Public Input No. 860-NFPA 70-2020 [Global Input]

Type your content here ...

Add to Article 100

Compact (as applied to conductor stranding) – a conductor where each layer of strands is pressed together to the extent that almost all the gaps between the strands are eliminated so that the overall diameter of the finished conductor is less than a concentric stranded conductor and less than a compressed stranded conductor.

Compressed (as applied to conductor stranding) – a conductor where the outer layer of strands is pressed together so that the overall diameter of the finished conductor is less than a concentric stranded conductor, but greater than a compact stranded conductor.

Concentric (as applied to conductor stranding) - a conductor consisting of a straight, central strand surrounded by one or more layers of strands, helically laid in a geometric pattern.

Revise footnote 3 to Chapter 9, Table 8

3. Conductors with compact and compressed stranding have ~~about 9 percent and 3 percent, respectively,~~ smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.

Delete footnote to Table C.1(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Delete footnote to Table C.2(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Delete footnote to Table C.3(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Delete footnote to Table C.4(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Delete footnote to Table C.5(A)

~~Definition: Compact stranding is the result of a manufacturing process where the~~

~~stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Delete footnote to Table C.6(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Delete footnote to Table C.7(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Delete footnote to Table C.8(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Delete footnote to Table C.9(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Delete footnote to Table C.10(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Delete footnote to Table C.11(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Delete footnote to Table C.12(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Delete footnote to Table C.13(A)

~~**Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.**~~

Additional Proposed Changes

File Name	Description	Approved
2023_code_proposals_Conductor_construction.docx	Proposal	

Statement of Problem and Substantiation for Public Input

Section 2.2.2.1 of the NEC Style Manual requires that, in general, definitions that appear in two or more articles be located in Article 100. The term compact appears in Table 312.6(A), Table 312.6(B), 501.15, 505.16, Chapter 9, Table 1, foot note (10), Table 5A, Table 8, and Annex C; the term compressed appears in footnote 3 to Chapter 9, Table 8; and the term concentric appears in Chapter 9, Table 1, foot note (10), and Annex C.

The definition of compact and compressed should not be located in the footnote to Table 8 in Chapter 9 and should be located in Chapter 1, Definitions.

The definition of compact stranding should not be located at the bottom of Tables C.1(A) thru C.13(A) and should be located in Chapter 1, Definitions.

These proposed additions and relocations will provide necessary clarity and usability with respect to application of definitions. These actions will also achieve compliance with the NEC Style Manual.

Submitter Information Verification

Submitter Full Name: Susan Stene
Organization: UL LLC
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Submittal Date: Fri Apr 10 14:47:41 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8428-NFPA 70-2021
Statement: The Definitions for conductor stranding have been relocated to Article 100 and text removed from Chapter 9 Table 8 and Annex C to align with the Style Manual.

Rationale:

Section 2.2.2.1 of the NEC Style Manual requires that, in general, definitions that appear in two or more articles be located in Article 100. The term compact appears in Table 312.6(A), Table 312.6(B), 501.15, 505.16, Chapter 9, Table 1, foot note (10), Table 5A, Table 8, and Annex C; the term compressed appears in footnote 3 to Chapter 9, Table 8; and the term concentric appears in Chapter 9, Table 1, foot note (10), and Annex C.

The definition of compact and compressed should not be located in the footnote to Table 8 in Chapter 9 and should be located in Chapter 1, Definitions.

The definition of compact stranding should not be located at the bottom of Tables C.1(A) thru C.13(A) and should be located in Chapter 1, Definitions.

These proposed additions and relocations will provide necessary clarity and usability with respect to application of definitions. These actions will also achieve compliance with the NEC Style Manual.

Proposal

Article 100, add new definitions

Compact (as applied to conductor stranding) – a conductor where each layer of strands is pressed together to the extent that almost all the gaps between the strands are eliminated so that the overall diameter of the finished conductor is less than a concentric stranded conductor and less than a compressed stranded conductor.

Compressed (as applied to conductor stranding) – a conductor where the outer layer of strands is pressed together so that the overall diameter of the finished conductor is less than a concentric stranded conductor, but greater than a compact stranded conductor.

Concentric (as applied to conductor stranding) - a conductor consisting of a straight, central strand surrounded by one or more layers of strands, helically laid in a geometric pattern.

Revise footnote 3 to Chapter 9, Table 8

3. Conductors with compact and compressed stranding have ~~about 9 percent and 3 percent, respectively,~~ smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.

Delete footnote to Table C.1(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Delete footnote to Table C.2(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

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~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

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Delete footnote to Table C.6(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

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~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

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Delete footnote to Table C.12(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Delete footnote to Table C.13(A)

~~Definition: Compact stranding is the result of a manufacturing process where the stranded conductor is compressed to the extent that the interstices (voids between strand wires) are virtually eliminated.~~

Public Input No. 2089-NFPA 70-2020 [New Article after 100]

TITLE OF NEW CONTENT Cable

Type your content here ... A factory assembly of one or more conductors.

Statement of Problem and Substantiation for Public Input

Some of the cable articles in Chapter 3 talk of a factory assembly and others do not. Of itself, that would not be a big deal. However, the term "cable" is not understood consistently. My impression is that Chapter 3 intends all the cable articles to refer to factory assemblies. Yet today I had an email from a 3-generation master electrician and contractor, saying ". . . if two K&T in individual loom enters one hitlock, is it considered a cable. A cable is two or more conductors." Presumably the author has not had occasion to install single-conductor SE (nor have I), or didn't realize it is considered a "cable assembly." Adding this definition to Article 100 seems better than trying to add "factory assembly" to each of the cable articles' .2 sections. If this lets the various CMPs remove a few words from their articles, so much the better.

Submitter Information Verification

Submitter Full Name: David Shapiro
Organization: Safety First Electrical
Street Address:
City:
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Zip:
Submittal Date: Wed Jul 29 19:56:22 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The definition as provided will present conflicts with the use of product standards and the NEC when using the terms cable and factory assembly. Its our assumption the submitters intent was to have a new definition rather than a New Article after 100 for “Cable” .

Public Input No. 2857-NFPA 70-2020 [Definition: Copper-Clad Aluminum Conductors.]

Copper-Clad Aluminum Conductors.

Conductors drawn from a copper-clad aluminum rod, with the copper metallurgically bonded to an aluminum core~~, where the copper forms a minimum of 10 percent of the cross-sectional area of a solid conductor or each strand of a stranded conductor.~~ . (CMP-6)

Additional Proposed Changes

File Name	Description	Approved
Proposed_Article_100_Definition_of_Copper-Clad_Aluminum_Draft_Fnl.docx	Word file attached for clarity.	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Technical Substantiation

Section 2.3.2.1 of NFPA Manual of Style states that definitions shall only describe the term being used and section 2.3.3.3 states that definitions shall not contain requirements. The present definition contains a requirement that the copper-clad aluminum have a minimum of 10 percent of the cross-sectional area being copper.

This requirement properly belongs in 310.3(B) along with the other requirements for conductor materials. A correlating public input is being made to revise the text of 310.3(B) to include this requirement along with the requirements for the aluminum core material that is already found in section 310.3(B).

Related Public Inputs for This Document

Related Input	Relationship

Public Input No. 3243-NFPA 70-2020 [Section No. 310.3(B)]	Relocated text from definition to the conductor materials requirements
Public Input No. 3243-NFPA 70-2020 [Section No. 310.3(B)]	

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: IEC
Affiliation: NEC Correlating Committee Task Group
Street Address:
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Zip:
Submittal Date: Wed Sep 02 22:24:08 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8430-NFPA 70-2021
Statement: This revision will remove the requirement out of the definition for CCA Conductors and ensure compliance with the Style Manual section 2.3.3.3.

Article 100 Definition of *Copper-Clad Aluminum*

Copper-Clad Aluminum Conductors. Conductors drawn from a copper-clad aluminum rod, with the copper metallurgically bonded to an aluminum core~~., where the copper forms a minimum of 10 percent of the cross-sectional area of a solid conductor or each strand of a stranded conductor.~~ (CMP-6)

Substantiation

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Technical Substantiation

Section 2.3.2.1 of NFPA Manual of Style states that definitions shall only describe the term being used and section 2.3.3.3 states that definitions shall not contain requirements. The present definition contains a requirement that the copper-clad aluminum have a minimum of 10 percent of the cross-sectional area being copper.

