ANSI C119.4-2011

American National Standard

for Electric Connectors—

Connectors for Use Between Aluminum-to-Aluminum and Aluminum-to-Copper Conductors Designed for Normal Operation at or Below 93°C and Copper-to-Copper Conductors Designed for Normal Operation at or Below 100°C

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Secretariat:

National Electrical Manufacturers Association

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American National Standards Institute, Inc.

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Foreword (Neither this foreword nor any of the informative annexes is a part of American National Standard C119.4-2011)

This standard describes electrical and mechanical tests used to establish performance characteristics of connectors used to join aluminum-to-aluminum, aluminum-to-copper, or copper-to-copper bare and insulated conductors.

It is the responsibility of the user to determine the proper connector for any particular application. The user may request the manufacturer to perform any additional desired testing beyond that required by the C119.4-2011 standard performance tests.

Substantive changes to the standard have been made in the C119.4-2011 version of the standard. A substantive change is one that directly and materially affects performance of a product and which requires testing or retesting to meet the current edition of a standard. The substantive changes to the standard are as follows:

1. Test requirements for copper connectors.
2. Test requirements for copper system stability, which were not part of earlier editions.
3. Requirement for retesting performance of a product if there have been substantive changes made to the product.

This revision includes the addition of spreadsheet files in Annex A that can be used to collect current cycle test data, calculate connector stability, generate graphs of the data, and print data to provide test results as part of the test report. The spreadsheets are provided to give a standardized format to collect, calculate, and report test data and test results. These spreadsheets were not part of earlier editions.

This revision includes the addition of two optional tests: Optional Fault Current Test (Annex D) and Optional Corrosion Test (Annex E). These optional tests are not a part of the required C119.4-2011 standard performance tests. The subcommittee has provided these optional performance tests as references in response to users who have requested guidance for these types of additional performance tests. The user may request that the manufacturer perform any additional tests that are not a part of the required C119.4-2011 standard performance tests.

This standard includes 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. There is also a new class of tensile strength—Class 1A, Normal Tension.

This standard includes an alternate, accelerated current cycle test method, henceforth referred to as the current cycle submersion test (CCST). The CCST method differs from the traditional current cycle test (CCT) in that test conductors are rapidly cooled by immersion in chilled water at the beginning of the "current-OFF" cycle, and the test 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 standard was initially developed under the direction of the Transmission and Distribution Committee of the Edison Electric Institute (EEI). 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 conductor research project (EEI Pub. No. 59-70 *Tentative Specifications for Connectors for Aluminum Conductors*).

Experience gained from extensive trial use further confirmed the performance criteria and test conditions of the tentative specifications and led to the development of Standard TDJ 162 in October 1962 by a joint committee of EEI and the National Electrical Manufacturers Association (NEMA). TDJ 162 was subsequently superseded by this document.

The C119.4 Subcommittee 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 will be welcome. They should be sent to the National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, 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:

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The C119.4 Subcommittee on Connectors for Use Between Aluminum-to-Aluminum and Aluminum-to-Copper Conductors Designed for Normal Operation at or Below 93°C and Copper-to-Copper Conductors Designed for Normal Operation at or Below 100°C, which developed the revisions of this standard, had the following members at the time of its approval:

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For Electric Connectors—

Connectors for Use Between Aluminum-to-Aluminum and Aluminum-to-Copper Conductors Designed for Normal Operation at or Below 93°C and Copper-to-Copper Conductors Designed for Normal Operation at or Below 100°C

1 Scope and Purpose

1.1 Scope

This standard covers connectors used for making electrical connections between aluminum-to-aluminum or aluminum-to-copper or copper-to-copper conductors used on 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 this 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.

1.3 Definitions

bolted-type connector: A connector that makes an electrical connection utilizing bolting (or a bolt and nut combination) to apply and maintain contact pressure to the conductor.

conductor: Conducting material used as a carrier of electric current.

connector: A device joining two or more conductors to provide a continuous electrical path.

connector current class: Nomenclature categorizing a connector's electrical performance by current cycle test duration.

Class AA (Extra Heavy duty)—High current cycle test duration
Class A (Heavy duty)—High current cycle test duration
Class B (Medium duty)—Moderate current cycle test duration
Class C (Light duty)—Low current cycle test duration

connector tension class: Nomenclature categorizing a connector's mechanical performance by tension test level.

Class 1—Full tension, 95% rated conductor strength
Class 1A—Normal tension, 60% rated conductor strength
Class 2—Partial tension, 40% rated conductor strength
Class 3—Minimum tension, 5% rated conductor strength

control conductor: A conductor in the current cycle loop that serves as a reference for setting test current and monitoring temperature.

equalizer: A device installed in the test loop to ensure a point of equipotential in a stranded conductor.

inhibitor: A compound used to inhibit the growth of oxides on electrical connection interfaces and to prevent the ingress of contaminants into electrical connection interfaces.

input conductor: Conductor on the supply side of the connector.

output conductor: Conductor on the load side of the connector.

range-taking connector: Connector designed to accept multiple conductor sizes.

rated conductor strength: The tensile strength of a conductor determined in accordance with the applicable ASTM standard or as furnished by the conductor manufacturer for non-standard conductors.

run conductor (main): A continuous conductor from which other conductors branch.

splice: A connector joining two or more conductor ends.

tang (pad): The flat portion of a connector used for electrical connection.

tap conductor: A separate conductor that branches off from the run conductor.

tap connector: Connector joining a tap conductor to a run conductor without breaking the run conductor.

tee connector: A connector joining a non-continuous run (main) conductor and a tap conductor.

terminal connectors: A connector that joins a conductor(s) to an electrical device.

wye connector: A connector used for connecting one size conductor end to two equal or smaller size conductor ends.

2 Referenced Standards

This standard is intended to be used in conjunction with, but not limited to, the following standards in their latest edition:

ASTM B117 *Standard Practice for Operating Salt Spray (Fog) Apparatus*

ASTM E4-01 *Standard Practices for Force Verification of Testing Machines*

IEEE 837 *Standard for Qualifying Permanent Connections Used in Substation Grounding*

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 Sections 5 through 8.

3.2 Current Cycle Tests

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

Exception—Copper-bodied connectors, for use with copper conductors only, do not require current cycling testing. This exception is provided since copper-bodied connectors, in conjunction with copper conductors, do not exhibit high thermal expansion characteristics and are required to demonstrate thermal stability per Section 4.5.

NOTE—This test is run on bare conductor to provide repeatability of test results.

3.3 Thermal Stability of All Copper Systems

Tests shall be conducted in accordance with Section 8 for 120 hours.

3.4 Mechanical Tests

Tests of tensile strength of the connection and effect on the strength of the run conductor shall be conducted in accordance with Section 7 for the strength class as listed below:

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

4 Performance Requirements

4.1 General

Connectors shall conform to the appropriate performance requirements in Sections 4.2 through 4.12, when installed and tested in accordance with the methods specified in Sections 5 through 8.

4.2 Sample Failure

For each test, unacceptable results attained on any single sample shall be considered an unacceptable result for the entire sample set.

4.3 Current Cycle Resistance Stability

The resistance of the connection tested in accordance with Section 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.

4.3.1 CCT

The resistance of the connection tested by the Current Cycle Test method in accordance with Section 6 shall be stable between the twenty-fifth (25^{th}) cycle and the completion of the number of current cycles required in Table 1 for the connector class.

4.3.2 CCST

The resistance of the connection tested by the Current Cycle Submersion Test method in accordance with Section 6 shall be stable between the tenth (10^{th}) cycle and the completion of the number of current cycles required in Table 1 for the connector class.

4.4 Current Cycle Temperature Stability

The temperature of the connector when tested in accordance with Section 6 shall not exceed the temperature of the control conductor.

The temperature difference between the control conductor and the connector shall be stable as determined as follows.

The stability factor "S_i" shall not exceed ±10 for each of the specified connector temperature measurements recorded at the intervals specified in Table 2.

The stability factor S_i for each of the specified recorded temperature measurements shall be determined by applying the following equations:

$$S_i = d_i - D$$

$$D = [d_1 + d_2 + ... + d_n)/n]$$

in which:

D is the average temperature difference;

The variable "i" signifies the individual temperature measurements taken at intervals given in Table 2, and d_i is a temperature difference for an individual temperature measurement.

$d_i = (T_{cc} - T_c)_i$
i = 1, 2, …, n
T_c is connector temperature in °C
T_{cc} is the control conductor temperature in °C
n = 5, Class C
8, Class B
11, Class A
25, Class AA

NOTE—For each connector, the value for d_i is determined by subtracting the connector temperature from the control conductor temperature for each of the specified data points. Next, the average temperature difference (D) is then calculated and subtracted from each of the individual data points to attain specified S_i values. Each of these specified S_i values are to be within the range of ±10. See the example in Annex A.

4.4.1 CCT

The temperature of the connector tested by the Current Cycle Test method shall be stable between the twenty-fifth (25^{th}) cycle and the completion of the number of current cycles required in Section 3.2 for the connector class being tested.

4.4.2 CCST

The temperature of the connector tested by the Current Cycle Submersion Test method shall be stable between the tenth (10^{th}) cycle and the completion of the number of current cycles required in Section 3.2 for the conductor class being tested.

4.5 Copper System Thermal Stability

4.5.1 Thermal Stability

The temperature of the connectors shall be thermally stable between 72^{nd} and the 120^{th} hour when tested according to Section 8.

Thermal stability is achieved if the change in connector temperature reading does not differ by more than 2°C (3.6°F) from the change in input conductor temperature.

4.5.2 Determination of Thermal Stability

Thermal stability is achieved if the following equation is satisfied over successive temperature measurements from the 72^{nd} hour through the 120^{th} hour.

$$ABS(\Delta T_{s,i} - \Delta T_{ic,i}) \leq 2°C$$

Where; $\Delta T_{s,i} = T_{s,i+1} - T_{s,i}$ is the change in connector temperature T_s from time interval i to i+1

And where; $\Delta T_{ic,i} = T_{ic,i+1} - T_{ic,I}$ is the change in the input conductor temperature T_{ic} from time interval i to i+1, ABS = Absolute Value

4.6 Tensile Strength and Rated Conductor Strength

4.6.1 Tensile Strength

The tensile strength of the connections tested in accordance with Section 7.3 shall be equal to or greater than the values listed in Section 4.6.3.

