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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

2101 L STREET N.W. WASHINGTON, D.C. 20037

March 5, 1979

TO ALL REPRESENTATIVES OF MEMBER COMPANIES
IN THE ELECTRICAL CONNECTOR SECTION

Subject: Reaffirmation and Editorial Reprinting of the NEMA Standards Publication for Connectors for Use Between Aluminum or Aluminum-copper Overhead Conductors, Publication No. CC 3-1973 (R 1978)

Gentlemen:

At its meeting on November 16, 1978, the Codes and Standards Committee approved the reaffirmation of the subject publication and directed that it be reprinted to editorially delete all references to the Edison Electric Institute (EEI) which no longer jointly sponsors this publication with NEMA.

Accordingly, we are pleased to enclose a complimentary copy of the reprinted publication which shows the 1978 reaffirmation on the front cover and from which references to EEI have been editorially deleted.

Additional copies of CC 3-1973 (R 1978) are available at $1.00 each. Please note that all orders must be accompanied by a remittance and should be marked to the attention of the NEMA Order Department.

Sincerely yours,

Nels M. Andersen
Standards Publications Editor

NMA:jps

cc: Technical Committees

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EEI Pub. No. TDJ-162
NEMA Pub. No. CC 3-1973
August 1973

EEI-NEMA Standards for CONNECTORS FOR USE BETWEEN ALUMINUM OR ALUMINUM-COPPER OVERHEAD CONDUCTORS

Report of the Joint Committee of the
Edison Electric Institute and the
National Electrical Manufacturers Association on
Connectors for Aluminum Conductors

Price: 85¢

EDISON ELECTRIC INSTITUTE
90 Park Ave., New York, N. Y. 10016

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
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These Standards contain engineering information and were developed by the EEI-NEMA Joint Committee on Connectors for Aluminum Conductors. To the extent utilized, they will promote understanding between the manufacturer and the purchaser and will assist the purchaser in selecting and obtaining the proper product for his particular need. The use of these Standards is optional with each manufacturer and purchaser. However, those who use them will derive benefits from stock simplification, production economies and other advantages of interchangeable technical equipment.

These Standards supersede EEI Publication No. TDJ-162, NEMA Publication No. SG 14.10 - 1962, EEI-NEMA Standards for Overhead Distribution Connectors for Aluminum Conductors dated October 1962.

EEI-NEMA Joint Committee on
Connectors for Aluminum Conductors

EEI Representatives	NEMA Representatives
W L Wagner, Chairman	R E Lipp, Chairman
L C Barry	G I Addis
R C Johnson	H Caldwell
G D Smith	N Shackman
	J H Hopkins (Alternate)
	P K Koletsos (Alternate)

The Committee wishes to express its appreciation to H Colin Smith of NEMA who acted as Secretary for the Committee.

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FOREWORD

These Standards for overhead connectors were developed in a program started under the direction of a subcommittee of the Transmission and Distribution Committee, Edison Electric Institute. It began with laboratory inspection and examination of connections removed from service and was followed by extensive testing under controlled conditions. Tentative performance type specifications for electrical characteristics were issued in joint report form in 1958 by a steering committee of EEI and an advisory committee of manufacturers on the aluminum connector research project. (EEI Publication No. 59-70)

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.

In this revised issue recognition has been given to the changes in design of various connectors. Also test procedures have been included to assure adherence to the Performance Criteria of the Standard.

The inclusion of corrosion tests in the Standard as recommended in 1962 was also considered. However, because of a better understanding of corrosion, changes in connector metals, extensive use of inhibitors and the wide acceptance, use and experience by the industry of aluminum conductor connectors, the Joint Committee considered the inclusion of such tests unnecessary. The Joint Committee, in arriving at this conclusion, recognizes that connector material and design can contribute to corrosion but considers the preparation and application by the user which cannot be controlled by this Standard to be much more important.