This requirement properly belongs in 310.3(B) along with the other requirements for conductor materials. A correlating public input is being made to revise the text of 310.3(B) to include this requirement along with the requirements for the aluminum core material that is already found in section 310.3(B).

Public Input No. 440-NFPA 70-2020 [Definition: Free Air (as applied to conductors).]

~~**Free Air (as applied to conductors).**~~

~~Open or ventilated environment that allows for heat dissipation and air flow around an installed conductor. (CMP-6)~~

Statement of Problem and Substantiation for Public Input

This definition may lead to confusion. Does ventilated mean a conductor installed in a panel with ventilated opening at the top and bottom of the panel cover? Does ventilated apply to a switchboard with similar openings. Is quadruplex wire not considered installed in free air since air flow does not technically occur around each individual conductor? Does cable tray with conductors installed in a triangular configuration mean there is no airflow and therefore one cannot use the free-air ampacity table? The definition needs to be clarified or deleted as it could be considered as removing long-standing applications of certain ampacity tables for free air.

Submitter Information Verification

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Submittal Date: Sat Feb 08 07:13:16 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: The removal of this definition does not increase usability of the NEC. The requirements associated with the terms “ventilated” and “open” should be addressed in the individual code articles.

Public Input No. 3829-NFPA 70-2020 [Section No. 310.1]

310.1 Scope.

This article covers general requirements for conductors rated up to and including 2000 volts and their type designations, insulations, markings, mechanical strengths, ampacity ratings, and uses. These requirements do not apply to conductors that form an integral part of equipment, such as motors, motor controllers, and similar equipment, or to conductors specifically provided for elsewhere in this *Code*.

Informational Note: ~~For~~ See 400.1 f or flexible cords and cables~~, see Article 400 . For fixture wires, see Article 402~~ . See 402.1 for fixture wires .

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to the entire articles, other than Article 100. This PI recommends referring to the scope statement of the respective article to comply. In addition, the order of the informational note was revised to match Section 4.1.3 of the 2020 NEC(r) Style Manual.

Submitter Information Verification

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Organization: The DuPont Company, Inc.
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Submittal Date: Wed Sep 09 13:44:46 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: In this case, the requirements being referenced are contained in the entire article, so just pointing to the scope is not more precise.

Public Input No. 658-NFPA 70-2020 [Section No. 310.1]

310.1 Scope.

This article covers general requirements for conductors rated up to and including 2000 volts and their type designations, insulations, markings, mechanical strengths, ampacity ratings, and uses. These requirements do not apply to conductors that form an integral part of Listed equipment, such as ~~motors~~ , motor controllers, and similar equipment, or to conductors specifically provided for elsewhere in this *Code*.

Informational Note: For flexible cords and cables, see Article 400. For fixture wires, see Article 402.

Statement of Problem and Substantiation for Public Input

internal conductors of a listed product have been reviewed and if not the AHJ needs too. Motor windings are not conductors

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Mon Mar 16 10:09:50 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Equipment such as industrial machinery is not required to be listed and is not required to use the conductors in Article 310.

Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]

(A) Minimum Size of Conductors.

The minimum size of conductors for voltage ratings up to and including 2000 volts shall be 14 AWG copper or ~~12 AWG aluminum or~~ copper-clad aluminum or 12 AWG aluminum , except as permitted elsewhere in this *Code*.

Additional Proposed Changes

File Name	Description	Approved
Proposed_310.3_A_Draft_Fnl.docx	Word file attached for clarity.	
Terminal_and_Conductor_Temperature_Testing_Part_I_Fnl.pdf	Terminal temperature static heating test report as requested by task group	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be

installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit the below applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

The following are possible applications considered for 14 AWG copper-clad aluminum assuming an ampacity of 10 Amps at 60°C with a 10 Amp branch circuit breaker or fuse as the OCPD.

Residential dwelling typically using NMB cable – (the copper-clad aluminum would require 90°C THHN or similar insulation as required in the UL listing for non-metallic sheathed cable). These applications could also include using other cables such as MC, AC, or other cable type where NMB is prohibited. These cable types would also require the proper temperature rated conductors in the cable assembly.

- Residential lighting circuits, particularly with LED lighting
- Maximum 1/3 horsepower garbage disposal on individual 120-volt branch circuit
- Hot water dispenser on individual branch circuit
- Trash compactor on individual branch circuit
- Residential exhaust fans on lighting circuit in bathroom, laundry or other room where no receptacles are installed on the circuit
- Gas fireplace igniter and fan on individual branch circuit
- Gas furnace igniter and fan on individual branch circuit
- Fire and/or burglar alarm on individual branch circuit
- Maximum 1/3 horsepower sump pump on individual branch circuit
- Maximum 1/3 horsepower whole house attic fan on individual branch circuit
- Septic tank ejector or habitable motor on individual branch circuit

Where there are possible applications, there are also needed limitations. The following are to be set as limitations elsewhere in the Code as uses not permitted except as specifically allowed in the above list with stated conditions.

- Prohibited for any circuits with multiple receptacles. Receptacles permitted only on individual branch circuits to specified loads
- Supplying fixed appliances
- Supplying garage door opener
- Supplying laundry equipment

Applications in other than dwelling branch circuits using 14 AWG THHN/THWN individual conductors with applicable ampacities from Table 310.16, in raceway, wireway, gutter, or in cable; MC, NMB, AC, TC cable assemblies.

- Small motors 1-phase or 3-phase less than 8 Amp FLA by motor tables.
- Small motors 1-phase or 3-phase less than 12 Amp FLA by motor tables and all terminals identified for 75°C
- Lighting circuits with LED – store window, display, and general lighting
- Control and signaling limited to 10 Amps. This is already allowed with a change to the 2020 NEC for TC and MC cables, but did not include any ampacity ratings to be applied.

For other than dwelling units, the following should be set as limitations elsewhere in the Code as uses not permitted except as specifically allowed in the above list with stated conditions.

- Prohibited for any circuits with multiple receptacles except as provided above with individual branch circuits to specified loads
- Supplying fixed appliances

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	Branch circuit AFCI protection
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	10 Amps for branch circuit ratings
Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	Individual branch circuit receptacle applications and limitations
Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]	Branch circuit applications and limitations
Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]	Summary branch circuit applications and limitations
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	14 AWG copper-clad aluminum OCPD requirements
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	10 amperes added as standard OCPD device
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]	Applications and limitations for snap switches
Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]	Applications and limitations for receptacles.
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	
Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	
Public Input No. 3237-NFPA 70-2020 [Section No. 210.52(B)(1)]	
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	

Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]

Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]

Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]

Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]

Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]

Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]

Public Input No. 3974-NFPA 70-2020 [Section No. 310.21]

Submitter Information Verification

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Zip:
Submittal Date: Mon Sep 07 10:03:55 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8371-NFPA 70-2021

Statement: The minimum conductor sizes for copper and copper-clad aluminum are being reduced to 16 AWG copper and 14 AWG copper-clad aluminum. These revisions are based on testing submitted in support of the use of copper-clad aluminum conductors for 10 amp circuits, and the decades of successful use of 16 AWG copper conductors in fixture wire, motor wiring, control wiring, and other current-carrying applications as permitted in the NEC.

Revised Text:

310.3 Conductors

310.3(A) Minimum Size of Conductors.

The minimum size of conductors for voltage ratings up to and including 2000 volts shall be 14 AWG copper or copper-clad aluminum or 12 AWG aluminum ~~or copper-clad aluminum~~, except as permitted elsewhere in this Code.

Substantiation:

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which

would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit the below applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

The following are possible applications considered for 14 AWG copper-clad aluminum assuming an ampacity of 10 Amps at 60°C with a 10 Amp branch circuit breaker or fuse as the OCPD.

Residential dwelling typically using NMB cable – (the copper-clad aluminum would require 90°C THHN or similar insulation as required in the UL listing for non-metallic sheathed cable). These applications could also include using other cables such as MC, AC, or other cable type where NMB is prohibited. These cable types would also require the proper temperature rated conductors in the cable assembly.

