AMERICAN NATIONAL STANDARD

American National Standard

ANSI C119.4-1998

American National Standard

for Electric Connectors

Connectors to Use Between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Conductors

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
1300 NORTH 17TH STREET, SUITE 1847, ROSSLYN, VA 22209
(703) 841-3200 FAX: (703) 841-3300

ANSI C119.4-1998

American National Standard

for Electric Connectors

Connectors for Use Between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Conductors

Secretariat

National Electrical Manufacturers Association

Approved November 20, 1998

American National Standard

Approval of an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by the standards developer.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

The use of American National Standards is completely voluntary; their existence does not in any respect preclude anyone, whether he has approved the standards or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standards.

The American National Standards Institute does not develop standards and will in no circumstances give an interpretation of any American National Standard. Moreover, no person shall have the right or authority to issue an interpretation of an American National Standard in the name of the American National Standards Institute. Requests for interpretations should be addressed to the secretariat or sponsor whose name appears on the title page of this standard.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Published by

National Electrical Manufacturers Association
1300 N. 17th Street, Rosslyn, Virginia 22209

Foreword (This foreword is not part of ANSI C119.4-1998.)

This standard describes current cycle and mechanical tests used to establish performance characteristics of connectors used to join aluminum-to-aluminum or aluminum-to-copper bare overhead conductors.

This revision incorporates an alternate, accelerated current cycle test method, hence forth referred to as the current cycle submersion test (CCST). The CCST method differs from the traditional current cycle test in that test conductors are rapidly cooled by immersion in chilled water at the beginning of the current OFF cycle and requires fewer total current ON and current OFF cycles. Comparative testing has demonstrated that the CCST method will provide essentially the same performance test results as the traditional current cycle test (CCT) in fewer test cycles. The current cycle test remains the preferred test method recommended for qualification of a connector.

This revision also incorporates an additional current cycle test method (CCT) utilizing elevated temperature testing for an extra heavy duty connector category, Class AA. The intent of elevated test temperature in Class AA testing is to provide a better performing connector.

Experience gained from extensive trial use further confirmed the performance criteria and test conditions of the tentative specifications and led to the development of a standard in October 1962 by a joint committee of EEI and the National Electrical Manufacturers Association (NEMA).

The Subcommittee on Overhead Connectors of the Accredited Standards Committee on Connectors for Electric Utility applications, C119, in its constant review of the publication, continues to seek out the views of responsible users that will contribute to the development of better standards.

Suggestions for improvement of this standard are welcome. They should be sent to the National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, Virginia 22209.

This standard was processed and approved for submittal to ANSI by the Accredited Standards Committee on Connectors for Electrical Utility Applications, C119. Committee approval of this standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the C119 Committee had the following members:

Robert J. Gurniak, Chair

Khaled Masri, Secretary

Organization Represented	*Name of Representative*
Aluminum Association	P. Pollak
Edison Electric Institute	R. Gurniak
	J. Harris
	H. Hayes
	G. Miller
	D. West
Institute of Electrical & Electronics Engineers	Vacant
International Brotherhood of Electrical Workers	Vacant

National Electrical Manufacturers Association .... R. Lai
D. Rolling
W. Scharer
F. Stepniak
Vacant

Tennessee Valley Authority .... J. Nelson

Underwriters Laboratories, Inc .... J. Killinger

U.S. Department of Agriculture .... H. Bowles

U.S. Department of the Army .... J. Gilson

U.S. Department of the Navy .... Vacant

The Subcommittee on Overhead Connectors, which developed the revisions of this standard, had the following members:

R.Gurniak, Chair
R. Lai, Vice Chair

J. Angelis
N. Annas
C. Baker
G. Beaudry
D. Bowden
H. Bowles
H. Cherry
G. Dauberger
C. Ek
J. Farrington
R. Gurniak
B. Johnson
M. Johnson
J. Killinger
D. Kovarik
R. Lai
R. Macdonald
W. Martin
G. Mathews
E. Mcgrane
T. Mckoon
G. Menchella
B. Molitor
R. Morin
D. Nardone
G. Neinaber
R. Oedemann
K. Rogers
B. Rosolowski
E. Schneider
E. Schutte
J. Sprecher
G. Swinehart
R. Waidelich
D. West
T. Woronik
J. Zahnen

Contents

Tables

AMERICAN NATIONAL STANDARD

for Connectors for Use between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Conductors

1 Scope and purpose

1.1 Scope

This standard covers connectors used for making electrical connections between aluminum-to-aluminum or aluminum-to-copper bare conductors used on overhead distribution and transmission lines for electric utilities.