4.6.2 Rated Conductor Strength

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

4.6.3 Classes of Tensile Strength

4.6.3.1 Class 1, Full Tension

The tensile strength shall be equal to or greater than 95% of the rated conductor strength of the weaker of the conductors being joined. Individual strand breakage or measurable slippage of the conductor below 95% of the rated conductor strength is unacceptable. Connectors of the type that do not have separate gripping means for different metals of non-homogeneous conductors, or that use nonferrous means on ferrous conductors or cores, shall first be tested in accordance with Section 7.3.3.1.1 without slippage or breakage of strands.

4.6.3.2 Class 1A, Normal Tension

The tensile strength shall be equal to or greater than 60% of the rated conductor strength of the weaker of the conductors being joined. Individual strand breakage or measurable slippage of the conductor below 60% of the rated conductor strength is unacceptable. Connectors listed for use on non-homogenous conductors shall be tested in accordance with Section 7.3.3.1.2 without slippage or breakage below 60% of the rated conductor strength.

4.6.3.3 Class 2, Partial Tension

The tensile strength shall be equal to or greater than 40% of the rated conductor strength of the weaker of the conductors being joined. Individual strand breakage or measurable slippage of the conductor below 40% of the rated conductor strength is unacceptable.

4.6.3.4 Class 3, Minimum Tension

The tensile strength shall be equal to or greater than 5% of the rated conductor strength of the weaker of the conductors being joined but not less than the values in Table 3 or 4. Individual strand breakage or measurable slippage of the conductor below 5% of the rated conductor strength is unacceptable.

4.7 Tap Connector

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

In a separate test, tap conductor connection(s) shall meet the tensile requirement as stated in Section 4.6.3.4.

4.8 Tee Connector

Tensile strength tests shall be performed on the connector attaching the non-continuous run conductor (main) in accordance with Section 4.6 as applicable for the class rating of the run connector.

Separate tensile strength tests shall be performed on the tap conductor connection in accordance with Section 4.6 as applicable for the class rating of the tap connector.

4.9 Wye Connector

Separate tensile strength tests shall be performed on the connector for each conductor attachment in accordance with Section 4.6 as applicable for the class rating of each conductor attachment.

4.10 Bolt Tightening

A bolted connector shall withstand 120% of the manufacturer's recommended tightening torque without cracking, rupture, or permanent distortion of any connector component that impairs its proper functioning. In the absence of manufacturer’s recommended torque, use 120% of values shown in Tables 5 or 6.

4.11 Reusable Connectors

Upon completion of all tests, a connector that is designated by the manufacturer to be reusable must be removable, be suitable to be reinstalled, and meet all requirements in this standard. Prior to reuse, any such connector shall be reconditioned in accordance with manufacturer’s instructions.

4.12 Substantive Change to a Product

A substantive change in a product is one that directly affects the electrical and/or mechanical performance of a product.

The following are examples of changes that may be substantive, but the list is not intended to be all inclusive:

- Change in material;
- Reduction in physical size;
- Change in wire range—increase or decrease;
- Change in wire type;
- Change in tooling;
- Inhibitor change;
- Temperature rating; and
- Increased class rating (e.g., Class 3 to Class 2).

Substantive changes will require either a full or partial retest, depending on the type and extent of change(s).

5 Test Procedures, General

5.1 Connector Family Sample Set

To qualify a family of connectors (group of connectors using similar design criteria), a minimum of three (3) sizes (largest, smallest, and intermediate) shall be tested.

5.2 Test Conductors

The conductors used in these tests shall be unused and unweathered. 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 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.

5.3.2 Conductor Preparation for Mechanical Tests

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

NOTE—This is to increase the severity of all mechanical tests.

Conductors shall be prepared in accordance with the manufacturer’s recommendations.

5.3.3 Connector Preparation

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

5.3.4 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 5 or 6 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 Sections 5 and 6. An accelerated current cycle test method, referred to as the 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 current cycle test (CCT) in that test connectors are rapidly cooled by immersion in chilled water (see Section 6.9.3) 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 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 the current through the connector. Tests shall be performed using aluminum-to-aluminum, aluminum-to-copper, and copper-to-copper conductor combinations if the connector is rated for all three combinations.

6.2.1.2 For Class AA connectors where the conductor selected limits the current, the other conductor shall be sized as close to but not less than the limiting conductor current rating. For example, if a tap connector has a run range of 2 to 1/0 AWG and a tap range of 6 to 1 AWG, the test conductors would be 1 AWG in the run and 1 AWG in the tap.

NOTE—In both Section 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 Section 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 on stranded conductors on each side of each connector in the current cycle loop.

Equalizers are not required on solid conductors.

NOTE 1—Any form of equalizer that ensures permanent contact among all the conductor strands for the test duration may be used.

NOTE 2—A welded equalizer, made from aluminum, is recommended for aluminum conductors.

NOTE 3—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.

NOTE 4—If a compression sleeve is employed as an equalizer, the conductor in the contact area of the equalizer should be mechanically cleaned on the outer surface of the bare conductor using a wire brush.

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 Tables 7 or 8. If a flat bus bar is used between terminal connectors, its length shall be twice that shown in Tables 7 or 8 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 lengths in Tables 7 and 8 do not include the length within the connector or equalizer. In a tap connector, where the design permits, the conductor end shall project 12.7 mm (1/2 in.) beyond the connector contact groove (Figure 1). 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 Tables 7 or 8.

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; equalizers are not required on solid 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 Tables 7 and 8. For Class AA, when the control conductor is copper, see Section 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 Tables 9 or 10 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 has the highest temperature rise, a control conductor of each type is required. The control conductor providing the higher rise in temperature for a fixed current shall be used as the reference control conductor for setting the test loop current (Section 6.8) and performing all temperature difference calculations.

6.5.2.2 For Class AA, if the control conductor for determining the test current is copper, then a second control conductor of aluminum shall be included for the purpose of evaluating stability. The second control conductor shall be chosen based on the values shown in Tables 9 or 10 with an ampacity closest to the copper control conductor. However, the copper control conductor shall be used for establishing the test loop current within the first twenty-five (25) cycles.

6.6 Loop Configuration and Location

6.6.1 CCT Method

The current cycle loop may be of any shape, provided the location of thermocouples for the connectors and the center of the control conductor are installed at the same elevation with at least an 200 mm (8 in.) separation between adjacent conductor-connector and equalizer assemblies and located at least 305 mm (12 in.) from any exterior wall and at least 610 mm (24 in.) from the floor and the ceiling. See Figures 2–6 for typical configurations.

NOTE—This is intended to ensure 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 current-ON period, no part of the circuit shall be less than 200 mm (8 in.) above the surface of the chilled water. At the beginning of the current-OFF period, the connectors and the control conductor shall be submerged to a minimum of 100 mm (4 in.) below the water surface. See Figures 2–6 for typical configurations.

NOTE—This is intended to ensure that the control conductor and the connectors begin the next current-ON period at the same temperature.

6.7 Ambient Conditions

Current cycle tests shall be conducted in a space free from 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 (59°F) and 35°C (95°F).

6.8 Test Current

The current values in Tables 9 and 10 are suggested initial test amperes to be utilized during test start up in order to help achieve the required temperature rise in the control conductor for connector Classes A, B, and C. Subsequently, the actual test current may have to be adjusted from these values to achieve the required control conductor temperature rise. For conductor sizes within the range of but not included in Tables 9 and 10, some experimentation or extrapolation of the test current values will be required to achieve the required control conductor temperature rise.

NOTE—The currents in Tables 9 and 10 are not intended to suggest conductor current ratings for actual service use.

6.8.1 CCT Current and Temperature Conditions

The current cycle test current shall be adjusted during the current-ON period of the first twenty-five (25) cycles to result in a stable maximum temperature rise in the control conductor of 100°C (212°F) to 105°C (221°F) above ambient temperature for Classes A, B, and C. For Class AA, the temperature rise of the control conductor shall be 175°C (347°F) to 180°C (356°F) above the 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 Current and Temperature Conditions

The current cycle submersion test current shall be adjusted during the current-ON period of the first five (5) cycles to result in a stable maximum temperature rise in the control conductor of 100°C (212°F) to 105°C (221°F) above 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.

6.9 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 CCT and CCST Current Cycle-ON Period

The minimum duration of the current-ON period shall be as listed in Tables 11 or 12, depending on the size of the control conductor. If the control conductor and connectors being tested do not reach thermal stability within the designated ON time, the duration shall be extended until the control conductor and the connectors reach thermal stability. Thermal stability is a variation of not more than 2°C (3.6°F) between any two (2) of three (3) connector temperature readings taken at intervals not less than ten (10) minutes apart.

6.9.2 CCT Current Cycle-OFF Period

Connectors tested by the Current Cycle Test (CCT) method shall cool in ambient air. The duration of the current-OFF period for connectors tested by the CCT method shall initially be the same as the current-ON period. The duration may be reduced by forced air cooling after the first twenty-five (25) cycles. With the manufacturer's concurrence, forced air cooling may be initiated during the current-OFF period after the first cycle. The duration for the reduced current-OFF period shall be established by adding five (5) minutes to the time required for the four connectors to reach thermal stability. Thermal stability is a variation of not more than 2°C (3.6°F) between any two (2) of three (3) connector temperature readings taken at intervals not less than ten (10) minutes apart.

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) (41°F ±7.2°F) within thirty (30) seconds of the start of the current-OFF period. The connectors shall remain immersed in the chilled water for a minimum of fifteen (15) minutes after the four (4) connectors have reached thermal stability. Thermal stability is a variation of not more than 2°C (3.6°F) between any two (2) of three (3) connector temperature readings taken at intervals not less than ten (10) minutes apart. 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 on a cycle within the intervals specified in Table 2, depending on the choice of test method. When the number of measurement datums exceeds those specified in Table 2, 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 (20) cycles.