- Residential lighting circuits, particularly with LED lighting
- Maximum 1/3 horsepower garbage disposal on individual 120-volt branch circuit
- Hot water dispenser on individual branch circuit
- Trash compactor on individual branch circuit
- Residential exhaust fans on lighting circuit in bathroom, laundry or other room where no receptacles are installed on the circuit
- Gas fireplace igniter and fan on individual branch circuit
- Gas furnace igniter and fan on individual branch circuit
- Fire and/or burglar alarm on individual branch circuit
- Maximum 1/3 horsepower sump pump on individual branch circuit
- Maximum 1/3 horsepower whole house attic fan on individual branch circuit
- Septic tank ejector or habitable motor on individual branch circuit

Where there are possible applications, there are also needed limitations. The following are to be set as limitations elsewhere in the Code as uses not permitted except as specifically allowed in the above list with stated conditions.

- Prohibited for any circuits with multiple receptacles. Receptacles permitted only on individual branch circuits to specified loads
- Supplying fixed appliances
- Supplying garage door opener
- Supplying laundry equipment

Applications in other than dwelling branch circuits using 14 AWG THHN/THWN individual conductors with applicable ampacities from Table 310.16, in raceway, wireway, gutter, or in cable; MC, NMB, AC, TC cable assemblies

- Small motors 1-phase or 3-phase less than 8 Amp FLA by motor tables.
- Small motors 1-phase or 3-phase less than 12 Amp FLA by motor tables and all terminals identified for 75°C
- Lighting circuits with LED – store window, display, and general lighting
- Control and signaling limited to 10 Amps. This is already allowed with a change to the 2020 NEC for TC and MC cables, but did not include any ampacity ratings to be applied.

  For other than dwelling units, the following should be set as limitations elsewhere in the Code as uses not permitted except as specifically allowed in the above list with stated conditions.

- Prohibited for any circuits with multiple receptacles except as provided above with individual branch circuits to specified loads
- Supplying fixed appliances

Public Input No. 3243-NFPA 70-2020 [Section No. 310.3(B)]

(B) Conductor Material.

Conductors in this article shall be of copper, aluminum, or copper-clad aluminum, ~~or copper~~ unless otherwise specified. Aluminum and copper-clad aluminum shall comply with the following.

(1) Solid aluminum conductors 8, 10, and 12 AWG shall be made of an AA-8000 series electrical grade aluminum alloy conductor material. Stranded aluminum conductors 8 AWG through 1000 kcmil marked as Type RHH, RHW, XHHW, THW, THHW, THWN, THHN, service-entrance Type SE Style U, and SE Style R shall be made of an AA-8000 series electrical grade aluminum alloy conductor material.

(2) Stranded aluminum conductors 8 AWG through 1000 kcmil marked as Type RHH, RHW, XHHW, THW, THHW, THWN, THHN, service-entrance Type SE Style U, and SE Style R shall be made of an AA-8000 series electrical grade aluminum alloy conductor material.

(3) For copper-clad aluminum conductors, the copper shall form a minimum 10 percent of the cross-sectional area of a solid conductor or each strand of a stranded conductor. The aluminum core of a copper-clad aluminum conductor shall be made of an AA-8000 series electrical grade aluminum alloy conductor material.

(4) Copper-clad aluminum conductor material shall be listed.

Additional Proposed Changes

File Name	Description	Approved
Proposed_310.3_B_Draft_Fnl.docx	Word file attached for clarity.	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Technical Substantiation

- Sequence of Conductor Types Consistent in Code. The sequence of the conductor types is rearranged to be consistent with how they are listed in other parts of the Code.

- List format. The 2020 NEC single paragraph is reformatted into a list format for clarity to users of the differing requirements and to permit better enforcement by Authorities Having Jurisdiction. A charging statement was added to the beginning paragraph for the new list format. There are no technical changes made or intended to 2020 NEC requirements for the text that is in new list items 1 or 2.

- New Requirements for Copper-Clad Aluminum. New list items 3 and 4 are added to provide the material requirements for copper-clad aluminum.

The material description requires a copper outer layer to be a minimum of 10 percent of the cross-sectional area of the conductor. This requirement is relocated from the definition of copper clad aluminum in Article 100, and correlates with the public input to modify the definition to remove requirements from definitions in accordance with the NEC style manual.

The aluminum core is also required to be electrical grade AA8000 consistent with the aluminum requirement in list items 1 and 2. These two changes were accepted by CMP-6 in the 2020 NEC cycle but due to procedural issues, the final text reverted back to the 2017 NEC.

A listing requirement is added to ensure the conductor material complies with all the requirements found in ASTM B-566 through the listing process. ASTM B566 governs the material characteristics of copper-clad aluminum wire. The definition of copper-clad aluminum wire as found in article 100 of the 2020 National Electrical Code and various UL standards is similar to the one found in ASTM. However, ASTM B566 requires both adhesion and cohesion testing to verify that a thorough bond exists. At this time, UL standards governing the testing of wire and cable products for listing requirements, specifically UL 2556, 44, 83 and 1581, do not require copper-clad conductor materials to be tested for adhesion nor cohesion. Therefore, there is a risk that a bad actor could provide bimetallic wire without true metallurgical (thorough) bonding, which could then become a component of a listed insulated conductor. The metallurgical (thorough) bonding of the two metals is important for corrosion resistance, electrical termination, thermal stability and mechanical strength of ASTM B566 copper-clad aluminum wire. Finished electrical conductors made with improperly bonded conductor material would not meet the long-standing requirements in the electrical industry

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2857-NFPA 70-2020 [Definition: Copper-Clad Aluminum Conductors.]	Definition revised to remove requirement of 10% and moved to this section
Public Input No. 2857-NFPA 70-2020 [Definition: Copper-Clad Aluminum Conductors.]	

Submitter Information Verification

Submitter Full Name: David Hittinger
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Affiliation: NEC Correlating Committee Task Group
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Submittal Date: Mon Sep 07 10:24:38 EDT 2020

Committee: NEC-P06

Committee Statement

Resolution: FR-8372-NFPA 70-2021

Statement: The composition requirements for copper-clad aluminum were removed from the definition and relocated into this section. The language was reorganized into a list format. Language was added to require that the copper-clad aluminum conductor be listed.

Insulation type XHHN and XHWN were added to the list as they were newly added to the code.

Public Input for 310.3(B)

Proposed Text:

(B) Conductor Material.

Conductors in this article shall be of copper, aluminum, or copper-clad ~~aluminum, or copper unless~~ aluminum unless otherwise specified. Aluminum and copper-clad aluminum shall comply with the following.

(1) Solid aluminum conductors 8, 10, and 12 AWG shall be made of an AA-8000 series electrical grade aluminum alloy conductor material.

(2) Stranded aluminum conductors 8 AWG through 1000 kcmil marked as Type RHH, RHW, XHHW, THW, THHW, THWN, THHN, service-entrance Type SE Style U, and SE Style R shall be made of an AA-8000 series electrical grade aluminum alloy conductor material.

(3) For copper-clad aluminum conductors, the copper shall form a minimum 10 percent of the cross-sectional area of a solid conductor or each strand of a stranded conductor. The aluminum core of a copper-clad aluminum conductor shall be made of an AA-8000 series electrical grade aluminum alloy conductor material.

(4) Copper-clad aluminum conductor material shall be listed.