This standard establishes the electrical and mechanical test requirements for electrical connectors. This standard is not intended to recommend operating conditions or temperatures.

1.2 Purpose

The purpose of the standard is to give reasonable assurance to the user that connectors meeting the requirements of this standard will perform in a satisfactory manner, provided they have been properly selected for the intended application and are installed in accordance with the manufacturer's recommendations. The service operating conditions and the selection of the connector class is the responsibility of the user.

Although there are 12 possible combinations of electrical and mechanical classes listed in this standard, it is intended that four to six combinations will meet the usual requirements for a given range of conductor sizes. This does not, however, prohibit other combinations.

2 Referenced standards

This standard is intended to be used in conjunction with the following standards:

ASTM B1-90,	Hard Drawn Copper Wire[1]
ASTM B2-88,	Medium Hard Drawn Copper Wire[1]
ASTM B8-86,	Concentric-Lay-Stranded Copper Conductor, Hard, Medium Hard, or Soft[1]
ASTM B228-88,	Concentric-Lay-Stranded Copper Clad Steel Conductors[1]
ASTM B229-90,	Concentric-Lay-Stranded Copper and Copper Clad Steel Composite Conductors[1]
ASTM B230-89,	Aluminum 1350-H19 Wire for Electrical Purposes[1]
ASTM B231-90,	Concentric-Lay-Stranded (AAC) Aluminum 1350 Conductors[1]
ASTM B232-92,	Concentric-Lay-Stranded Aluminum Conductors, Coated, Steel-Reinforced (ACSR)[1]
ASTM B341-88,	Aluminum-Coated (Aluminized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR/AZ)[1]

[1]Available from ASTM, 1916 Race Street, Philadelphia, PA 19103.

ASTM B396-87, Aluminum-Alloy 5005-H19 Wire for Electrical Purposes[1]

ASTM B397-85 (1992), Concentric-Lay-Stranded Aluminum-Alloy 5005-H19 Conductors[1]

ASTM B398-90, Aluminum-Alloy 6201-T-81 Wire for Electrical Purposes[1]

ASTM B399-92, Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors[1]

ASTM B400-92, Compact Round Concentric-Lay-Stranded 1350 Aluminum Conductors[1]

ASTM B401-92, Compact Round Concentric-Lay-Stranded Aluminum Conductors, Steel Reinforced (ACSR/COMP)[1]

ASTM B415-92, Hard-Drawn Aluminum-Clad Steel Wire[1]

ASTM B416-88, Concentric-Lay-Stranded Aluminum-Clad Steel Conductors[1]

ASTM B498-88, Zinc-Coated (Galvanized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR)[1]

ASTM B500-92, Zinc-Coated (Galvanized) and Aluminum-Coated (Aluminized) Stranded Steel Core for Aluminum Conductors, Steel-Reinforced (ACSR)[1]

ASTM B502-88, Aluminum-Clad Steel Core Wire for Aluminum Conductors, Aluminum-Clad, Steel-Reinforced[1]

ASTM B524-87, Concentric-Lay-Stranded, Aluminum Conductors, Aluminum Alloy Reinforced (ACAR and 1350/6201)[1]

ASTM B549-88, Concentric-Lay-Stranded, Aluminum Conductors, Aluminum-Clad Steel Reinforced (ACSR/AW)[1]

ASTM B606-88, High-Strength Zinc-Coated (Galvanized) Steel Core Wire for Aluminum and Aluminum-Alloy Conductors, Steel Reinforced[1]

ASTM B609-91, Aluminum 1350 Round Wire, Annealed and Intermediate Tempers for Electrical Purposes[1]

ASTM B701-91, Concentric-Lay-Stranded Self-Damping Aluminum Conductors, Steel Reinforced (ACSR/SD)[1]

ASTM B778-92, Shaped Wire Compact Concentric-Lay-Stranded Aluminum Conductors (AAC/TW)[1]

ASTM B779-91, Shaped Wire Compact Concentric-Lay-Stranded Aluminum Conductors, Steel Reinforced (ACSR/TW)[1]

ASTM E4-89, Practices for Load Verification of Testing Machines[1]

3 Test conditions

3.1 General

Connectors shall be installed and tested for current-carrying and mechanical performance in accordance with the conditions noted in clauses 5 through 7.