6.10.1 Temperature Measurements

Temperature measurements of the connectors, control conductors, and ambient air shall be taken at the end of the specified current-ON cycle, immediately before the current is turned off. Ambient temperature during resistance measurements should be as close to 20°C (68°F) as practical. In no case shall the ambient temperature during resistance measurements be below 15°C (59°F) nor above 35°C (95°F). At least one thermocouple shall be installed in the current path of each connector at a point where the highest temperature is anticipated. Suggested thermocouple locations are shown in Annex C. One thermocouple shall be installed at the midpoint of the control conductor. The ambient temperature shall be measured within 61 cm (2 ft) of the test loop at a location that minimizes the effect of thermal convection.

Connector, control conductor, and ambient air temperature measurements shall be taken at the end of the current-OFF cycle; these measurements are utilized to determine minimum stable temperature drop and to normalize all resistance measurements to 20°C (68°F).

6.10.2 Resistance Measurements

Resistance measurements shall be taken at the end of the specified current-OFF period with all connectors thermally stabilized at the room ambient temperature. Resistance measurements shall be taken across each connector, between a marked point on the equalizer, preferably at the midpoint thereon, or at the midpoint of a solid conductor. A low magnitude direct current not to exceed 12A shall be used for these measurements. The resistance of each connector assembly shall be corrected from the measured temperature to 20°C (68°F). 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 (68°F) with the following formula:

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

Where R_m is the measured resistance, T_m is the temperature (°C) (°F) of the connector, and α_{20} is the resistance variation coefficient at 20°C (68°F). This coefficient can be taken equal to:

$$\alpha_{20} = 4 \text{ X } 10^{-3}/°C\ (°F) \text{ for copper and ACSR}$$

$$\alpha_{20} = 3.6 \text{ X } 10^{-3}/°C\ (°F) \text{ for aluminum}$$

6.11 Maximum Number of Current Cycles

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

7 Mechanical Test Procedures

7.1 General

Mechanical tests shall be conducted in accordance with Sections 5 and 7.2 through 7.5.2.

7.2 Test Connectors

7.2.1 Unless otherwise specified, three samples of each connector-conductor combination shall be subjected to each applicable mechanical test described in Sections 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 type of device is selected, 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:

(1) The highest rated tensile strength conductor
(2) 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, such as ACSR, AAC, AAC/TW, etc., the test shall be performed on each applicable conductor category.

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 non-homogenous conductors, or that use nonferrous means on ferrous conductors or cores, shall first be tested by installing the connectors in assemblies as described in

Sections 7.3.3.1.3 and 7.3.3.1.4. A constant tensile load equal to 77% ±2% of the rated conductor strength, as determined in Section 4.6.2, shall be applied and maintained on the assemblies for a minimum of one hundred sixty-eight (168) hours.

7.3.3.1.2 Class 1A, normal-tension connectors for use on non-homogenous conductors, shall first be tested by installing the connectors in assemblies as described in Sections 7.3.3.1.3 and 7.3.3.1.4. A constant tensile load equal to 60% minimum of the rated strength of the conductor, as determined in Sections 4.6.2, shall be applied and maintained on the assemblies for a minimum of one hundred sixty-eight (168) hours.

7.3.3.1.3 New, unaged or non-weathered, unused conductor shall be used for all tests. Conductor preparation and connector installation shall be in accordance with the connector manufacturer's recommendations and normal service installation practice. Those procedures and any exceptions shall be recorded in the test report.

7.3.3.1.4 The length of the exposed conductor in the test assembly between each gripping means and each connector shall not be less than the length specified in Table 13. The gripping means may be any device capable of securely gripping all strands without slippage for the duration of the test. Care should be taken to ensure that all strands of stranded conductor being tested are loaded simultaneously. 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 A conductor of homogenous construction will be terminated at both ends in identical connectors. For non-homogenous conductor samples, the three (3) connector samples previously tested in accordance with 7.3.3.1 shall be tested.

7.3.4.2 New, unaged or non-weathered, unused conductor shall be used for all tests. Conductor preparation and connector installation shall be in accordance with the connector manufacturer's recommendations and normal service installation practice. Those procedures and any exceptions shall be recorded in the test report.

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

7.3.4.4 The load shall be applied at a cross-head speed not exceeding 20.8 mm per min per m (1/4 in. per min per ft) of the total length of the exposed conductor between gripping means.

7.3.4.5 The length of the exposed conductor between each gripping means and each connector shall not be less than that given in Table 13.

7.3.4.6 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 and Class 1A connectors and 5% for Class 2 and Class 3 connectors with instruments calibrated according to ASTM E4. The mode of failure shall be recorded.

7.3.4.7 Minimum values indicated in Section 4.6.3 are required.

7.4 Bolt Tightening Test

7.4.1 The torque strength of the bolted connector (see Section 4.10) shall be measured using conductors of the largest and smallest diameters for which the connector is designed.

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

7.5 Conductor Damage Test

7.5.1 The conductor damage test for the tap connector shall be performed on maximum diameter run and minimum diameter 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 shall not be less than the length as specified for Class 1 or Class 1A in Table 13, and is under a tensile load of 20% of its rated conductor strength as determined in Section 4.6.2. Relaxation of the load shall not occur during connector installation. The run conductor shall then be stressed to the breaking point.

8 Copper System Stability Test

The thermal stability test shall be conducted on connectors assembled in series in a loop in accordance with Sections 5, 6.4, 6.5, and 6.6.1 (see Figure 6). This test 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 (59°F) and 35°C (95°F). The ambient temperature shall not vary more than ±5°C (±9°F) during the entire test.

A minimum of two (2) copper connector/cable systems shall be assembled in accordance with the recommendations of the connector manufacturer, on the combination of conductors that represents in number, size, and arrangement the most severe thermal condition for which the connector is designed.

The input current shall be adjusted to produce 100°C (212°F) ±5°C (±9°F) on the hottest conductor. The temperature of the input conductor shall be measured at a point 300 mm (12 in.) from the connector. The temperature of the connector shall be measured as close as possible to the midpoint of the current path between the input and output.

The temperature measurements shall be recorded a minimum of once every twelve (12) hours (plus or minus two (2) hours) beginning with the seventy second (72nd) hour (plus or minus two (2) hours) and continuing through the one hundred twentieth (120th) hour.

9 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
- Name and location of the test facility and the names and titles of the individuals performing the test
- Description of all test assemblies and measuring equipment
- Description of connectors and inhibiting compound before testing to ensure traceability
- Electrical: Class AA, A, B, C
- Mechanical: Class 1, 1A, 2, 3
- Description of conductors, including rated conductor strengths and diameters
- Description of connector installation procedure for each test sequence
- Current cycle and current stability amperages
- Description of the condition of connectors after testing
- Test Method: CCT, CCST
- All options used in performance of the test, including the mounting method (drilled or surface mounted) of the thermocouples. (Diagrams of test setup are desirable.)

- Description of optional tests, if performed
- Other pertinent information, such as installation details not specifically defined or required by this standard
- Certification (if required)

10 Connector Marking

The principal component(s) of a connector shall be marked with the following, space permitting: the manufacturer's name or trademark, the catalog number, conductor range, and die number, if applicable. The marking shall also be on the unit container (the smallest container in which the connector is packaged) subject to user approval. The location of the markings shall be at the manufacturer's convenience.

11 Installation Instructions

Installation instructions shall be provided with the connector. The installation instructions shall be marked on the unit container or on an instruction sheet provided in each unit container. The installation instructions shall include but are not limited to:

- Manufacturer's name, part number, and wire range;
- Wire connector installation instructions (torque, tooling, etc.); and
- Conductor preparation procedures.

Table 1
Test Duration

Connector Current Class	Number of Test Cycles for:	
	CCT Method	**CCST Method**
Class AA (Extra Heavy duty)	500	Not Applicable
Class A (Heavy duty)	500	100
Class B (Medium duty)	250	75
Class C (Light duty)	125	50

Table 2
Resistance and Temperature Measurement Intervals

Data Point Number for Different Classes (i)	Current Cycle Test Method (CCT) (Cycles)	Current Cycle Submersion Test Method (CCST) (Cycles)
1	25 – 30	5 – 7
2	45 – 55	13 – 17
3	70 – 80	23 – 27
4	95 – 105	35 – 39
5 (Class C)	120 – 130	48 – 52
6	160 – 170	57 – 61
7	200 – 210	66 – 70
8 (Class B)	245 – 255	73 – 77
9	320 – 330	81 – 85
10	400 – 410	89 – 93
11 (Class A)	495 – 505	98 – 102
25 (Class AA)	Every 20 cycles, starting on the 25th cycle	Not Applicable

Table 3
Tensile Force, AWG Wire

Wire Size		Force					
AWG	mm^2	Copper		Aluminum		ACSR	
		N	lbf	N	lbf	N	lbf
16	1.3	133	30	67	15	---	---
14	2.1	222	50	111	25	---	---
12	3.3	311	70	156	35	---	---
10	5.3	356	80	178	40	---	---
8	8.4	400	90	200	45	445	100
6	13.3	445	100	222	50	445	100
4	21.1	623	140	311	70	667	150
3	26.6	712	160	356	80	667	150
2	33.6	801	180	400	90	890	200
1	42.4	890	200	445	100	890	200

Table 4
Tensile Force, mm^2 Wire

Wire Size	Force					
	Copper		Aluminum		ACSR	
mm^2	N	lbf	N	lbf	N	lbf
1.5	178	40	---	---	---	---
2.5	267	60	---	---	---	---
4	334	75	---	---	---	---
6	378	85	---	---	---	---
10	422	95	214	48	---	---
12.5	---	---	---	---	450	101
16	535	120	267	60	450	101
20	---	---	---	---	450	101
25	665	150	334	75	675	152
31.5	---	---	---	---	875	197
35	845	190	423	95	---	---
40	---	---	---	---	890	200