Substantiation:

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6,

310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Technical Substantiation

- **Sequence of Conductor Types Consistent in Code.** The sequence of the conductor types is rearranged to be consistent with how they are listed in other parts of the Code.
- **List format.** The 2020 NEC single paragraph is reformatted into a list format for clarity to users of the differing requirements and to permit better enforcement by Authorities Having Jurisdiction. A charging statement was added to the beginning paragraph for the new list format. There are no technical changes made or intended to 2020 NEC requirements for the text that is in new list items 1 or 2.
- **New Requirements for Copper-Clad Aluminum**. New list items 3 and 4 are added to provide the material requirements for copper-clad aluminum.
    - The material description requires a copper outer layer to be a minimum of 10 percent of the cross-sectional area of the conductor. This requirement is relocated from the definition of copper clad aluminum in Article 100, and correlates with the public input to modify the definition to remove requirements from definitions in accordance with the NEC style manual.
    - The aluminum core is also required to be electrical grade AA8000 consistent with the aluminum requirement in list items 1 and 2. These two changes were accepted by CMP-6 in the 2020 NEC cycle but due to procedural issues, the final text reverted back to the 2017 NEC.
    - A listing requirement is added to ensure the conductor material complies with all the requirements found in ASTM B-566 through the listing process. ASTM B566 governs the material characteristics of copper-clad aluminum wire. The definition of copper-clad aluminum wire as found in article 100 of the 2020 National Electrical Code and various UL standards is similar to the one found in ASTM. However, ASTM B566 requires both adhesion and cohesion testing to verify that a thorough bond exists. At this time, UL standards governing the testing of wire and cable products for listing requirements, specifically UL 2556, 44, 83 and 1581, do not require copper-clad conductor materials to be tested for adhesion nor cohesion. Therefore, there is a risk that a bad actor could provide bimetallic wire without true metallurgical (thorough) bonding, which could then become a component of a listed insulated conductor. The metallurgical (thorough) bonding of the two metals is important for corrosion resistance, electrical termination, thermal stability and mechanical strength of ASTM B566 copper-clad aluminum wire. Finished electrical conductors made with improperly bonded conductor material would not meet the long-standing requirements in the electrical industry

Public Input No. 2348-NFPA 70-2020 [New Section after 310.3(D)]

310.3(D)1

Insulated conductors shall be listed

Additional Proposed Changes

File Name	Description	Approved
310.3.docx		

Statement of Problem and Substantiation for Public Input

Insulated conductors are subjected to a variety of different environmental and installation conditions and should be designed to withstand these conditions. Requiring insulated conductors to be listed will ensure that they are suitably designed and manufactured.

Submitter Information Verification

Submitter Full Name: Susan Stene
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Submittal Date: Mon Aug 17 14:02:34 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Insulated conductors in Article 310 already have product safety standards in place, additional justification would need to be provided to make this a global requirement.

310.3(D) Insulated.

Conductors not specifically permitted elsewhere in this *Code* to be covered or bare shall be insulated.

Informational Note: See 250.184 for insulation of neutral conductors of a solidly grounded high-voltage system.

310.3(D)1

Insulated conductors shall be listed

Rationale

Insulated conductors are subjected to a variety of different environmental and installation conditions and should be designed to withstand these conditions. Requiring insulated conductors to be listed will ensure that they are suitably designed and manufactured.

Public Input No. 1088-NFPA 70-2020 [Section No. 310.4]

310.4 Conductor Constructions and Applications.

Insulated conductors shall comply with Table 310.4(A) and Table 310.4(B), as applicable .

Informational Note: Thermoplastic insulation may stiffen at temperatures lower than −10°C (+14°F). Thermoplastic insulation may also be deformed at normal temperatures where subjected to pressure, such as at points of support.

Table 310.4(A) Conductor Applications and Insulations Rated 600 Volts[1]

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	
Fluorinated ethylene propylene	FEP or FEPB	90°C (194°F)	Dry and damp locations	Fluorinated ethylene propylene	14–10	0.51	
					8–2	0.76	
		200°C (392°F)			14–8	0.36	
			Dry locations — special applications[3]	Fluorinated ethylene propylene	6–2	0.36	
Mineral insulation (metal sheathed)	MI	90°C (194°F)	Dry and wet locations	Magnesium oxide	18–16[4]	0.58	
		250°C (482°F)	For special applications[3]		16–10	0.91	
					9–4	1.27	
					3–500	1.40	
Moisture-, heat-, and oil-resistant thermoplastic	MTW	60°C (140°F)	Machine tool wiring in wet locations	Flame-retardant, moisture-, heat-, and oil-resistant thermoplastic	-		(A)
		90°C (194°F)	Machine tool wiring in dry locations.		22–12	0.76	0.38
					10	0.76	0.51
			-		-	8	1.14
			-			6	1.52
			-		Informational Note: See NFPA 79.	4–2	1.52
			-			1–4/0	2.03
			-			213–500	2.41
			-			501–1000	2.79
Paper	-		85°C (185°F)	For underground service conductors, or by special permission	Paper	-	-
Perfluoro-alkoxy	PFA	90°C (194°F)	Dry and damp locations	Perfluoro-alkoxy	14–10	0.51	
					8–2	0.76	
		200°C (392°F)	Dry locations — special applications[3]		1–4/0	1.14	
					-	-	
Perfluoro-alkoxy	PFAH	250°C	Dry locations only. Only for leads within apparatus or within raceways	Perfluoro-alkoxy	14–10	0.51	

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	
		(482°F)			8–2	0.76	
					1–4/0	1.14	
Thermoset	RHH	90°C (194°F)	Dry and damp locations		14-10	1.14	
					8–2	1.52	
					1–4/0	2.03	
					213–500	2.41	
					501–1000	2.79	
					1001–2000	3.18	
Moisture-resistant thermoset	RHW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	1.14	
					8–2	1.52	
					1–4/0	2.03	
	RHW-2	90°C (194°F)			213–500	2.41	
					501–1000	2.79	
					1001–2000	3.18	
Silicone	SA	90°C (194°F) 200°C (392°F)	Dry and damp locations For special application[3]	Silicone rubber	14–10	1.14	
					8–2	1.52	
					1–4/0	2.03	
					213–500	2.41	
					501–1000	2.79	
					1001–2000	3.18	
Thermoset	SIS	90°C (194°F)	Switchboard and switchgear wiring only	Flame-retardant thermoset	14–10	0.76	
					8–2	1.14	
					1–4/0	1.40	
Thermoplastic and fibrous outer braid	TBS	90°C (194°F)	Switchboard and switchgear wiring only	Thermoplastic	14–10	0.76	
					8	1.14	
					6–2	1.52	
					1–4/0	2.03	
Extended polytetra-fluoro-ethylene	TFE	250°C (482°F)	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus, or as open wiring (nickel or nickel-coated copper only)	Extruded polytetra-fluoroethylene	14–10	0.51	
					8–2	0.76	
					1–4/0	1.14	
Heat-resistant thermoplastic	THHN	90°C (194°F)	Dry and damp locations	Flame-retardant, heat-resistant thermoplastic	14–12	0.38	
					10	0.51	
					8–6	0.76	
					4–2	1.02	

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation	
					AWG or kcmil	mm
					1–4/0	1.27
					250–500	1.52
					501–1000	1.78
Moisture- and heat-resistant thermoplastic	THHW	75°C (167°F)	Wet location	Flame-retardant, moisture- and heat-resistant thermoplastic	14–10	0.76
					8	1.14
					6–2	1.52
		90°C (194°F)	Dry location		1–4/0	2.03
					213–500	2.41
					501–1000	2.79
					1001–2000	3.18
Moisture- and heat-resistant thermoplastic	THW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	14–10	0.76
					8	1.14
		90°C (194°F)	Special applications within electric discharge lighting equipment. Limited to 1000 open-circuit volts or less. (Size 14-8 only as permitted in 410.68.)		6–2	1.52
					1–4/0	2.03
					213–500	2.41
					501–1000	2.79
					1001–2000	3.18
	-	THW-2	90°C (194°F)	Dry and wet locations	-	-
Moisture- and heat-resistant thermoplastic	THWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	14–12	0.38
					10	0.51
					8–6	0.76
					4–2	1.02
	THWN-2	90°C (194°F)			1–4/0	1.27
					250–500	1.52
					501–1000	1.78
Moisture-resistant thermoplastic	TW	60°C (140°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoplastic	14–10	0.76
					8	1.14
					6–2	1.52
					1–4/0	2.03
					213–500	2.41
					501–1000	2.79
					1001–2000	3.18

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation	
					AWG or kcmil	mm
Underground feeder and branch-circuit cable — single conductor (for Type UF cable employing more than one conductor, see Article 340).	UF	60°C (140°F)	See Article 340.	Moisture-resistant	14–10	1.52
					8–2	2.03
					1–4/0	2.41
		75°C (167°F)[5]		Moisture- and heat-resistant		
Underground service-entrance cable — single conductor (for Type USE cable employing more than one conductor, see Article 338).	USE	75°C (167°F)[5]	See Article 338.	Heat- and moisture-resistant	14–10	1.14
					8–2	1.52
					1–4/0	2.03
					213–500	2.41
					501–1000	2.79
					1001–2000	3.18
	USE-2	90°C (194°F)	Dry and wet locations			
Thermoset	XHH	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–10	0.76
					8–2	1.14
					1–4/0	1.40
					213–500	1.65
					501–1000	2.03
					1001–2000	2.41
Thermoset	XHHN	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–12	0.38
					10	0.51
					8–6	0.76
					4–2	1.02
					1–4/0	1.27
					250–500	1.52
					501–1000	1.78
Moisture-resistant thermoset	XHHW	90°C (194°F)	Dry and damp locations	Flame-retardant, moisture-resistant thermoset	14–10	0.76
					8–2	1.14
		75°C (167°F)	Wet locations		1–4/0	1.40
					213–500	1.65
					501–1000	2.03
					1001–2000	2.41