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EEI-NEMA STANDARDS
FOR
CONNECTORS FOR USE BETWEEN
ALUMINUM OR ALUMINUM-COPPER OVERHEAD CONDUCTORS

SECTION I

1. SCOPE

1.1 These Standards cover devices used for making electrical connections between aluminum conductors, or aluminum conductors in combination with copper conductors.

1.2 These Standards are concerned with performance requirements for the electrical and mechanical characteristics of connectors for the usual operating conditions.

2. GENERAL

2.1 These Standards are intended to give reasonable assurance to the user that connectors meeting the requirements will perform in a satisfactory manner, provided the proper functional class is selected for the application and they are installed correctly. The quality of the electrical connection is also affected by the surface condition in the area of contact of the conductors to be joined.

2.2 Although there are nine possible combinations of the indicated electrical and mechanical classes, it is expected and considered desirable that a maximum of four to six combinations in a given range of conductor sizes will be sufficient for listing to meet the usual requirements of application. This does not, however, preclude other combinations in use.

3. TEST CONDITIONS

Connections shall be assembled and tested in accordance with the methods given in detail in Section II. Principal test conditions and measurements shall be in accordance with the following paragraphs:

3.1 Heat Cycle Tests. Heat cycle tests shall be conducted in accordance with Paragraph B of Section II and shall be of the following duration:

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Class A	500 Cycles
Class B	250 Cycles
Class C	125 Cycles

3.2 Mechanical Tests. Tests of tensile strength, reusability, and effect on the strength of the run conductor shall be conducted in accordance with Paragraph C of Section II. Connectors shall be classified regarding tensile strength as follows:

Class 1	Full Tension
Class 2	Partial Tension
Class 3	Minimum Tension

4. PERFORMANCE CRITERIA

When installed in an assembly and tested in accordance with the methods outlined above, connections shall conform to the following performance criteria:

4.1 The resistance of the connections tested in accordance with Paragraph B shall show a condition of stability between the 25th cycle and the completion of the number of heating cycles required in Paragraph 3.1, as indicated by a variation of not more than 5% from the average of the measured values in this interval. (This includes allowances for measurement error.)

4.2 The temperature of the connector tested in accordance with Paragraph B shall not exceed the temperature of the control conductor, and the temperature difference between the control conductor and the connector shall show a condition of stability from the 25th cycle to the end of the test, as indicated by a decrease of this difference of not more than $10^{\circ}C$ from the average of the measured differences in this interval for this connector. (This includes allowance for measurement error.)

4.3 The tensile strength of all the samples tested in accordance with Paragraph C3 shall be at least equal to the following values:

Class 1, Full Tension:	95% of the applicable ASTM rated strength of the weaker of the conductors joined. Failure must be accompanied by the breakage of at least one strand.

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Class 2, Partial Tension: 40% of the applicable ASTM rated strength of the weaker of the conductors joined.

Class 3, Minimum Tension: 5% of the applicable ASTM rated strength of the weaker of the conductors joined or 200 lbs whichever is larger, for connectors joining a conductor combination of which the weaker conductor is larger than #6 AWG: or 100 lbs if the weaker conductor of the conductor combination is #6 AWG or smaller.

4.3.1 Class I, full tension connectors of the type that do not have a separately installed gripping means for the different metals of composite conductors, shall also be tested in accordance with Paragraph C 3.5 without slippage or breakage after the load has been initially applied.

4.4 When removed, a reusable connector shall be suitable for reinstallation on all conductor combinations for which it is intended.

A bolted connector shall be deemed to fulfill this requirement if its torque strength as determined in accordance with Paragraph C4 is at least equal to 120% of the applicable tightening torque as given in Table I.

4.5 A tap connector shall not adversely affect the mechanical and electrical properties of the run conductor.

A tap connector shall be deemed to fulfill these requirements if, as a result of the conductor damage test of Paragraph C5, the mechanical strength of the run conductor does not reduce to a value lower than 90% of the applicable ASTM rated strength of the run conductor. In addition, if the connector is removable, there shall be no such damage to the strands as to impair the electrical conductance of the cable.

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SECTION II

A. TEST CONDITIONS, GENERAL

A1. Description of Connectors. A description adequate for complete identification of the test connectors shall be included in the test report.