3.2 Current cycle tests

Tests shall be conducted in accordance with clause 6 and shall be of the duration listed in Table 1, depending on the current class of the connector and the choice of test method (Current Cycle Test (CCT) or Current Cycle Submersion Test (CCST)).

Table 1 – Test duration

Connector Class	Number of Test Cycles for:	
	CCT Method	CCST Method
Extra heavy duty (Class AA)	500	NA
Heavy duty (Class A)	500	100
Medium duty (Class B)	250	75
Light duty (Class C)	125	50

3.3 Mechanical tests

Tests of tensile strength of the connection, reusability of the connector, and effect on the strength of the in-line conductor shall be conducted in accordance with clause 7 for the strength class as listed.

Full tension—Class 1
Partial tension—Class 2
Minimum tension—Class 3

4 Performance

4.1 General

Connectors shall conform to the appropriate performance requirements in 4.2 through 4.7, when installed and tested in accordance with the methods specified in clauses 5 through 7.

4.2 Resistance

The resistance of the connection tested in accordance with clause 6 shall be stable. Stability is achieved if any resistance measurement, including allowance for measurement error, does not vary by more than ±5% from the average of all the measurements at specified intervals during the course of the test.

4.2.1 CCT resistance

The resistance of the connection tested by the Current Cycle Test method in accordance with clause 6 shall be stable between the twenty-fifth cycle and the completion of the number of current cycles required in 3.2 for the connector class tested.

4.2.2 CCST resistance

The resistance of the connection tested by the Current Cycle Submersion Test method in accordance with clause 6 shall be stable between the tenth cycle and the completion of the number of current cycles required in 3.2 for the connector class being tested.

4.3 Temperature

The temperature of the connector tested in accordance with clause 6 shall not exceed the temperature of the control conductor. The temperature difference between the control conductor and the connector shall be stable. Stability is achieved if any temperature difference between the control conductor and the connector, including allowance for measurement error, is not more than 10°C below the average of all temperature differences in this interval.

4.3.1 CCT temperature

The temperature of the connector tested by the Current Cycle Test method shall be stable between the twenty-fifth cycle and the completion of the number of current cycles required in 3.2 for the connector class being tested.

4.3.2 CCST temperature

The temperature of the connector tested by the Current Cycle Submersion Test method shall be stable between the tenth cycle and the completion of the number of current cycles required in 3.2 for the conductor class being tested.

4.4 Tensile strength and rated conductor strength

4.4.1 Tensile strength

The tensile strength of the connections tested in accordance with 7.3.4.1 shall be equal to or greater than the values listed in 4.4.3.

4.4.2 Rated conductor strength

Rated conductor strength, as used in this standard, shall be determined in accordance with the applicable ASTM standard listed in clause 2, or as furnished by the conductor manufacturer for nonstandard conductors.

4.4.3 Classes of tensile strength

4.4.3.1 Class 1, full tension

95% of the rated conductor strength of the weaker of the conductors being joined. A conductor shall be considered a failure when at least one strand breaks. Connectors that do not have separate gripping means for the different metals of composite conductors or that use nonferrous means on ferrous conductors or cores shall first be tested in accordance with 7.3.3.1 without slippage or breakage after the sustained load has been completed.

4.4.3.2 Class 2, partial tension

40% of the rated conductor strength of the weaker of the conductors being joined.

4.4.3.3 Class 3, minimum tension

5% of the rated conductor strength of the weaker of the conductors being joined but not less than the values in Table 2.