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation	
					AWG or kcmil	mm
Moisture-resistant thermoset	XHHW-2	90°C (194°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	0.76
					8–2	1.14
					1–4/0	1.40
					213–500	1.65
					501–1000	2.03
					1001–2000	2.41
Moisture-resistant thermoset	XHWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–12	0.38
					10	0.51
					8–6	0.76
	XHWN-2	90°C (194°F)			4–2	1.02
					1–4/0	1.27
					250–500	1.52
					501–1000	1.78
Modified ethylene tetrafluoro-ethylene	Z	90°C (194°F)	Dry and damp locations	Modified ethylene tetrafluoro-ethylene	14–12	0.38
					10	0.51
		150°C (302°F)	Dry locations — special applications[3]		8–4	0.64
					3–1	0.89
					1/0–4/0	1.14
Modified ethylene tetrafluoro-ethylene	ZW	75°C (167°F)	Wet locations	Modified ethylene tetrafluoro-ethylene	14–10	0.76
		90°C (194°F)	Dry and damp locations			
		150°C (302°F)	Dry locations — special applications[3]		8–2	1.14
	ZW-2	90°C (194°F)	Dry and wet locations			

[1]Conductors shall be permitted to be rated up to 1000 volts if listed and marked.

[2]Outer coverings shall not be required where listed without a covering.

[3]Higher temperature rated constructions shall be permitted where design conditions require maximum conductor operating temperatures above 90°C (194°F).

[4]Conductor sizes shall be permitted for signaling circuits permitting 300-volt insulation.

[5]The ampacity of Type UF cable shall be limited in accordance with 340.80.

[6]Type UF insulation thickness shall include the integral jacket.

[7]Insulation thickness shall be permitted to be 2.03 mm (80 mils) for listed Type USE conductors that have been subjected to special investigations. The nonmetallic covering over individual rubber-covered conductors of aluminum-sheathed cable and of lead-sheathed or multiconductor cable shall not be required to be flame retardant.

Table 310.4(B) Thickness of Insulation for Nonshielded Types RHH and RHW Solid Dielectric Insulated Conductors Rated 2000 Volts

Conductor Size (AWG or kcmil)	Column A[1]		Column B[2]	
	mm	mils	mm	mils
14–10	2.03	80	1.52	60
8	2.03	80	1.78	70
6–2	2.41	95	1.78	70
1–2/0	2.79	110	2.29	90
3/0–4/0	2.79	110	2.29	90
213–500	3.18	125	2.67	105
501–1000	3.56	140	3.05	120
1001–2000	3.56	140	3.56	140

[1]Column A insulations shall be limited to natural, SBR, and butyl rubbers.

[2]Column B insulations shall be materials such as cross-linked polyethylene, ethylene propylene rubber, and composites thereof.

Statement of Problem and Substantiation for Public Input

Thicknesses listed in Table 310.4(B) applies only to RHH and RHW insulations of 2000 volts. They do not conform to RHH and RHW thicknesses listed in Table 310.4(A) for 600 volt insulations.

Submitter Information Verification

Submitter Full Name: David Bredhold
Organization: DB Technical Services
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 16 09:19:49 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The titles of the tables clearly state which apply to 600v and which apply to 2000v insulations.

Public Input No. 3837-NFPA 70-2020 [Section No. 310.4]

310.4 Conductor Constructions and Applications.

Insulated conductors shall comply with Table 310.4(A) and Table 310.4(B).

Informational Note: Thermoplastic insulation may stiffen at temperatures lower than −10°C (+14°F). Thermoplastic insulation may also be deformed at normal temperatures where subjected to pressure, such as at points of support.

Table 310.4(A) Conductor Applications and Insulations Rated 600 Volts[1]

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	
Fluorinated ethylene propylene	FEP or FEPB	90°C (194°F)	Dry and damp locations	Fluorinated ethylene propylene	14–10	0.51	
					8–2	0.76	
		200°C (392°F)			14–8	0.36	
			Dry locations — special applications[3]	Fluorinated ethylene propylene	6–2	0.36	
Mineral insulation (metal sheathed)	MI	90°C (194°F)	Dry and wet locations	Magnesium oxide	18–16[4]	0.58	
					16–10	0.91	
		250°C (482°F)	For special applications[3]		9–4	1.27	
					3–500	1.40	
Moisture-, heat-, and oil-resistant thermoplastic	MTW	60°C (140°F)	Machine tool wiring in wet locations	Flame-retardant, moisture-, heat-, and oil-resistant thermoplastic	-		(A)
		90°C (194°F)	Machine tool wiring in dry locations.		22–12	0.76	0.38
					10	0.76	0.51
			-		-	8	1.14
			-			6	1.52
			-		Informational Note: See NFPA 79.	4–2	1.52
			-			1–4/0	2.03
			-			213–500	2.41
			-			501–1000	2.79
Paper	-		85°C (185°F)	For underground service conductors, or by special permission	Paper	-	-
Perfluoro-alkoxy	PFA	90°C (194°F)	Dry and damp locations	Perfluoro-alkoxy	14–10	0.51	
					8–2	0.76	
		200°C (392°F)	Dry locations — special applications[3]		1–4/0	1.14	
					-	-	
Perfluoro-alkoxy	PFAH	250°C	Dry locations only. Only for leads within apparatus or within raceways	Perfluoro-alkoxy	14–10	0.51	

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	
		(482°F)			8–2	0.76	
					1–4/0	1.14	
Thermoset	RHH	90°C (194°F)	Dry and damp locations		14-10	1.14	
					8–2	1.52	
					1–4/0	2.03	
					213–500	2.41	
					501–1000	2.79	
					1001–2000	3.18	
Moisture-resistant thermoset	RHW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	1.14	
					8–2	1.52	
					1–4/0	2.03	
	RHW-2	90°C (194°F)			213–500	2.41	
					501–1000	2.79	
					1001–2000	3.18	
Silicone	SA	90°C (194°F) 200°C (392°F)	Dry and damp locations For special application[3]	Silicone rubber	14–10	1.14	
					8–2	1.52	
					1–4/0	2.03	
					213–500	2.41	
					501–1000	2.79	
					1001–2000	3.18	
Thermoset	SIS	90°C (194°F)	Switchboard and switchgear wiring only	Flame-retardant thermoset	14–10	0.76	
					8–2	1.14	
					1–4/0	1.40	
Thermoplastic and fibrous outer braid	TBS	90°C (194°F)	Switchboard and switchgear wiring only	Thermoplastic	14–10	0.76	
					8	1.14	
					6–2	1.52	
					1–4/0	2.03	
Extended polytetra-fluoro-ethylene	TFE	250°C (482°F)	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus, or as open wiring (nickel or nickel-coated copper only)	Extruded polytetra-fluoroethylene	14–10	0.51	
					8–2	0.76	
					1–4/0	1.14	
Heat-resistant thermoplastic	THHN	90°C (194°F)	Dry and damp locations	Flame-retardant, heat-resistant thermoplastic	14–12	0.38	
					10	0.51	
					8–6	0.76	
					4–2	1.02	