A2. Test Conductors. The conductors used in the test assemblies shall be new bare conductors, conforming to the applicable ASTM Standards.

For terminal connectors, the word "conductor" may also be interpreted as the flat bar conductor to which the terminal is bolted. The size of the flat bar shall be the nearest standard size that can be bolted to the terminal, and whose ampere capacity is closest that of the maximum round conductor accommodated.

A3. Test Assembly Methods. All installation details not specifically defined in this paragraph shall be completely described in the test report.

A3.1 Connector Preparation: Connectors shall be prepared in accordance with the manufacturer's recommendations.

A3.2 Conductor Preparation for Electrical Tests: The outer surface of the conductors in the region of the contact area shall be mechanically cleaned by brushing with a steel wire brush until the entire contacting area of the conductor is entirely scoured by the wire brush.

A3.3 Conductor Preparation for Mechanical Tests: The portion of the conductor that will be inserted into the connector shall be treated by wiping with a cloth coated with a particle-free petroleum jelly.

A3.4 Installation Method. The method of installation and the installation tooling shall be that recommended by the manufacturer, except that when clamping bolts are employed they shall be tightened to the torques specified in Table I. The tightening torque selected shall depend on the bolt size and material.

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B. HEAT CYCLE TESTS

Heat cycle tests shall be conducted on connectors assembled in series in a heat cycle loop in accordance with the details of Paragraph A and the following paragraphs.

B1. Test Connectors

B1.1 Conductor Combinations. The conductor types and sizes joined by a connector in the heat cycle loop shall be that combination resulting in the maximum heat cycle current, determined from Table III, with the conductors matched as closely as possible in current carrying capacity.

If the connector is recommended for joining both aluminum to aluminum conductor and aluminum to copper conductor, it shall be tested on both combinations.

B1.2 Number of Samples. For each size and type of connector, for each combination of conductors required, in each of the tests, four connectors are required.

B2. Equalizers. To provide equipotential planes for resistance measurements, and to prevent the influence of one connector on the other in the heat cycle loop, equalizers, as described below, shall be installed in the stranded conductor on each side of each connector. Equalizers are not required on solid conductor.

Any form of equalizer may be used that assures permanent contact with all the strand of a conductor for the duration of the heat cycle test. For aluminum conductor, the most reliable form, when made with the proper skill and care, is the welded equalizer.

A welded equalizer may be made of a suitable aluminum flat bar having holes into which the cable ends are welded. It may be made using welding terminals, welded to each cable end, with pairs of terminals being bolted together to construct a heat cycle loop.

When the cable ends to be joined in a heat cycle loop are identical, a continuous piece of cable may be used between the connectors, with a short compression sleeve in the center to act as an equalizer. With aluminum cable, the strands in the region of such an equalizer should be carefully cleaned and smeared with a good connector compound before the equalizer is slipped in place and compressed.

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B3. Conductor Lengths. The exposed length of the conductors in the heat cycle loop, between the connectors and the equalizers, shall be as given in Table II. The exposed length of solid round conductor between connectors shall be twice that in Table II. The length of flat bus bar between the ends of terminals shall be twice that of Table II based on the size of round conductor being used in the terminal.

The length of conductor in Table II does not include the amount within the connector and equalizer, which must be added to get the total length required. Also, where the connector design permits, the end of the conductor shall project beyond the connector contact groove by 1/2 inch, and this amount must also be added to get the total length.

The loop shall be joined to the appropriate power source using additional lengths of the test conductor sizes, joined to the equalizers at each end of the loop. The length of these additional conductors shall be not less than those specified in Table II.

B4. Ambient Condition. Heat cycle tests shall be conducted in a space free of drafts at an ambient temperature of 20°C to 35°C. A space is considered free of drafts, if the temperature rise of the control conductor above ambient is 95°C to 105°C at the end of each heating period during the evaluation portion of the test.