Table 2 – Tensile load

Wire Size	Pullout Load (lb_f)		
(AWG)	Copper	Aluminum	ACSR
16	30	15	---
14	50	25	---
12	70	35	---
10	80	40	---
8	90	45	100
6	100	50	100
4	140	70	150
3	160	80	150
2	180	90	200
1	200	100	200

4.5 Reusable connectors

Upon completion of all tests, a connector which is designated by the manufacturer to be reusable shall still function as originally designed. Reusable means that the connector may be removed from service and installed again. Prior to reuse, any reusable connector shall be reconditioned in accordance with manufacturer's instructions.

4.6 Tap connector

A tap connection satisfies the mechanical requirement if, after performing the conductor damage test in 7.5, the run conductor retains at least 90% of its rated breaking strength.

4.7 Torque requirements

A bolted connector shall withstand 120% of the manufacturer's tightening torque or, in the absence of such, those shown in Table 3 without damage to any component part. Damage is defined as a crack, detected by visual means (see 7.4).

Table 3 – Tightening torque[1,2]

Threaded Fastener Size		Aluminum Fastener		Galvanized Steel, Stainless Steel or Silicon Bronze Fastener	
in	mm*	lb in	N m*	lb in	N m*
5/16	7.9	-	-	180	20.3
3/8	9.5	168	19.0	240	27.1
13/32	10.3	204	23.0	288	32.5
7/16	11.1	240	27.1	360	40.6
1/2	12.7	300	33.9	480	54.2
9/16	14.3	384	43.4	576	65.0
5/8	15.9	480	54.2	660	74.5

* For reference only.

[1] For use only in absence of the manufacturer's recommendation.

[2] Connectors to be installed as supplied by the manufacturer.

5 Test procedures, general

5.1 Test connectors

5.1.1 Description

A complete description of the test connectors, conductors, and inhibiting compound shall be included in the test report (see clause 8).

5.1.2 Family sample set

To qualify a family of connectors (group of connectors using similar design criteria), a minimum of three sizes (largest, smallest, and intermediate) shall be tested. When only one smaller-size connector of the same design parameter is added to a previously tested family, additional testing is not required.

5.2 Test conductors

The conductors used in these tests shall be unused bare conductors. Flat bars to which terminal connectors are bolted shall be considered conductors. The flat-bar conductor shall be the nearest size that can be bolted to the terminal and have a current capacity closest to that of the maximum conductor accommodated.

5.3 Test assembly methods

5.3.1 Installation details

All installation details, including methods and tools, not specifically defined or required in clauses 5 through 7, shall be completely described in the test report.

5.3.2 Conductor preparation for electrical tests

The outer surface of the conductors in the contact area shall be mechanically cleaned using a wire brush until the entire contact area of the conductor is clean.

5.3.3 Conductor preparation for mechanical tests

The portion of the conductor that is to be inserted into the connector shall be wiped with a particle-free cloth coated with petroleum jelly, unless the connector is used with an inhibiting compound.

5.3.4 Connector preparation

Connectors shall be prepared in accordance with the manufacturer's recommendations.

5.3.5 Connector installation

The methods and tools used to install the connector shall be in accordance with the manufacturer's recommendations. Installation shall take place in an ambient environment between 15°C (59°F) and 35°C (95° F). When clamping fasteners are used, they shall be tightened in accordance with the manufacturer's recommendations. In the absence of a recommended torque, the values specified in Table 3 shall be used.

6 Current cycle test procedures

6.1 General

Current cycle tests shall be conducted on connectors assembled in series in a loop in accordance with clause 5 and 6.2 through 6.12.2. An accelerated current cycle test method, referred to as current cycle submersion test (CCST) is offered as an alternate test method used primarily to quickly assess connector performance. The current cycle test (CCT) remains the preferred test method recommended for the qualification of a connector.

NOTE—The CCST method differs from the traditional current cycle test (CCT) in that test connectors are rapidly cooled by immersion in chilled water at the beginning of the current OFF cycle. Comparative testing has demonstrated that the CCST method will provide essentially the same performance test results as the traditional current cycle test (CCT) in fewer test cycles.

6.2 Test assembly

6.2.1 Conductors

6.2.1.1 Conductor combinations shall be selected to maximize current through the connector. If the connector is recommended for use between aluminum-to-aluminum and aluminum-to-copper conductors, it shall be tested on both combinations.

6.2.1.2 For Class AA connectors where the conductor selected limits the current, the other conductor should be sized as close to but not less than the limiting conductor current rating.