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation	
					AWG or kcmil	mm
					1–4/0	1.27
					250–500	1.52
					501–1000	1.78
Moisture- and heat-resistant thermoplastic	THHW	75°C (167°F)	Wet location	Flame-retardant, moisture- and heat-resistant thermoplastic	14–10	0.76
					8	1.14
					6–2	1.52
		90°C (194°F)	Dry location		1–4/0	2.03
					213–500	2.41
					501–1000	2.79
					1001–2000	3.18
Moisture- and heat-resistant thermoplastic	THW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	14–10	0.76
					8	1.14
		90°C (194°F)	Special applications within electric discharge lighting equipment. Limited to 1000 open-circuit volts or less. (Size 14-8 only as permitted in 410.68.)		6–2	1.52
					1–4/0	2.03
					213–500	2.41
					501–1000	2.79
					1001–2000	3.18
	-	THW-2	90°C (194°F)	Dry and wet locations	-	-
Moisture- and heat-resistant thermoplastic	THWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	14–12	0.38
					10	0.51
					8–6	0.76
					4–2	1.02
	THWN-2	90°C (194°F)			1–4/0	1.27
					250–500	1.52
					501–1000	1.78
Moisture-resistant thermoplastic	TW	60°C (140°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoplastic	14–10	0.76
					8	1.14
					6–2	1.52
					1–4/0	2.03
					213–500	2.41
					501–1000	2.79
					1001–2000	3.18

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation	
					AWG or kcmil	mm
Underground feeder and branch-circuit cable — single conductor (for Type UF cable employing more than one conductor, see Article 340).	UF	60°C (140°F) 75°C (167°F)[5]	See ~~Article~~ 340.1.	Moisture-resistant Moisture- and heat-resistant	14–10 8–2 1–4/0	1.52 2.03 2.41
Underground service-entrance cable — single conductor (for Type USE cable employing more than one conductor, see Article 338).	USE	75°C (167°F)[5]	See ~~Article~~ 338.1.	Heat- and moisture-resistant	14–10 8–2 1–4/0 213–500 501–1000 1001–2000	1.14 1.52 2.03 2.41 2.79 3.18
	USE-2	90°C (194°F)	Dry and wet locations			
Thermoset	XHH	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–10 8–2 1–4/0 213–500 501–1000 1001–2000	0.76 1.14 1.40 1.65 2.03 2.41
Thermoset	XHHN	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–12 10 8–6 4–2 1–4/0 250–500 501–1000	0.38 0.51 0.76 1.02 1.27 1.52 1.78
Moisture-resistant thermoset	XHHW	90°C (194°F)	Dry and damp locations	Flame-retardant, moisture-resistant thermoset	14–10 8–2 1–4/0 213–500 501–1000 1001–2000	0.76 1.14 1.40 1.65 2.03 2.41
		75°C (167°F)	Wet locations			

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation	
					AWG or kcmil	mm
Moisture-resistant thermoset	XHHW-2	90°C (194°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	0.76
					8–2	1.14
					1–4/0	1.40
					213–500	1.65
					501–1000	2.03
					1001–2000	2.41
Moisture-resistant thermoset	XHWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–12	0.38
					10	0.51
					8–6	0.76
	XHWN-2	90°C (194°F)			4–2	1.02
					1–4/0	1.27
					250–500	1.52
					501–1000	1.78
Modified ethylene tetrafluoro-ethylene	Z	90°C (194°F)	Dry and damp locations	Modified ethylene tetrafluoro-ethylene	14–12	0.38
					10	0.51
		150°C (302°F)	Dry locations — special applications[3]		8–4	0.64
					3–1	0.89
					1/0–4/0	1.14
Modified ethylene tetrafluoro-ethylene	ZW	75°C (167°F)	Wet locations	Modified ethylene tetrafluoro-ethylene	14–10	0.76
		90°C (194°F)	Dry and damp locations			
		150°C (302°F)	Dry locations — special applications[3]		8–2	1.14
	ZW-2	90°C (194°F)	Dry and wet locations			

[1]Conductors shall be permitted to be rated up to 1000 volts if listed and marked.

[2]Outer coverings shall not be required where listed without a covering.

[3]Higher temperature rated constructions shall be permitted where design conditions require maximum conductor operating temperatures above 90°C (194°F).

[4]Conductor sizes shall be permitted for signaling circuits permitting 300-volt insulation.

[5]The ampacity of Type UF cable shall be limited in accordance with 340.80.

[6]Type UF insulation thickness shall include the integral jacket.

[7]Insulation thickness shall be permitted to be 2.03 mm (80 mils) for listed Type USE conductors that have been subjected to special investigations. The nonmetallic covering over individual rubber-covered conductors of aluminum-sheathed cable and of lead-sheathed or multiconductor cable shall not be required to be flame retardant.

Table 310.4(B) Thickness of Insulation for Nonshielded Types RHH and RHW Solid Dielectric Insulated Conductors Rated 2000 Volts

Conductor Size (AWG or kcmil)	Column A[1]		Column B[2]	
	mm	mils	mm	mils
14–10	2.03	80	1.52	60
8	2.03	80	1.78	70
6–2	2.41	95	1.78	70
1–2/0	2.79	110	2.29	90
3/0–4/0	2.79	110	2.29	90
213–500	3.18	125	2.67	105
501–1000	3.56	140	3.05	120
1001–2000	3.56	140	3.56	140

[1]Column A insulations shall be limited to natural, SBR, and butyl rubbers.

[2]Column B insulations shall be materials such as cross-linked polyethylene, ethylene propylene rubber, and composites thereof.

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to the entire articles, other than Article 100. This PI recommends referring to the scope statement of the respective article to comply. Changes are proposed to the reference in the UF and USE type rows accordingly.

Submitter Information Verification

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Street Address:
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Zip:
Submittal Date: Wed Sep 09 13:50:20 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8342-NFPA 70-2021
Statement: Changes made to comply with style manual.

Public Input No. 3381-NFPA 70-2020 [Section No. 310.6]

310.6 Conductor Insulation Identification.

(A) Grounded Conductors.

~~Insulated~~ The insulation or ~~covered~~ covering of grounded conductors shall be identified in accordance with 200.6.

(B) Equipment Grounding Conductors.

~~Equipment~~ The insulation or covering of equipment grounding conductors shall be identified in accordance with 250.119.

(C) Ungrounded Conductors.

~~Conductors~~ The insulation of conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from the insulation of grounded and equipment grounding conductors. Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1). ~~Branch~~ The insulation of branch -circuit ungrounded conductors shall be identified in accordance with 210.5(C). ~~Feeders~~ The insulation of feeder conductors shall be identified in accordance with 215.12.

Exception: - ~~Conductor identification shall~~ C onductor insulation identification shall be permitted in accordance with 200.7.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is colored or identified and not the conductor itself. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults.
In spite of the statement to the contrary in 90.1, the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

Submitter Full Name: Phil Simmons
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City:
State:
Zip:
Submittal Date: Tue Sep 08 12:44:55 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the

conductor and insulation.

Public Input No. 1003-NFPA 70-2020 [Section No. 310.6(B)]

(B) Equipment Grounding Conductors and Supply-Side Bonding Jumpers .

Equipment grounding conductors and supply-side bonding jumpers shall be identified in accordance with 250.119.

Statement of Problem and Substantiation for Public Input

What color can a system bonding jumper, supply-side bonding jumper, main bonding jumper, or grounding electrode conductor be? There is presently no Code rule specifically covering these conductors. Can they be green? Section 250.119 does not specifically permit or prohibit the use of green insulation. Supply-side bonding jumpers should be identified in the same manner as equipment grounding conductors since they both perform the same type of grounding/bonding functions. Can a system bonding jumper, supply-side bonding jumper, main bonding jumper or grounding electrode conductor be black, red, blue, brown, orange or yellow? Actually yes they can! Section 310.6(C) requires ungrounded conductors to be " finished to be clearly distinguishable from grounded and equipment grounding conductors", but makes no mention of system bonding jumpers, supply-side bonding jumpers, main bonding jumpers or grounding electrode conductors. This means that these bonding jumpers and the grounding electrode conductor CAN be the same color as any UNGROUNDED conductor! I will be submitting a companion proposal to that section as well. Can a system bonding jumper, supply-side bonding jumper, main bonding jumper or grounding electrode conductor be white or gray? No, they cannot! The present wording in 200.7 does not permit the use of white or gray insulation because a system bonding jumper, supply-side bonding jumper, main bonding jumper, or grounding electrode conductor are NOT the grounded CIRCUIT conductor. Permitting the use of green, or green with yellow stripes for any the main bonding jumper, system bonding jumper or grounding electrode conductors will not result in a negative impact on safety due to the location and function of these conductors

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1002-NFPA 70-2020 [Section No. 250.119]	Identification of MBJ, SBJ, SSBJ, and GEC
Public Input No. 1001-NFPA 70-2020 [Section No. 200.7]	Identification of MBJ, SBJ, SSBJ, and GEC
Public Input No. 1004-NFPA 70-2020 [Section No. 310.6(C)]	

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
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City:
State:
Zip:
Submittal Date: Fri May 08 09:40:42 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The title of 250.119 makes it clear that it is meant only for equipment grounding conductors. ID of supply side bonding jumpers is under the purview of CMP 5.