B5. Control Conductor. A control conductor, used for the purpose of obtaining conductor temperature, shall be installed in the heat cycle loop between two equalizers. It shall be of the same type and size as that conductor, of those being joined by the connectors under test, that would run at the higher temperature. Its length shall be at least twice that given in Table II.

The control conductor size may be determined from Table III by selecting the one of those being joined in the test for which the current listed in Table III is the least.

B6. Heat Cycle Current. The heat cycle current shall be adjusted to result in a steady-state temperature rise of 100°C on the control conductor, the adjustment to be made during the heating periods of the first 25 cycles. This heating current shall then be used for the remainder of the heating periods of the test, regardless of the deviation of the steady-state control conductor temperature rise. (See Table III for suggested initial test currents.)

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The current values in Table III are strictly test values used for these Standards. They are not to be confused with currents permitted in actual service, since they are intended to accelerate the deterioration influence of service load cycling.

B7. Heat Cycle Period. Each cycle of the heat cycle test shall consist of "current-on" and "current-off" periods of equal duration. The length of these periods shall be as given in Table IV based on the control conductor size. The total cycle time is double the values in the table. These periods were chosen to permit equilibrium temperature to be reached within 2°C.

The lengths of the periods in which resistance and temperature measurements are made shall be extended for the time necessary to take measurements.

B8. Loop Configuration. Prior to connector installation the heat cycle loop may be bent back on itself in a "U" or "zig-zag" shape in which the connectors shall be mounted in a horizontal plane with at least 8 inches of separation between adjacent conductors. It shall be spaced from the walls by at least one foot and spaced from the floor or ceiling by at least two feet. Other thermally equivalent loop arrangements may be used.

B9. Measurements. Resistance and temperature measurements shall be made at the beginning of the test and after approximately:

every 25 cycles to the 125th cycle;
every 40 cycles to the 250th cycle;
and every 80 cycles to the 500th cycle.

The actual number of cycles between measurements may be adjusted to conform to normal working hours.

Resistance measurements shall be made at the end of the current-off period. The measurements shall be made across each connector, between potential points located on the equalizers 1/8 inch from the edge adjacent to the conductor, or located at the mid-point of the solid conductor. For these measurements direct current shall be used, of a sufficiently low magnitude to avoid appreciable heating.

The ambient temperature shall be recorded concurrently with each set of resistance measurements, and the resistances shall be corrected to 20°C. The corrected resistances shall be used in evaluating the performance of the connectors.

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Temperature measurements shall be made of the connectors and the control conductor at the end of the heating period, with current on. The temperatures shall be measured by means of thermocouples permanently installed throughout the heat cycle test. At least one thermocouple shall be installed on each connector, as close as possible to the point in the current path midway between the two conductors. One thermocouple shall be installed at the midpoint of the control conductor.

B10. Number of Heat Cycles. The number of cycles for completion of the test as given in Paragraph 3.1 may be extended a sufficient number of cycles to permit taking the final measurements during the normal working hours.

B11. Evaluation Interval. The evaluation of connector performance as specified in Paragraphs 4.1 and 4.2 shall be made on the basis of measurements made during an interval that includes as its first and last cycles those cycles for which measurements of resistance and temperature were taken such that the first is at or just before the 25th cycle and the last at or just beyond the specified end point of the test.

C. MECHANICAL TEST PROCEDURES

Mechanical tests shall be conducted in accordance with the details of Paragraph A and of the following paragraphs.

C1. Test Connectors

C1.1 Three samples of each connector/conductor combination specified, shall be subjected to each mechanical test.

C2. Test Conductors

C2.1 Pullout strength tests shall be performed on the connector joining the strongest conductor combination for which a connector is designed and also joining the smallest diameter conductors of the hardest temper for which the connector is designed.

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

The torque strength of the connector shall be measured using the largest diameter conductor the connector can accommodate.

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The conductor damage test shall be performed on all maximum diameter run conductors for which the connector is intended. In all tests, the maximum diameter tap conductor of the highest yield strength for which the connector is designed shall be used.

C3. Tensile Strength

C3.1 When placing the sample in the tensile testing machine, care shall be taken to insure that all strands of the conductor are loaded simultaneously.