NOTE—In both 6.2.1.1 and 6.2.1.2, additional conductor combinations and current values may also be used if agreed to by both the manufacturer and user.

6.2.2 Connectors

Four connectors of the same size and type are required for each combination of conductors, as determined in 6.2.1. Terminal connectors may be connected to flat bar conductors or tang-to-tang (pad-to-pad).

6.3 Equalizers

To provide equipotential planes for resistance measurements and to prevent the influence of one connector on another, equalizers shall be installed in stranded conductor on each side of each connector in the current cycle loop, except where two terminal connectors are tested tang-to-tang (pad-to-pad). Equalizers are not required on solid conductors. Any form of equalizer that ensures permanent contact among all the conductor strands for the test duration may be used.

6.3.1 Welded equalizers

A welded equalizer is recommended for stranded aluminum conductors. Welded equalizers are made from aluminum

6.3.2 Compression sleeve equalizers

When the connectors to be tested are identical, a continuous piece of conductor may be used between the connectors, with an equalizer in the center. If a compression sleeve is employed as an equalizer with aluminum conductors, the conductor in the contact area of the equalizer should be prepared as in 5.3.1 and 5.3.2.

6.4 Conductor lengths

The exposed length of stranded conductor between the connector and the equalizer, or between the connectors of solid conductors in the current cycle loop, shall be in accordance with Table 4. If a flat bus bar is used between terminal connectors, its length shall be twice that shown in Table 4 for the stranded conductor size being used in the terminal, or the same length of the solid conductor being used in the terminal. The conductor length in Table 4 does not include the length within the connector or equalizer. In addition, where connector design permits, the conductor end shall project 1/2 inch (12.7 mm) beyond the connector contact groove. The equalizers at each end of the current cycle loop shall be joined to the power source with additional lengths of the test conductor to be not less than the lengths specified in Table 4.

Table 4 – Conductor lengths for current cycle tests

Composite Aluminum Composite	Copper or Copper Composite	Exposed Length			
		Stranded		Solid	
		in	cm*	in	cm*
Up through 4/0 AWG	Up through 2/0 AWG	12	30.5	24	61.0
Over 4/0 AWG through 795 kcmil	Over 2/0 AWG through 500 kcmil	24	61.0	48	121.9
Over 795 kcmil	Over 500 kcmil	36	91.4	72	182.9

* For reference only

6.5 Control conductor

A control conductor, for determining test current, shall be installed in the current cycle loop (between two equalizers for stranded conductors). The control conductor shall be the same type and size as the conductor in the current cycle loop that would be at the highest temperature. Its length shall be twice that given in Table 4. For Class AA, when the control cable is copper, see 6.5.2.

6.5.1 Equivalent aluminum/copper conductors

At the manufacturer's option, the size of the control conductor may be determined by selecting from Table 5 the conductor in the current cycle loop that has the least current for equivalent aluminum/copper conductors.

6.5.2 Multiple control conductors

6.5.2.1 If the test loop includes different conductors, and a question arises as to which conductor causes the highest temperature rise, a control conductor of each type is required. The test current shall cause the higher temperature rise in one of the control conductors to meet the requirements of 6.8.

6.5.2.2 For Class AA, if the conductor for determining test current is copper, then a second control conductor of aluminum shall be included for the purpose of evaluating stability. The second control cable shall be of the closest ampacity and chosen based on the values shown in Table 5. However, the copper control conductor shall be used for establishing the current within the first 25 cycles.

6.6 Loop configuration and location

6.6.1 CCT method

The current cycle loop may be of any shape, provided the connectors and the control conductor are installed in the same horizontal plane, with at least an 8-inch (20.3 cm) separation between conductors and located at least 1 foot (30.5 cm) from any wall and at least 2 feet (61 cm) from the floor and the ceiling.

NOTE—This assures that the control conductor and the connectors begin the next current ON period at the same temperature.

6.6.2 CCST method

The control conductor shall be installed on the same horizontal plane as the test connectors. During the ON period, no part of the circuit shall be less than 8 inches (20 cm) above the surface of the chilled water. At the beginning of the OFF period, the connectors and the control conductor shall be submerged to a minimum of 4 inches (10 cm) below the water surface.