Public Input No. 1004-NFPA 70-2020 [Section No. 310.6(C)]

(C) Ungrounded Conductors.

Conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, or cords shall be finished to be clearly distinguishable from grounded ~~and~~ conductors, equipment grounding conductors, supply-side bonding jumpers, system bonding jumpers, main bonding jumpers and grounding electrode conductors . Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1). Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C). Feeders shall be identified in accordance with 215.12.

Exception: Conductor identification shall be permitted in accordance with 200.7.

Statement of Problem and Substantiation for Public Input

What color can a system bonding jumper, supply-side bonding jumper, main bonding jumper, or grounding electrode conductor be? There is presently no Code rule specifically covering these conductors. 250.119 only addresses equipment grounding conductors. Can a system bonding jumper, supply-side bonding jumper, main bonding jumper or grounding electrode conductor be black, red, blue, brown, orange or yellow? Actually yes they can! Section 310.6(C) requires ungrounded conductors to be " finished to be clearly distinguishable from grounded and equipment grounding conductors", but makes no mention of system bonding jumpers, supply-side bonding jumpers, main bonding jumpers or grounding electrode conductors. This means that these bonding jumpers and the grounding electrode conductor CAN be the same color as any UNGROUNDED conductor! Can you imagine how dangerous it could be to have both an ungrounded conductor and the supply-side bonding jumper in the same raceway be colored red? This type of installation is presently permitted since there is no color scheme specified for supply-side bonding jumpers, and 310.6(C) does NOT require ungrounded conductors to be clearly distinguishable from supply-side bonding jumpers. Ungrounded conductors need to be clearly distinguishable from all of these grounding/bonding conductors to prevent inadvertently mixing them up! I have submitted companion proposals to 250.119 and 200.7 addressing the means of identification for supply-side bonding jumpers, system bonding jumpers, main bonding jumpers, and grounding electrode conductors as well. The addition of the word "cords" in this rule is needed to distinguish ungrounded conductors in cords.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1001-NFPA 70-2020 [Section No. 200.7]	Identification of supply-side bonding jumpers, system bonding jumpers, main bonding jumpers, and grounding electrode conductors
Public Input No. 1002-NFPA 70-2020 [Section No. 250.119]	Identification of supply-side bonding jumpers, system bonding jumpers, main bonding jumpers, and grounding electrode conductors
Public Input No. 1003-NFPA 70-2020 [Section No. 310.6(B)]	Identification of supply-side bonding jumpers, system bonding jumpers, main bonding jumpers, and grounding electrode conductors

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:
City:
State:
Zip:
Submittal Date: Fri May 08 09:45:31 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Grounding and bonding conductor ID is under the purview of CMP 5.

Public Input No. 1095-NFPA 70-2020 [Section No. 310.6(C)]

(C) Ungrounded Conductors.

Conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from grounded and equipment grounding conductors. ~~Distinguishing~~ Field made distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1). An effort to install conductors and cables shall be made in a manner that does not conceal manufacturer markings at all conductor and cable access points. Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C). Feeders shall be identified in accordance with 215.12.

Exception: Conductor identification shall be permitted in accordance with 200.7.

Statement of Problem and Substantiation for Public Input

It is difficult for inspectors to inspect a job, service electricians to do their work, estimators, etc. when you can't read manufacturer markings on the conductors or cables. This works with the existing text of 310.6C and things like 200.6B and 250.119A2c. It means, try to install conductors and cables with the markings facing the enclosure opening where practicable. I wrote 'An effort to install...' in the public input. This considers manufacturer interval markings, varied conductor lengths, concealment by adjacent conductors, etc.

This proposal would apply more to individual conductors than cables since cable jackets are removed at their enclosure destinations.

Submitter Information Verification

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State:
Zip:
Submittal Date: Sat May 16 10:35:13 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This is vague and unenforceable language.

Public Input No. 1832-NFPA 70-2020 [Section No. 310.6(C)]

(C) Ungrounded Conductors.

Conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from grounded and equipment grounding conductors. Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1). Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C). Feeders shall be identified in accordance with 215.12(C) .

Exception: Conductor identification shall be permitted in accordance with 200.7.

Statement of Problem and Substantiation for Public Input

Adding (C) to the reference will provide the reader with the specific reference similar to the style used in 210.5(C).

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 10 12:11:24 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8344-NFPA 70-2021
Statement: Adds the reference to the correct section. Provides more clarity.

Public Input No. 237-NFPA 70-2020 [Section No. 310.6(C)]

(C) Ungrounded Conductors.

Conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from both grounded conductors and equipment grounding conductors. Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1). Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C). Feeders shall be identified in accordance with 215.12.

Exception: Conductor identification shall be permitted in accordance with 200.7.

Statement of Problem and Substantiation for Public Input

Clarity - the word "grounded" is not an adjective.

A "grounded conductor" is a noun and a defined term, as is "equipment grounding conductor."

This small change makes the meaning of the sentence clearer, especially to the journeyman electrician.

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: Clark County Building and Fire
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 02 17:26:12 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8344-NFPA 70-2021
Statement: Adds the reference to the correct section. Provides more clarity.

Public Input No. 3385-NFPA 70-2020 [Section No. 310.8]

310.8 Marking.

(A) Required Information.

~~All~~ The insulation of conductors and cables shall be marked to indicate the following information, using the applicable method described in 310.8(B):

(1) The maximum rated voltage.

(2) The proper type letter or letters for the type of wire or cable as specified elsewhere in this *Code*.

(3) The manufacturer's name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified.

(4) The AWG size or circular mil area.

Informational Note: See Chapter 9, Table 8, Conductor Properties, for conductor area expressed in SI units for conductor sizes specified in AWG or circular mil area.

(5) Cable assemblies where the neutral conductor is smaller than the ungrounded conductors shall be so marked.

(B) Method of Marking.

(1) Surface Marking.

The insulation of the following conductors and cables shall be durably marked on the surface:

(1) Single-conductor and multiconductor thermoset and thermoplastic-insulated wire and cable

(2) Nonmetallic-sheathed cable

(3) Service-entrance cable

(4) Underground feeder and branch-circuit cable

(5) Tray cable

(6) Irrigation cable

(7) Power-limited tray cable

(8) Instrumentation tray cable

The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).

(2) Marker Tape.

Metal-covered multiconductor cables shall employ a marker tape located within the cable and running for its complete length.

Exception No. 1: Type MI cable shall not require a marker tape.

Exception No. 2: Type AC cable shall not require a marker tape.

Exception No. 3: The information required in 310.8(A) shall be permitted to be durably marked on the outer nonmetallic covering of Type MC, Type ITC, or Type PLTC cables at intervals not exceeding 1.0 m (40 in.).

Exception No. 4: The information required in 310.8(A) shall be permitted to be durably marked on a nonmetallic covering under the metallic sheath of Type ITC or Type PLTC cable at intervals not exceeding 1.0 m (40 in.).

Informational Note: Included in the group of metal-covered cables are Type AC cable (Article 320), Type MC cable (Article 330), and lead-sheathed cable.

(3) Tag Marking.

The following conductors and cables shall be marked by means of a printed tag attached to the coil, reel, or carton:

(1) Type MI cable

(2) Switchboard wires

(3) Metal-covered, single-conductor cables

(4) Type AC cable

(4) Optional Marking of Wire Size.

The information required in 310.8(A)(4) shall be permitted to be marked on the surface of the individual insulated conductors for the following multiconductor cables:

(1) Type MC cable

(2) Tray cable

(3) Irrigation cable

(4) Power-limited tray cable

(5) Power-limited fire alarm cable

(6) Instrumentation tray cable

(C) Suffixes to Designate Number of Conductors.