C3.2 The load shall be applied at a crosshead speed not exceeding 1/4" per minute per foot of length between jaws.

C3.3 The length of free conductor between the gripping device and the connector shall not be less than:

10" for Class 3 connectors
2' for Class 2 connectors
2' for Class 1 connectors intended for single metal conductors with 19 strands or less.
12' for Class 1 connectors intended for single metal conductors with more than 19 strands.
12' for Class 1 connectors intended for multiple metal conductors except:

For connectors of size 4/0 and smaller, the length of free conductor between the gripping device and the connector may be shortened from 12' to a minimum of 2' if suitable procedures assure simultaneous loading of all strands.

C3.4 The tensile strength shall be determined as the maximum load applied before failure. This load shall be measured to an accuracy of 1% for Class 1 connectors and 5% for all other classes with instruments calibrated according to ASTM Specification E4. The mode of failure shall be recorded.

C3.5 Class 1, full tension connectors of the type that do not have a separately installed gripping means for different metals of a composite conductor, shall be tested by installing the connectors in

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assemblies as described in C 3.5.1. A constant tensile load shall be applied to and maintained on the assemblies equal to 77% ± 2% of the applicable ASTM rated strength of the conductor for a period of 168 hours.

C3.5.1 The length of free conductor in the test assembly between the gripping device and the connector shall be at least 12 feet. The gripping device may be any device capable of securely gripping all strands without slipping for the duration of the test. Another connector of the same type as the connector under test may be used as the gripping device, in which case it shall also be considered as a test connector.

C4. Torque Strength

C4.1 The torque strength of a connector is taken as a threshold value of tightening torque at which rupture or permanent deformation of any connector component occurs, such as to impair its proper functioning on any of the conductor combinations for which the connector is intended.

C4.2 Torque values shall be measured to an accuracy of 10%. Running torque rather than static torque values shall be read.

C5. Conductor Damage

C5.1 Tap connectors shall be tested to evaluate any damage to the run conductor caused by installing the connector. The connector shall be installed on the run conductor which is under a tensile load of 20% of its applicable ASTM rated strength. Provision shall be made to prevent relaxation of the load during connector installation. The conductor shall then be stressed to the breaking point. The length between the grips on the run conductor shall be at least 3'.

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TABLE I

CLAMPING BOLT TIGHTENING TORQUE, INCH-POUNDS

Bolt Size	Aluminum Bolts	Galvanized Steel or Silicon Bronze
5/16"	-	180
3/8"	168	240
13/32"	204	288
7/16"	240	360
1/2"	300	480
9/16"	384	576
5/8"	480	660

TABLE II

CONDUCTOR LENGTHS IN HEAT CYCLE TESTS

Aluminum or Aluminum Composite	Copper or Copper Composite	Exposed Length
Up to 4/0	Up to 2/0	12 inches
Over 4/0 to 795 kcmil	Over 2/0 to 500 kcmil	24 inches
Over 795 kcmil	Over 500 kcmil	36 inches

TABLE III

SUGGESTED INITIAL TEST CURRENTS FOR HEAT CYCLING for a Conductor Temperature Rise of 100°C

Aluminum or Aluminum Composite		Copper or Copper Composite	
Size	Amperes	Size	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

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TABLE III
(Continued)

SUGGESTED INITIAL TEST CURRENTS FOR HEAT CYCLING
for a Conductor Temperature Rise of 100°C

Aluminum or Aluminum Composite Size	Amperes	Copper or Copper Composite Size	Amperes
266.8 kcmil	450	250 kcmil	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		

TABLE IV

HEAT CYCLE PERIODS - CONDUCTOR SIZE

Aluminum or Aluminum Composite	Copper or Copper Composite	Current-On Period
Up to 336.4 kcmil	Up to 4/0	1 hr
Over 336.4 to 795 kcmil	Over 4/0 to 500 kcmil	1-1/2 hrs
Over 795 to 1590 kcmil	Over 500 to 1000 kcmil	2 hrs

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