Table 5
Tightening Torque, Inch Size Fasteners

Tightening Torque						
Size	**Aluminum Fastener**			**Galvanized Steel, Stainless Steel, or Silicon Bronze Fastener**		
in.	**N m**	**lb in.**	**lb ft.**	**N m**	**lb in.**	**lb ft.**
5/16	-	--	-	20	180	15
3/8	19	168	14	27	240	20
13/32	23	204	17	33	288	24
7/16	27	240	20	41	360	30
1/2	34	300	25	54	480	40
9/16	43	384	32	65	576	48
5/8	54	480	40	75	660	55
3/4	73	650	54	95	840	70

Table 6
Tightening Torque, Metric Size Fasteners

Tightening Torque						
Size	**Aluminum Fastener**			**Galvanized Steel, Stainless Steel, or Silicon Bronze Fastener**		
mm	**N m**	**lb in.**	**lb ft.**	**N m**	**lb in.**	**lb ft.**
M8	-	--	-	25	216	18
M10	30	264	22	49	432	36
M12	50	444	37	85	756	63
M14	60	528	44	135	1200	100
M16	75	660	55	210	1860	155
M18	90	792	66	300	2652	221
M20	100	888	74	425	3756	313

Table 7
Conductor Lengths for Current Cycle Tests, AWG/kcmil Sizes

Conductor Type		Exposed Length			
Aluminum	**Copper**	**Stranded**		**Solid**	
		mm	**in.**	**mm**	**in.**
4/0 AWG and below	2/0 AWG and below	305	12	610	24
Over 4/0 AWG through 795 kcmil	Over 2/0 AWG through 500 kcmil	610	24	1220	48
Over 795 kcmil	Over 500 kcmil	914	36	1830	72

Table 8
Conductor Lengths for Current Cycle Tests, mm^2 Sizes

Conductor Type		Exposed Length			
Aluminum	**Copper**	**Stranded**		**Solid**	
		mm	**in.**	**mm**	**in.**
120 mm^2 and below	70 mm^2 and below	305	12	610	24
Over 120 mm^2 through 400 mm^2	Over 70 mm^2 through 240 mm^2	610	24	1220	48
Over 400 mm^2	Over 240 mm^2	914	36	1830	72

Table 9
Suggested Initial Test Current to Raise AWG/kcmil
Control Conductor Temperature 100°C (212°F) Above Ambient

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

Table 10
Suggested Initial Test Current to Raise mm^2
Control Conductor Temperature 100°C (212°F) Above Ambient

Aluminum or Aluminum Composite		**Copper or Copper Composite**	
Conductor Size (mm^2)	**Current (amperes)**	**Conductor Size (mm^2)**	**Current (amperes)**
-	-	10	105
16	100	16	145
25	135	25	195
35	170	35	245
50	225	50	330
70	270	70	400
95	345	95	505
120	405	120	600
150	450	150	700
185	550	185	795
240	700	240	970
300	805	300	1100
400	930	400	1300
500	1085	500	1565

Table 11
Minimum Current-ON Duration for AWG/kcmil Control Conductors

Aluminum or Aluminum Composite (kcmil)	**Copper or Copper Composite**	**Minimum Current-ON Period (Hours)**
Up through 336.4 kcmil	Up through 4/0 AWG	1.0
Over 336.4 kcmil through 795 kcmil	Over 4/0 AWG through 500 kcmil	1.5
Over 795 kcmil	Over 500 kcmil	2.0

Table 12
Minimum Current-ON Duration for mm^2 Control Conductors

Aluminum	**Copper**	**Minimum Current-ON Period (Hours)**
Up through 185 mm^2	Up through 120 mm^2	1.0
Over 185 mm^2 through 400 mm^2	Over 120 mm^2 through 240 mm^2	1.5
Over 400 mm^2	Over 240 mm^2	2.0

Table 13
Length of Exposed Conductor

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

*Exception—For conductors 4/0 AWG and smaller, the length of the exposed conductor may be shortened from 3.66 m (144 in.) to 0.61 m (24 in.), if procedures ensure simultaneous loading of all strands and the manufacturer agrees.

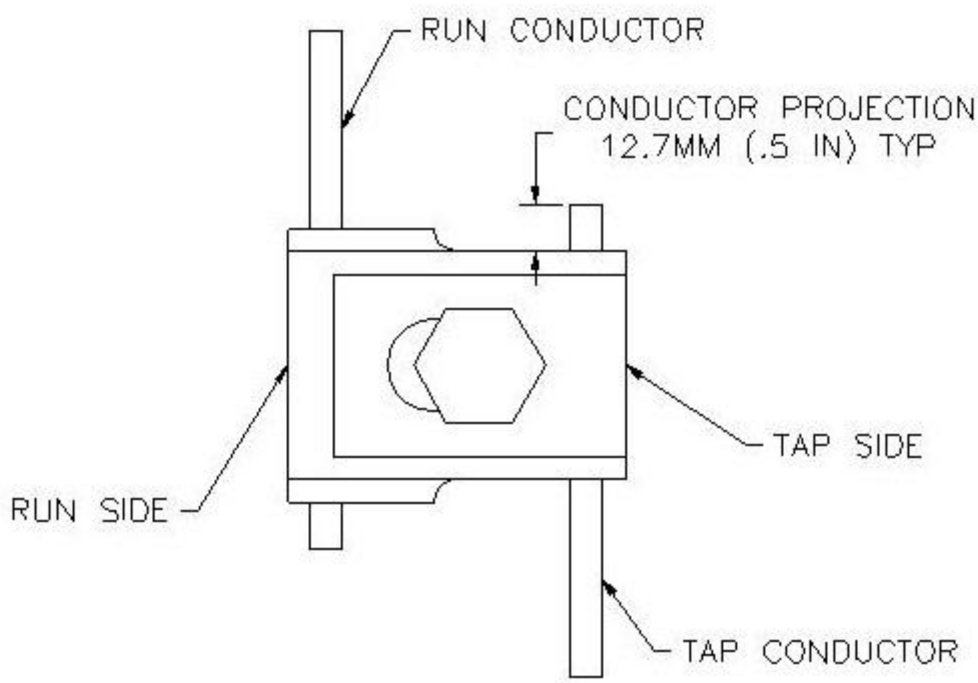
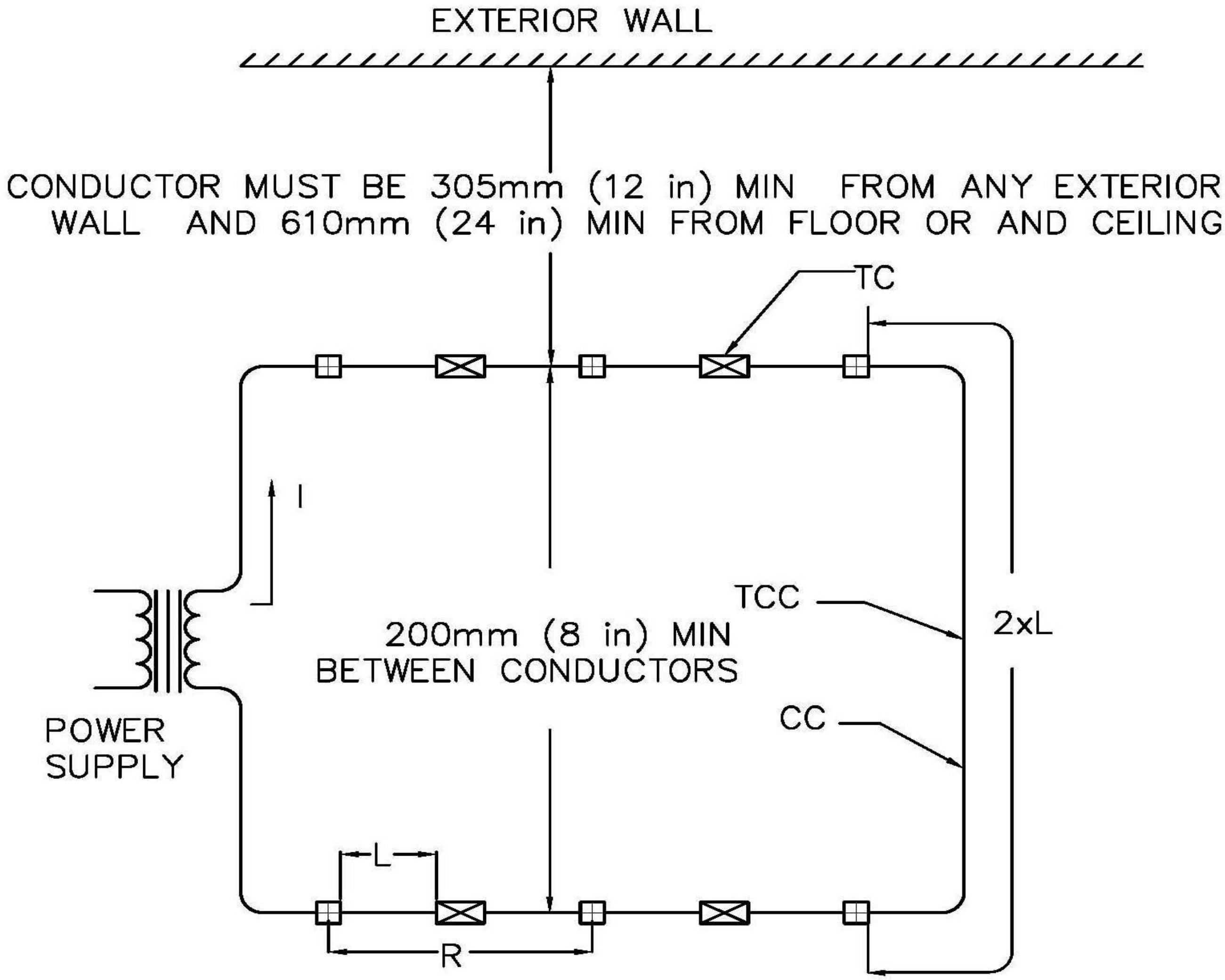