NOTE—This assures that the control conductor and the connectors begin the next current ON period at the same temperature.

Table 5 – Suggested initial test current to raise control conductor temperature 100°C

Aluminum or Aluminum Composite		Copper or Copper Composite	
Conductor (AWG)	**Current (Amperes)**	**Conductor (AWG)**	**Current (Amperes)**
6	90	8	95
4	125	6	130
2	170	4	180
1	200	2	245
1/0	230	1/0	340
2/0	270	2/0	400
3/0	320	3/0	470
4/0	380	4/0	550
(kcmil)		**(kcmil)**	
266.8	450	250	615
336.4	525	300	700
397.5	590	350	780
477	670	400	850
556.5	750	500	990
636	820	750	1300
795	955	1000	1565
954	1085	-	-
1033.5	1150	-	-
1113	1220	-	-
1192	1275	-	-
1272	1350	-	-
1351.5	1390	-	-
1431	1450	-	-
1590	1560	-	-

6.7 Ambient conditions

Current cycle tests shall be conducted in a space free of forced air currents or radiated heat striking (directly or indirectly) any portion of the test loop during the current ON period. The ambient temperature shall be held between 15°C and 35°C.

6.8 Test current

The current values in Table 5 are the suggested initial test amperes for this standard for Class A, B, C and have been selected to simplify current selection in order to achieve the required temperature rise in the control conductor. For conductors larger than those shown in Table 5, the current is determined by reaching a stable temperature. These currents are not intended to suggest current values for use in actual service. Class AA test currents are established by obtaining the proper temperature rise.

6.8.1 CCT temperature conditions

The current cycle test current shall be adjusted during the current ON period of the first twenty-five cycles to result in a steady-state temperature rise on the control conductor of 100°C to 105°C over ambient temperature for Class A, B, C. The Class AA rise will be 175 to 180°C over ambient temperature. This current shall then be used during the remainder of the test current ON periods, regardless of the temperature of the control conductor.

6.8.2 CCST temperature conditions

The current cycle submersion test current shall be adjusted during the current ON period of the first five cycles to result in a steady-state temperature rise on the control conductor of 100°C to 105°C over ambient temperature. This current shall then be used during the remainder of the test current ON periods, regardless of the temperature of the control conductor.

6.8.3 CCT method elevated temperature current stabilization

The current cycle test current shall be increased from that shown in Table 5 to achieve the appropriate elevated temperature within the first twenty-five cycles.

6.8.4 CCST method elevated temperature current stabilization

The current cycle submersion test current shall be increased from that shown in Table 5 to achieve the appropriate elevated temperature within the first five cycles.

6.9 Current cycle period

Each test cycle shall consist of a current ON and a current OFF period. The time required to make resistance and temperature measurements is not considered a part of the current ON or current OFF time periods.

6.9.1 Current cycle ON period

The length of the current ON period shall be as listed in Table 6, depending on the size of the control conductor. For conductors larger than those shown in Table 6, the current ON time is determined by reaching and maintaining thermal stability in the connector. Thermal stability is defined as not more than a variation of 2°C between any two of three readings taken at not less than 10-minute intervals.

Table 6 – Current cycle periods for control conductors

Aluminum or Aluminum Composite (kcmil)	Copper or Copper Composite	Current ON Period (Hour)
Up through 336.4	Up through #4/0 AWG	1.0
Over 336.4 through 795	Over #4/0 AWG through 500 kcmil	1.5
Over 795 through 1590	Over 500 kcmil through 1000 kcmil	2.0

6.9.2 CCT current cycle OFF period

Connectors tested by the Current Cycle Test (CCT) method shall cool in ambient temperature air. The time length of the current OFF period for connectors tested by the CCT method shall initially be the same as the current ON period. The time length may be reduced by forced air cooling after the first twenty-five cycles. With the manufacturer's concurrence, forced air cooling may be initiated during the current OFF period after the first cycle. The time length for the reduced current OFF period shall be established by adding 5 minutes to the time required for the four connectors to reach ambient temperature.

