99, *Standard Specification for Aluminum 1350-H19 Wire for Electrical Purposes*

ASTM B231/B231M-99, *Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors*

ASTM B400-94, *Standard Specification for Compact Round Concentric-Lay-Stranded Aluminum 1350 Conductors*

ASTM B496-99, *Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors*

ASTM B609/B609M-99, *Standard Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes*

ASTM B638-99, *Standard Test Method for Tensile Properties of Plastics*

ASTM B800-05 (2015), *Standard Specification for 8000 Series Aluminum Alloy Wire for Electrical Purposes – Annealed and Intermediate tempers*

ASTM B801-07 (2012), *Standard Specification for Concentric-Lay-Stranded Conductors of 8000 Series Aluminum Alloy for Subsequent Covering or Insulation*

ASTM B836-00 (2011), *Standard Specification for Compact Round Stranded Aluminum Conductors Using Single Input Wire Construction*

ASTM B901-04 (2011), *Standard Specification for Compressed Round Stranded Aluminum Conductors Using Single Input Wire Construction*

IEC† Standards

IEC 60228 (1978-01), *Conductors of Insulated Cables*

IEC 60228A (1993-01), *Conductors of Insulated Cables* Amendment No. 1.

*American Society for Testing and Materials.

†International Electrotechnical Commission.