Figure 1
Length of Projected Conductor



⊞ –EQUALIZER

⊠ –TEST CONNECTOR

TC –TEMPERATURE MEASUREMENT POINT
SELECT EXACT MEASUREMENT POINT BASED UPON THE HOTTEST POINT ON THE CONNECTOR

CC –CONTROL CONDUCTOR , LENGTH = 2 x L

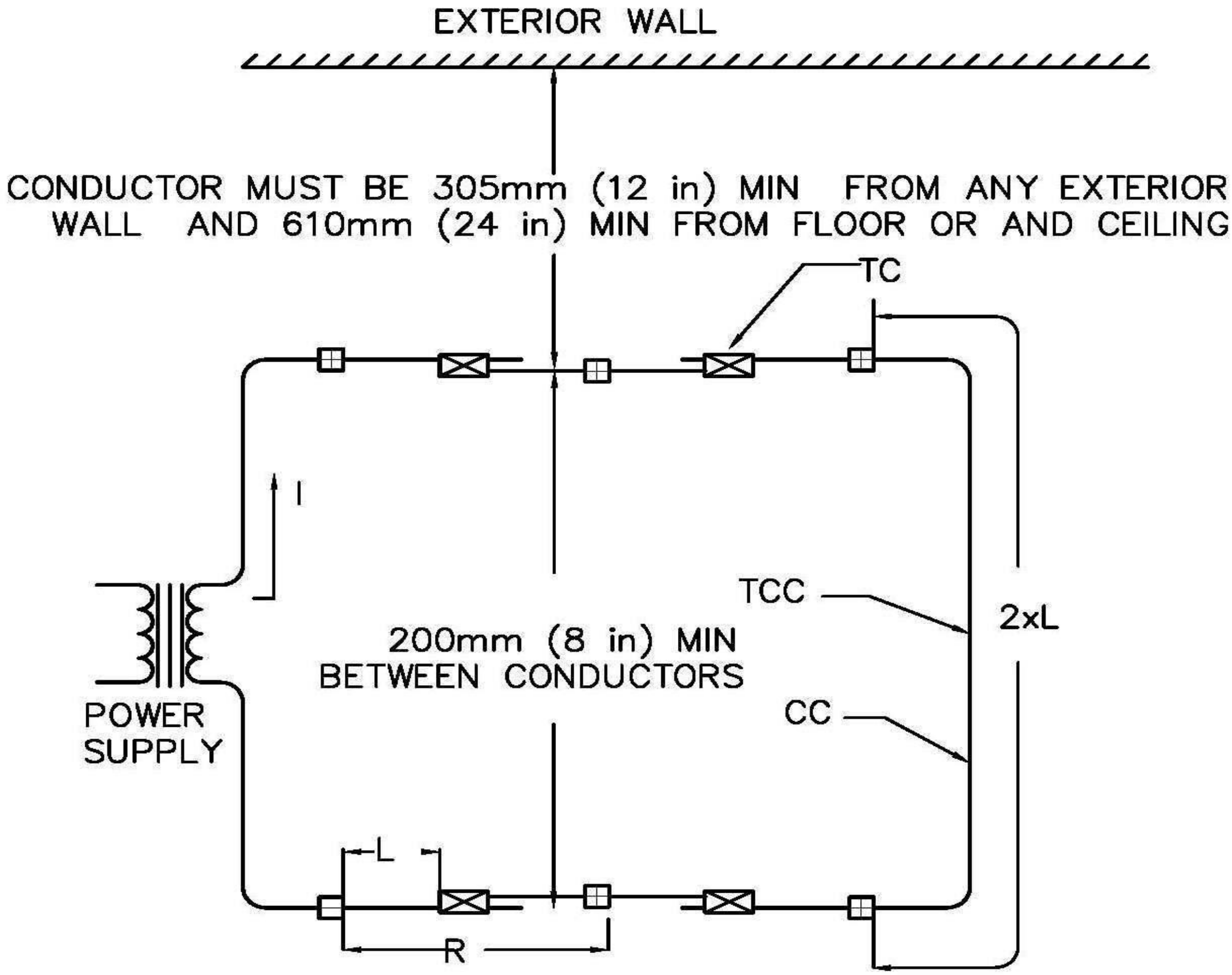
L –EXPOSED CABLE LENGTH BETWEEN EQUALIZER AND CONNECTOR PER TABLE 5 OR 6

R –EQUALIZER TO EQUALIZER RESISTANCE

I –TEST CURRENT

TCC –CONTROL CONDUCTOR TEMPERATURE MEASUREMENT POINT (MIDPOINT OF THE CONDUCTOR)

Figure 2
Horizontal Schematic



⊞ —EQUALIZER

⊠ —TEST CONNECTOR

TC —TEMPERATURE MEASUREMENT POINT
SELECT EXACT MEASUREMENT POINT BASED UPON THE HOTTEST POINT ON THE CONNECTOR

CC —CONTROL CONDUCTOR , LENGTH = 2 x L

L —EXPOSED CABLE LENGTH BETWEEN EQUALIZER AND CONNECTOR PER TABLE 5 OR 6

R —EQUALIZER TO EQUALIZER RESISTANCE

I —TEST CURRENT

TCC —CONTROL CONDUCTOR TEMPERATURE MEASUREMENT POINT (MIDPOINT OF THE CONDUCTOR)

Figure 3
Tap Schematic

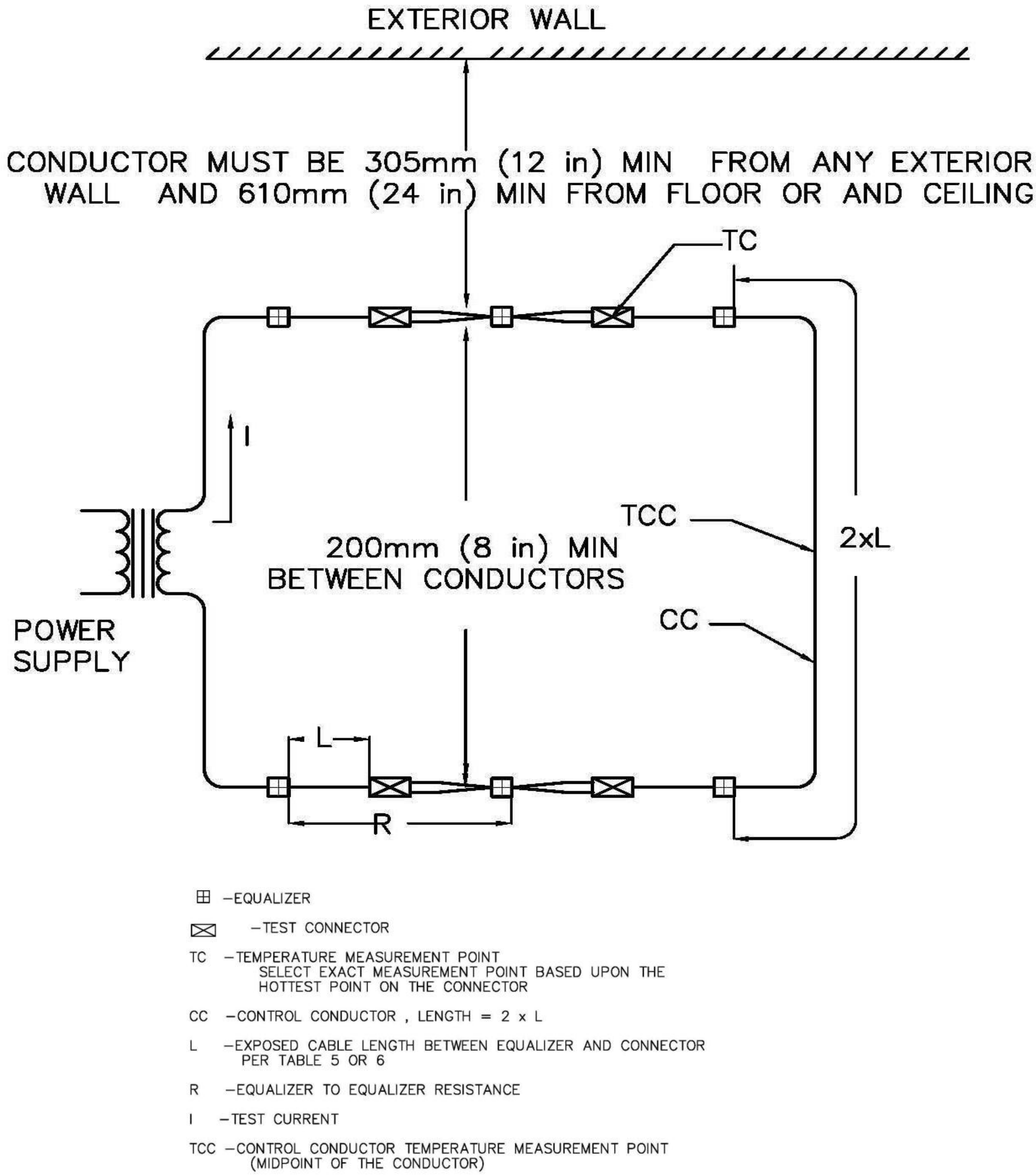
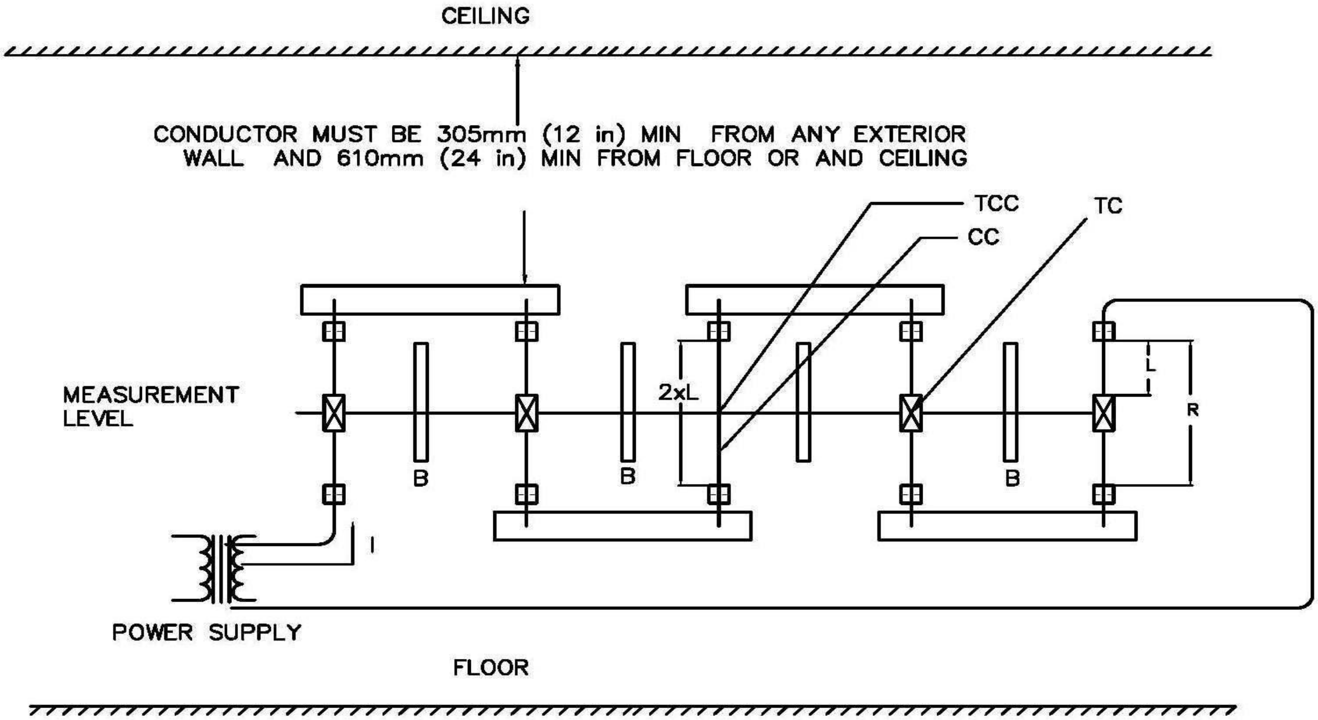