6.9.3 CCST current cycle OFF period

Connectors tested by the Current Cycle Submersion Test (CCST) method shall be immersed in still, chilled water (5°C ± 4°C maximum) within 30 seconds of the start of the current OFF period. The connectors shall remain immersed in the chilled water for a minimum of 15 minutes after the temperature of the connector is reduced to the temperature of the water. The connectors shall be removed from the water before they are energized at the beginning of the next current ON cycle.

6.10 Measurements

Resistance and temperature measurements shall be made according to Table 7, depending on the choice of test method. When the number of measurement datums exceeds those specified in Table 7, the measurements nearest each specified cycle shall be used to evaluate performance for Class A, B, and C connectors. For Class AA connectors, resistance and temperature measurements shall be taken a minimum of once every twenty cycles.

Table 7 – Resistance and temperature measurement intervals*

Current Cycle Test Method (CCT)	Current Cycle Submersion Test Method (CCST)
25 – 30	5 – 7
45 – 55	8 – 12
70 – 80	18 – 22
95 – 105	28 – 32
120 – 130	38 – 42
160 – 170	48 – 52
200 – 210	58 – 62
245 – 255	68 – 72
320 – 330	78 – 82
400 – 410	88 – 92
495 – 505	98 – 102

* Does not apply to Class AA Connectors.

6.10.1 Resistance measurements

Resistance measurements shall be made at the end of a current OFF period with all connectors thermally stabilized at the room ambient temperature. Thermal stability is defined as not more than a variation of 2°C between any two of three readings taken at not less than 10-minute intervals. Resistance measurements shall be made across each connector, between potential points located either on the equalizers a maximum of one conductor diameter from the edge adjacent to the conductor or at the midpoint of a solid conductor. A low magnitude direct current not to exceed 12A shall be used for these measurements. Ambient temperature shall be measured within 2 feet (61 cm) of the test loop at a location that minimizes the effect of thermal convection. The ambient temperature shall be recorded at the time of each set of resistance measurements. The resistance of each connector assembly shall be corrected from the measured temperature to 20°C. The corrected resistance values shall be used to evaluate the performance of the connectors.

NOTE—The resistance values obtained shall be corrected to 20°C with the following formula:

$$R_{20} = R_m / [1 + \alpha (T_m - 20)]$$

where R_m is the measured resistance, T_m is the temperature (°C) of the connector, and α is the resistance variation coefficient with the temperature. This coefficient can be taken equal to:

$$\alpha = 4 \times 10^{-3}/°C \text{ for copper and ACSR}$$

$$\alpha = 3.6 \times 10^{-3}/°C \text{ for aluminum}$$

6.10.2 Temperature measurements

Temperature measurements of the connectors, control conductors, and ambient air shall be made at the end of the specified current ON cycle, immediately before the current is turned off. The temperatures shall be measured by means of thermocouples that have been permanently installed for the current cycle tests. At least one thermocouple shall be installed in the current path of each connector at a point where the highest temperature is anticipated. One thermocouple shall be installed at the midpoint of the control conductor.

6.11 Maximum number of current cycles

The number of cycles specified in clause 3.2, Table 1, to complete the test may be extended to permit taking the final measurements during normal working hours.

6.12 Evaluation interval

The evaluation of the connector performance, as specified in clauses 4.2 and 4.3, shall be made on the basis of resistance and temperature measurements.

6.12.1 Evaluation by the CCT method

The resistance and temperature measurements in accordance with section 6.10 shall be used to evaluate connectors tested by the Current Cycle Test (CCT) method.

6.12.2 Evaluation by the CCST method

The resistance and temperature measurements taken in accordance with section 6.10 shall be used to evaluate connectors tested by the Current Cycle Submersion Test (CCST) method.

7 Mechanical test procedures

7.1 General

Mechanical tests shall be conducted in accordance with clause 5 and 7.2 through 7.5.

7.2 Test connectors

7.2.1 Three samples of each connector-conductor combination shall be subjected to each mechanical test described in 7.3, 7.4, and 7.5.

7.2.2 Both deadends and splices shall be tested unless it can be shown that the same design parameters and materials are used for both devices. If only one device is tested, it shall be the deadend.

7.3 Pullout test

7.3.1 Pullout strength tests shall be performed on the following two conductor combinations for which the connector is designed:

a) The highest rated tensile strength conductor, and

b) The smallest diameter conductor of the highest rated tensile strength.

NOTE—If the conductor core has been grease-filled, special joining techniques may be required and the connector manufacturer should be consulted.

7.3.2 If the connectors can be used on different construction and/or materials, the test shall be run on each conductor category such as ACSR, AAC, AAC/TW, etc.

7.3.3 Tensile strength

The same samples shall be used for both the sustained load testing and maximum load testing. Relaxation of tension between tests is permissible.

7.3.3.1 Sustained load

7.3.3.1.1 Class 1, full-tension connectors of the type that do not have separately installed gripping means for the different metals of composite conductors, or which use nonferrous means on ferrous conductors or cores, shall first be tested by installing the connectors in assemblies as described in 7.3.3.1.2. A constant tensile load equal to 77%±2% of the rated strength of the conductor, as determined in 4.4.2, shall be applied and maintained on the assemblies for a minimum of 168 hours.

7.3.3.1.2 The length of the exposed conductor in the test assembly between each gripping means and each connector shall be at least 12 feet (3.66 meters). The gripping means may be any device capable of securely gripping all strands without slippage for the duration of the test. If another connector of the same type as the connector being tested is used, it may also be considered as a test connector.

7.3.4 Maximum load

7.3.4.1 When conducting the tensile strength test, care shall be taken to ensure that all strands of the conductor are loaded simultaneously.

7.3.4.2 The load shall be applied at a cross-head speed not exceeding 1/4 inch per minute per foot (20.8 mm per minute per meter) of the total length of the exposed conductor between jaws.

7.3.4.3 The length of the exposed conductor between each gripping means and each connector shall not be less than that given in Table 8.

7.3.4.4 The tensile strength shall be determined as the maximum load that can be applied. This load shall be measured to an accuracy of 1% for Class 1 connectors and 5% for Class 2 and 3 connectors with instruments calibrated according to ASTM E4-83A. The mode of failure shall be recorded.

7.3.4.5 Minimum values indicated in 4.4.3 are required.

7.4 Torque strength test

7.4.1 The torque strength of the bolted connector shall be measured using conductors of the largest and smallest diameters for which the connector is designed (see 4.7).

7.4.2 Tightening torque values shall be measured using a measuring device which is accurate within 2%.

7.4.3 The torque strength of a bolted connector is the threshold value of the bolt tightening torque at which rupture or permanent distortion of any connector component occurs that impairs its proper functioning on any of the conductor combinations for which the connector was designed.

7.5 Conductor damage test

7.5.1 The conductor damage test for the tap connector shall be performed on maximum-run and minimum-run conductors of each type for which the connector is designed. In all tests, the maximum-diameter tap conductor of the hardest temper for which the connector is designed shall be used.

7.5.2 A tap connector shall be installed on a run conductor whose length between gripping means is as specified as Class 1 in Table 8, and is under a tensile load of 20% of its rated strength as determined in 4.4.2. Relaxation of the load shall not occur during connector installation. The conductor shall then be stressed to the breaking point.

Table 8 – Length of exposed conductor

Connector Class	Description	Length Inches	Length Meters
Class 1 (a)	Intended for single metal or single alloy conductors with 19 strands or less.	24	0.61
(b)	Intended for single metal or single alloy conductors with more than 19 strands	144*	3.66*
(c)	Intended for multiple metal or multiple alloy conductors	144*	3.66*
Class 2		24	0.61
Class 3		10	0.25

*Exception: For conductors 4/0 AWG and smaller, the length of the exposed conductor may be shortened from 144 inches (3.66 meters) to 24 inches (0.61 meter), if procedures ensure simultaneous loading of all strands.

8 Test report

The test report shall include the necessary data to support conformance or nonconformance to the requirements of this standard, and also the following:

- Date of test
- Description of test assemblies
- Description of connectors and inhibiting compound before testing to ensure traceability
- Description of conductors, including rated conductor strengths
- Description of connector installation procedure
- Current cycle amperage
- Description of the condition of connectors after testing
- Electrical: Class AA, A, B, C
Mechanical: Class 1, 2, 3
Method: CCT, CCST
- Name and location of the test facility
- All options used in performance of the test
- Certification (if required)
- Other pertinent information, such as installation details not specifically defined or required in this standard