Figure 4
Wye Schematic



⊞ –EQUALIZER

⊠ –TEST CONNECTOR

TC –TEMPERATURE MEASUREMENT POINT
SELECT EXACT MEASUREMENT POINT BASED UPON THE HOTTEST POINT ON THE CONNECTOR

CC –CONTROL CONDUCTOR , LENGTH = 2 x L

L –EXPOSED CABLE LENGTH BETWEEN EQUALIZER AND CONNECTOR PER TABLE 5 OR 6

R –EQUALIZER TO EQUALIZER RESISTANCE

I –TEST CURRENT

TCC –CONTROL CONDUCTOR TEMPERATURE MEASUREMENT POINT (MIDPOINT OF THE CONDUCTOR)

B – BAFFLE TO SEPARATE TEST SPECIMENS

Figure 5
Vertical Configuration

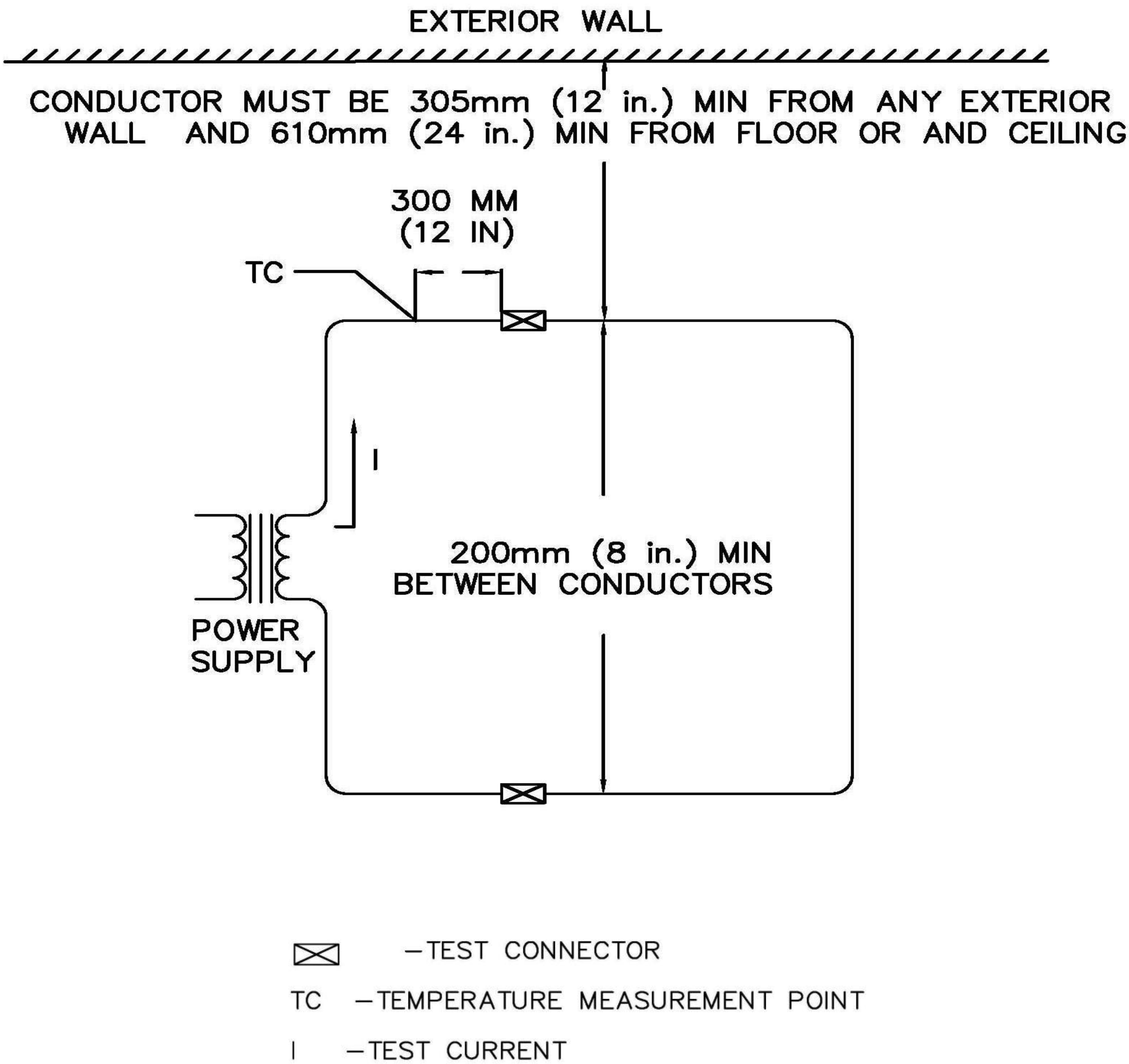


Figure 6
Copper System Stability Schematic

Annex A
Heat Cycle Data Sheet

(informative)

Table A1
Example of Stability Factor Calculation for Class A CCT

Cycle number (i)	**Temperature °C**		**d_i**	**S_i**
	Control conductor (T_{cc})	**Connector (T_c)**		
25	125	108	17	7.1
50	128	110	18	8.1
75	126	114	12	2.1
100	129	113	16	6.1
125	127	115	12	2.1
175	128	117	11	1.1
225	126	120	6	-3.9
275	125	118	7	-2.9
350	128	122	6	-3.9
425	127	124	3	-6.9
500	125	124	1	-8.9
			Sum 109 Average (D) = 9.9	

Stability Worksheet Example

Example

Stability Worksheet

Data Sheet

Current Cycle Data Sheet

To access and download the spreadsheets, double click on the above Excel icons or download them from the standard's webpage: www.nema.org/stds/c119-4.cfm.

Annex B
Applicable Standards

(informative)

ASTM B1 *Hard-Drawn Copper Wire*

ASTM B2 *Medium-Hard-Drawn Copper Wire*

ASTM B8 *Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*

ASTM B228 *Concentric-Lay-Stranded Copper-Clad Steel Conductors*

ASTM B229 *Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors*

ASTM B230/B230M *Aluminum 1350-H19 Wire for Electrical Purposes*

ASTM B231/B231M *Concentric-Lay-Stranded Aluminum 1350 Conductors*

ASTM B232/B232M *Concentric-Lay-Stranded Aluminum Conductors, Coated-Steel Reinforced (ACSR)*

ASTM B398/B398M *Aluminum-Alloy 6201-T81 Wire for Electrical Purposes*

ASTM B399/B399M *Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors*

ASTM B400 *Compact Round Concentric-Lay-Stranded Aluminum 1350 Conductors*

ASTM B401 *Compact Round Concentric-Lay-Stranded Aluminum Conductors, Steel-Reinforced (ACSR/COMP)*

ASTM B415 *Hard-Drawn Aluminum-Clad Steel Wire*

ASTM B416 *Concentric-Lay-Stranded Aluminum-Clad Steel Conductors*

ASTM B498/B498M *Zinc-Coated (Galvanized) Steel Core Wire for Use in Overhead Electrical Conductors*

ASTM B500/B500M *Metallic Coated Stranded Steel Core for Use in Overhead Electrical Conductors*

ASTM B502 *Aluminum-Clad Steel Core Wire for Use in Overhead Electrical Aluminum Conductors*

ASTM B524/B524M *Concentric-Lay-Stranded Aluminum Conductors, Aluminum-Alloy Reinforced (ACAR, 1350/6201)*

ASTM B549 *Concentric-Lay-Stranded Aluminum Conductors, Aluminum-Clad Steel Reinforced for Use in Overhead Electrical Conductors*

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

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

ASTM B701/B701M *Concentric-Lay-Stranded Self-Damping Aluminum Conductors, Steel Reinforced (ACSR/SD)*

ASTM B778 *Shaped Wire Compact Concentric-Lay-Stranded Aluminum Conductors (AAC/TW)*

ASTM B779 *Shaped Wire Compact Concentric-Lay-Stranded Aluminum Conductors, Steel-Reinforced (ACSR/TW)*

Annex C
Suggested Thermocouple Locations

(informative)

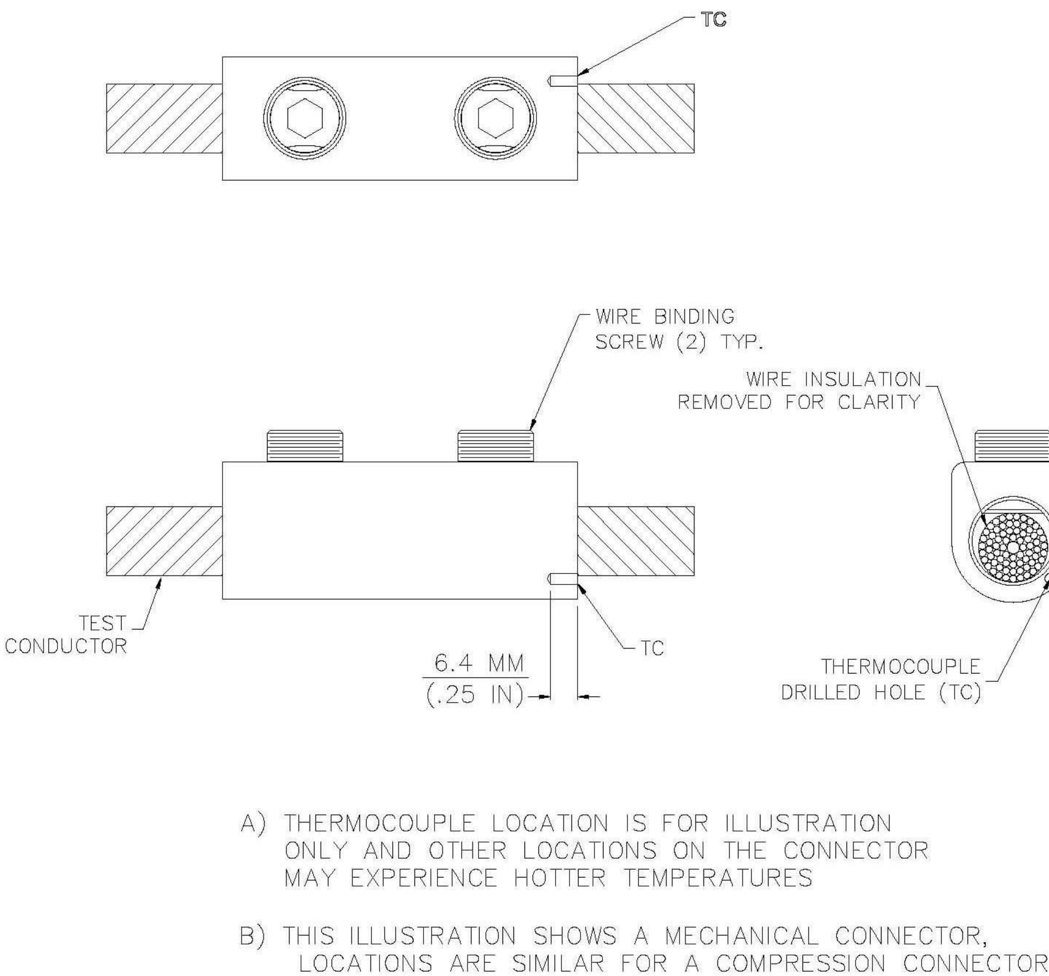


Figure C-1
Suggested Thermocouple Locations

Annex D
Optional Fault Current Test Class "F" Connectors

(normative)

D1 Background

D1.1 An optional fault current test may be performed by agreement between the supplier and the purchaser.

D1.2 All connectors shall first acceptably complete the CCT or CCST test applicable to that connector class.

D1.3 This optional fault current performance test shall be applied to new connectors of the same type that have been previously qualified under ANSI C119.4.

D1.4 Connectors specified for use on both copper and aluminum conductors shall be tested with both types of conductors.

D1.5 The nominal fault current levels used in the testing are specified in Tables D1 and D2. Factors to consider when specifying the fault current level may include, but are not limited to: application for the connector, fault current ratings of other equipment on the power system, expected fault current levels on the power system where the connector will be used, and protection equipment ratings.

D1.6 Connectors that acceptably pass the fault current performance test shall be designated by "F-X" (fault current tested), where "X" is the nominal fault current level to which the connector was tested (e.g., F-12.5 kA).

D1.7 IEC 61284 Section 13.5.2.1 can be substituted for fault current testing described in Annex D if agreed upon by both the manufacturer and purchaser; however, a class "F-X" rating will not be designated.

D2 Sampling Requirements

D2.1 Four samples of each connector/conductor combination, of the specific class of connector being tested, shall be mounted in a test loop in a horizontal plane.

D2.2 This loop shall be assembled with separable equalizers, and with a minimum exposed conductor length that is appropriate for the conductor size, as specified in the ANSI C119.4 CCT procedures, Tables 7 and 8.

D2.3 The connector/conductor position shall be marked prior to the test so any conductor slippage can be determined.

D3 Connector Family Sample Set

To qualify a family of connectors (group of connectors using similar design criteria), a minimum of three (3) sizes (largest, smallest, and intermediate) shall be tested. The results of testing a single connector-conductor combination to Annex D may be extended to cover other members of a family of connectors to Annex D provided the following conditions are met.

D3.1 Mechanical Range Taking Connectors

Example—For requirements for a family of mechanical connectors, See Table D3.

D3.2 Compression Connectors

Example—For requirements for a family of compression connectors, See Table D4.

D3.3 Range Taking Connectors

Range taking connectors are tested with the smallest conductor size having the largest fault current rating. Conductor sizes with a smaller fault current rating need not be tested.

Example—For requirements for range taking connectors, See Table D5.

D4 Test Methods

D4.1 The test samples shall complete a minimum of 100 conditioning cycles using the C119.4 CCT procedure prior to applying a fault current, to ensure that the connector/conductor assemblies are fully conditioned and that both thermal and electrical stability of the interface has been achieved. The samples shall be tested at the current and temperature levels appropriate for the connector class.

D4.2 Following conditioning, the connector/conductor samples shall be disassembled at each of the back to back connector/conductor equalizers so that each of the four connector/conductor assemblies can be individually subjected to the fault current testing. Each connector/conductor assembly shall be physically restrained at one end by clamping the conductor near the equalizer, while the connector end is grounded and unrestrained. To limit movement of the grounding conductor, the grounding conductor may be restrained no closer than 5 feet away from the free end of the connector sample assembly. Suggested minimum sizes for the flexible grounding conductor are given in Tables D1 and D2. Each connector sample assembly shall initially be placed with the conductor in a straight (in-line) position before the first application of fault current.

D4.3 Current surges at a suitable level for the required fault current class, as specified in Tables D1 or D2, shall be applied to each connector/conductor assembly.

D4.4 Each connector/conductor assembly shall be allowed to cool to 100°C (212°F) or less after each current surge. To speed up the testing process, forced air cooling may be applied between current surges.

Table D1
Fault Current Levels for Connectors Used in Primary (Greater than 600 V) Circuits

Nominal Fault Current Rating (kA)	**12.5**	**15**	**25**	**38**	**60**
Typical Continuous Current Rating (A)	100–199	200–299	300–599	600–1199	≥ 1200
RMS Current (kA)	12.5	15	25	38	60
Minimum X/R Ratio	8	10	20	20	20
Surge Duration (seconds)	0.13 sec/8 cycles @ 60 Hz	0.13 sec/8 cycles @ 60 Hz	0.3 sec/18 cycles @ 60 Hz	0.3 sec/18 cycles @ 60 Hz	0.3 sec/18 cycles @ 60 Hz
Number of Surges	10	10	10	10	10
Minimum Grounding Conductor Size	#2 AWG Cu	#1 AWG Cu	4/0 AWG Cu	350 kcmil Cu	500 kcmil Cu
Minimum Conductor Size for Test Samples	#4 AWG Cu #1 AWG Al	#1 AWG Cu 1/0 Al	2/0 Cu 250 kcmil Al	250 kcmil Cu 350 kcmil Al	400 kcmil Cu 556.5 kcmil Al

Table D2
Fault Current Levels for Connectors Used in Secondary (600 V or Less) Circuits

Nominal Fault Current Rating (kA)	**10**	**20**	**30**
Typical Continuous Current Rating (A)	100–399	400–599	≥ 600
RMS Current (kA)	10	20	30
Minimum X/R Ratio	6	12	20
Surge Duration (seconds)	0.083 sec/5 cycles @ 60 Hz	0.25 sec/15 cycles @ 60 Hz	0.25 sec/15 cycles @ 60 Hz
Number of Surges	10	10	10
Minimum Grounding Conductor Size	#2 AWG Cu	3/0 AWG Cu	250 kcmil Cu
Minimum Conductor Size for Test Samples	#6 AWG Cu #2 AWG Al	2/0 Cu 250 kcmil Al	250 kcmil Cu 350 kcmil Al

NOTE 1—The typical continuous current ratings (A) noted in Tables D1 and D2 are representative of the relationship between the continuous current ratings of the attached conductor and fault current requirements of equipment used for electric distribution systems. These values are not specific to conductor sizing or current ratings, but are used as a guide to determine the appropriate fault current test level for a connector based upon the continuous current rating of the attached conductor.

NOTE 2—Minimum Conductor Size for Test Samples in Tables D1 and D2 are based on two criteria: 1) IEEE 837 with calculated temperature <60% of fusing current; 2) copper conductor must be larger than the Minimum Grounding Conductor Size specified for the next lower current rating.

Table D3
Mechanical Range Taking Connectors

Family of Secondary URD Mechanical Connectors					
Connector Cable Range		Max Conductor Continuous Current (Amps)	Current Range (Amps)	Fault Current Level Table D2 (kA)	Test Conductor (Table D2)
Min	Max				
#6 AWG Al (USE)	4/0 AWG Al (USE)	290	100 – 399	10	#2 AWG Al
#6 AWG Al (USE)	350 kcmil Al (USE)	385	100 – 399	10	Not Tested
#2 AWG Al (USE)	500 kcmil Al (USE)	465	400 – 599	20	250 kcmil Al
1/0 AWG Al (USE)	1000 kcmil Al (USE)	670	≥ 600	30	350 kcmil Al

Table D4
Compression Connectors

Family of Compression Connectors Aluminum/Copper Rated from #4 AWG – 1000 kcmil				
Connector Conductor Size	Max Continuous Current (Amps)	Current Range (Amps)	Fault Current Level Table D1 (kA)	Test Conductor
#4 AWG AAC	185	100 – 199	12.5	#4 AWG AAC
#1 AWG AAC	214	200 – 299	15	Not Tested
3/0 AWG AAC	331	300 – 599	25	3/0 AWG AAC
500 kcmil AAC	658	600 – 1199	38	Not Tested
1000 kcmil Cu	1180	600 – 1199	38	1000 kcmil Cu

Table D5
Range Taking Connectors

Range Taking Compression Connector from #4 AWG to 350 kcmil Aluminum				
Conductor Size	Max Continuous Current (Amps)	Current Range (Amps)	Fault Current Level Table D1 (kA)	Test Conductor
#4 AWG AAC	185	100 – 199	12.5	Not Tested
3/0 AWG AAC	331	300 – 599	25	3/0 AWG AAC
350 kcmil	526	300 – 599	25	Not Tested

D4.5 Conductor and connector surface temperature shall be measured and plotted as a function of current, *I*, and time, *t.*

D4.6 Following the test, the electrical resistance shall be recorded for each sample when samples have returned to ambient temperature.

D5 Performance Requirements

D5.1 Electrical continuity shall be maintained throughout testing, as indicated by resistance measurements made before and after the current surge testing.

D5.2 The connector shall remain intact throughout the test, with no physical damage, broken conductor strands, connector breakage, or movement of the conductor relative to the connector.

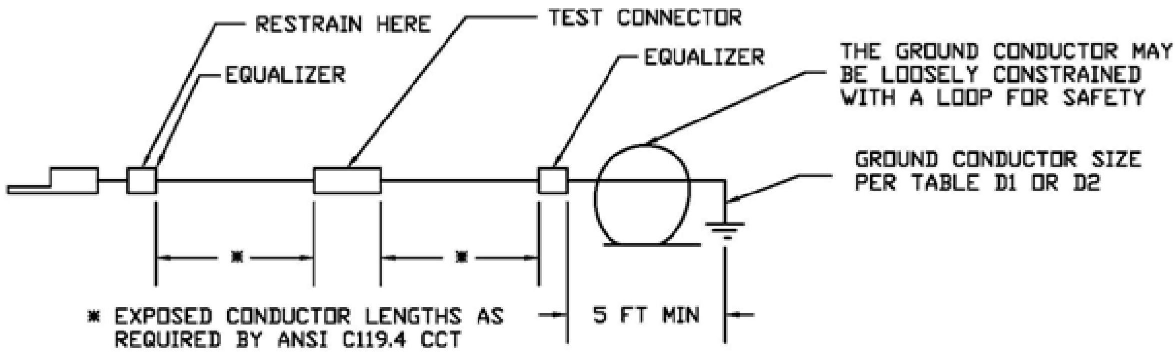


Figure D1
Typical Circuit Schematic for an Overhead Splice Fault Current Test

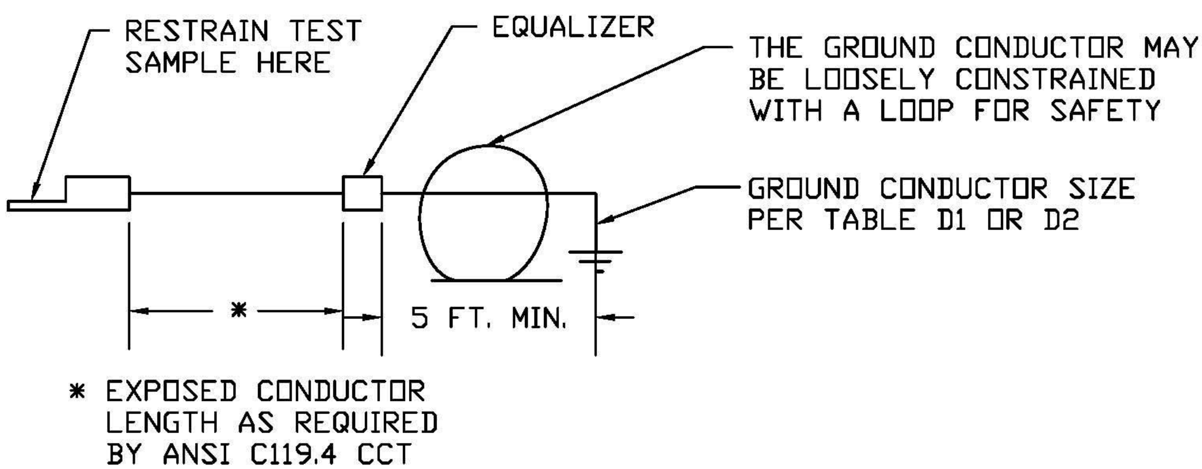


Figure D2
Typical Circuit Schematic for an Overhead Termination Fault Current Test

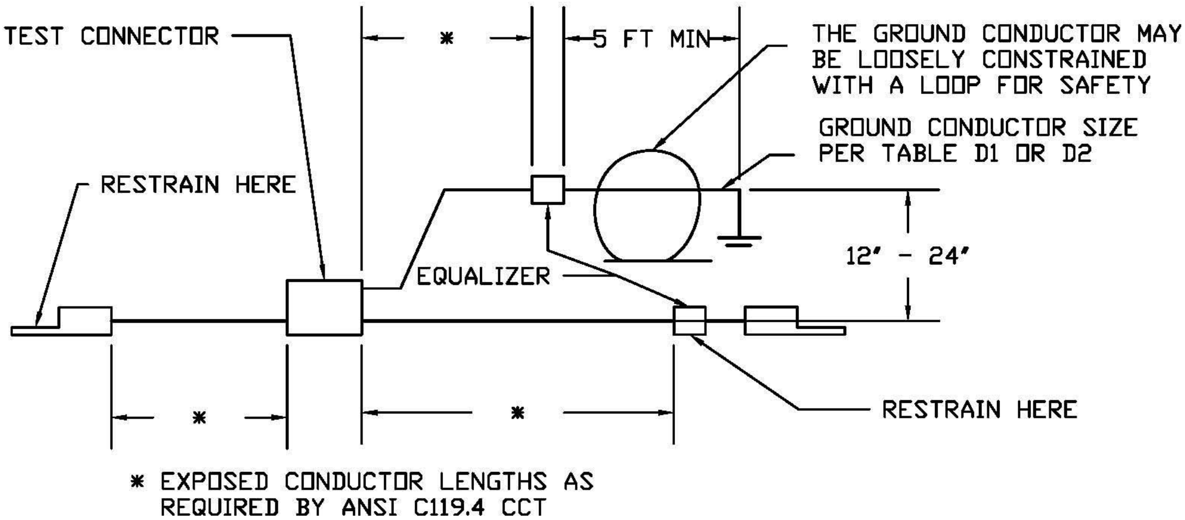


Figure D3
Typical Circuit Schematic for a Tap Connector Fault Current Test

D6 References

(1) *Aluminum Electrical Conductor Handbook*, 3rd Edition, 1989; reaffirmed in 1998
(2) IEEE 837-1989 *Standard for Qualifying Permanent Connections Used in Substation Grounding*
(3) ANSI/IEEE C37.41 *Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories*
(4) ANSI/IEEE C37.34 *Standard Test Code For High-Voltage Air Switches*

Annex E
Optional Corrosion Test Addition to Current Cycle Test (CCT) Class "S" Connectors

(normative)

E1 Scope and Purpose

E1.1 Scope

An optional corrosion test may be performed by agreement between the supplier and the purchaser. This optional test establishes the parameters and performance requirements for a corrosion test of electrical connectors covered by ANSI C119.4. This test is conducted as a precondition for the ANSI C119.4 Current Cycle Test (CCT). The mechanical requirements of ANSI C119.4 are not addressed.

E1.2 Purpose

The purpose of this optional test is to simulate a corrosive environment exposure and give reasonable assurance to the user that connectors complying with the requirements of this optional test will perform in a satisfactory manner in a corrosive environment, provided they are installed in accordance with the manufacturer's recommendations.

E2 Sample Preparation

E2.1 Four (4) samples of each connector and conductor combination required by the ANSI C119.4 Current Cycle Test (CCT) shall be used.

E2.1.1 The CCT loop as specified by ANSI C119.4 may be assembled without disconnects when a complete loop is to be exposed.

E2.1.2 The CCT loop as specified by ANSI C119.4 may be assembled with disconnects between equalizers when an individual connector/conductor/equalizer sample is to be exposed.

E3 Test Procedure

E3.1 The samples shall be subjected to a 5% salt fog exposure for 1,000 hours in accordance with ASTM B117.

E3.1.1 The complete test loop shall be exposed and later assembled into the ANSI C119.4 CCT test.

E3.1.2 When disconnects are installed between equalizers, the individual samples shall be exposed and later assembled into the ANSI C119.4 CCT test loop.

E3.1.2.1 When individual samples are used, the complete connector/conductor/equalizer shall be exposed.

E3.1.2.2 Additional installed parts needed to assemble the individual sample into the test loop shall be protected from the corrosion environment or designed to ensure the corrosion environment does not affect the resistance measurement of the ANSI C119.4 CCT test.

E4 Performance Requirements

E4.1 Connectors exposed to the corrosion environment shall conform to the operating temperature and resistance requirements of the ANSI C119.4 CCT test for the duration of the class under consideration.

E4.2 The force or torque to remove a connector designed to be removed shall not exceed twice the initial recommended installation force or torque.

E5 Marking

E5.1 In addition to the marking required by ANSI C119.4, an "S" designation shall be added for connectors that comply with the requirements of this test.

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