A type letter or letters used alone shall indicate a single insulated conductor. The letter suffixes shall be indicated as follows:

(1) D — For two insulated conductors laid parallel within an outer nonmetallic covering

(2) M — For an assembly of two or more insulated conductors twisted spirally within an outer nonmetallic covering

(D) Optional Markings.

All conductors and cables contained in Chapter 3 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistant, and so forth.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is colored or identified and not the conductor itself. It is the insulation of conductors

that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 13:23:10 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 531-NFPA 70-2020 [Section No. 310.8(B)(1)]

(1) Surface Marking.

The following conductors and cables shall be durably marked on the surface:

(1) Single-conductor and multiconductor thermoset and thermoplastic-insulated wire and cable

(2) Nonmetallic-sheathed cable

(3) Service-entrance cable

(4) Underground feeder and branch-circuit cable

(5) Tray cable

(6) Irrigation cable

(7) Power-limited tray cable

(8) Instrumentation tray cable

The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).

Exception: If a cable's sheathing or cladding is removed and installed in a raceway 610 mm (24 in.) or less.

Additional Proposed Changes

File Name	Description	Approved
0.jfif	NM cable to EMT change over attached to a cabinet	

Statement of Problem and Substantiation for Public Input

the attached picture shows this is a common installation, however there are no marking on the cable conductors making it a violation of this section. The new exception would allow this limited use based on the allowed interval of 24 inch markings.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Tue Feb 25 13:06:46 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: Removal of the sheathing or cladding could invalidate a listing.


4357-NM
MULTI-PORT
EMT TO NM CABLE
TRANSITION FITTING

Public Input No. 3844-NFPA 70-2020 [Section No. 310.8(B)(2)]

(2) Marker Tape.

Metal-covered multiconductor cables shall employ a marker tape located within the cable and running for its complete length.

Exception No. 1: Type MI cable shall not require a marker tape.

Exception No. 2: Type AC cable shall not require a marker tape.

Exception No. 3: The information required in 310.8(A) shall be permitted to be durably marked on the outer nonmetallic covering of Type MC, Type ITC, or Type PLTC cables at intervals not exceeding 1.0 m (40 in.).

Exception No. 4: The information required in 310.8(A) shall be permitted to be durably marked on a nonmetallic covering under the metallic sheath of Type ITC or Type PLTC cable at intervals not exceeding 1.0 m (40 in.).

Informational Note: Included in the group of metal-covered cables are Type AC cable (~~Article~~ See 320.1), Type MC cable (~~Article~~ See 330.1), and lead-sheathed cable.

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to an entire article, other than Article 100. This PI recommends modifying the informational note to refer to the scope statement of the respective article to comply. Alternatively, the CMP may wish to reference a specific part of the relative article.

Submitter Information Verification

Submitter Full Name: Richard Holub
Organization: The DuPont Company, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 13:53:38 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8345-NFPA 70-2021
Statement: References were not necessary, and referring to the scope is not helpful.

Public Input No. 2294-NFPA 70-2020 [Section No. 310.10(D)]

(D) Locations Exposed to Direct Sunlight.

Insulated conductors or cables used where exposed to direct rays of the sun shall comply with (D)(1) or (D)(2):

(1) Conductors and cables shall be ~~listed, or listed and marked, as~~ listed as being sunlight resistant

(2) Conductors and cables shall be covered with insulating material, such as tape or sleeving, that ~~is listed, or listed and marked, as~~ is listed as being sunlight resistant

Statement of Problem and Substantiation for Public Input

the use of "shall be listed, or listed and marked" is superfluous and is not used elsewhere in NEC. Other NEC requirements on the topic of sunlight resistant more often mention "listed" than "listed and marked" Those that potentially substantiate an intent to be "listed and marked" are: 600.33(A)(4), 690.31(C)(1), 690.31(C)(3).

Submitter Information Verification

Submitter Full Name: John Blissett
Organization: Bernhard TME
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 13 17:32:53 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8306-NFPA 70-2021
Statement: The use of "shall be listed, or listed and marked" is superfluous and is not used elsewhere in NEC.

Public Input No. 3404-NFPA 70-2020 [Section No. 310.10(D)]

(D) Locations Exposed to Direct Sunlight.

~~Insulated conductors or~~ The insulation of conductors or outer covering of cables used where exposed to direct rays of the sun shall comply with (D)(1) or (D)(2):

(1) ~~Conductors~~ The insulation of conductors and cables shall be listed, or listed and marked, as being sunlight resistant

(2) Conductors and cables shall be covered with insulating material, such as tape or sleeving, that is listed, or listed and marked, as being sunlight resistant

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is colored or identified and not the conductor itself. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 13:53:04 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3406-NFPA 70-2020 [Section No. 310.10(E)]

(E) Direct-Burial Conductors and Cables .

~~Conductors~~ The insulation of conductors and cables that are used for direct-burial applications shall be of a type identified for such use.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is colored or identified and not the conductor itself. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.
"Cables" is added to this section as clearly, several cables in the NEC are identified for direct-burial applications.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 13:56:10 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3407-NFPA 70-2020 [Section No. 310.10(F)]

(F) Corrosive Conditions.

~~Conductors~~ The insulation of conductors that are exposed to oils, greases, vapors, gases, fumes, liquids, or other substances having a deleterious effect on the conductor or insulation shall be of a type suitable for the application.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code.
The insulation of the conductor or jacket of the cable must be suitable for the environmental conditions the wiring method will be exposed to. This insulation or covering protects the conductor from any adverse corrosive effects.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 14:01:09 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 1316-NFPA 70-2020 [Section No. 310.10(G)]

(G) Conductors in Parallel.

(1) General.

Aluminum, copper-clad aluminum, or copper conductors for each phase, polarity, neutral, or grounded circuit shall be permitted to be connected in parallel (electrically joined at both ends) only in sizes 1/0 AWG and larger where installed in accordance with 310.10(G)(2) through (G)(6).

Exception No. 1: Conductors in sizes smaller than 1/0 AWG shall be permitted to be run in parallel to supply control power to indicating instruments, contactors, relays, solenoids, and similar control devices, or for frequencies of 360 Hz and higher, provided all of the following apply:

(1) They are contained within the same raceway or cable.

(2) The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors.

(3) The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected.

Exception No. 2: Under engineering supervision, 2 AWG and 1 AWG grounded neutral conductors shall be permitted to be installed in parallel for existing installations.

Informational Note to Exception No. 2: Exception No. 2 can be used to alleviate overheating of neutral conductors in existing installations due to high content of triplen harmonic currents.

(2) Conductor and Installation Characteristics.

The paralleled conductors in each phase, polarity, neutral, grounded circuit conductor, equipment grounding conductor, ~~or equipment bonding jumper shall~~ equipment bonding jumper, or supply-side bonding jumper shall comply with all of the following:

(1) Be the same length

(2) Consist of the same conductor material

(3) Be the same size in circular mil area

(4) Have the same insulation type

(5) Be terminated in the same manner

(3) Separate Cables or Raceways.

Where run in separate cables or raceways, the cables or raceways with conductors shall have the same number of conductors and shall have the same electrical characteristics. Conductors of one phase, polarity, neutral, grounded circuit conductor, ~~or equipment~~ equipment grounding conductor ~~shall~~ , or supply-side bonding jumper shall not be required to have the same physical characteristics as those of another phase, polarity, neutral, grounded circuit conductor, ~~or equipment~~ equipment grounding conductor, or supply-side bonding jumper .

(4) Ampacity Adjustment.

Conductors installed in parallel shall comply with the provisions of 310.15(C)(1).

(5) Equipment Grounding Conductors.

Where parallel equipment grounding conductors are used, they shall be sized in accordance with 250.122. Sectioned equipment grounding conductors smaller than 1/0 AWG shall be permitted in multiconductor cables, if the combined circular mil area of the sectioned equipment grounding conductors in each cable complies with 250.122.

(6) Bonding Jumpers.

Where parallel equipment bonding jumpers or supply-side bonding jumpers are installed in raceways, they shall be sized and installed in accordance with 250.102.

Statement of Problem and Substantiation for Public Input

The revisions here are necessary to recognize that supply-side bonding jumpers, as specified in Sections 310.10(G)(6), 250.30(A)(2), and 250.30(B)(3) are not the same as equipment grounding conductors, but both types of conductors are permitted to be connected in parallel. Theses conductors both perform essentially the same grounding/bonding functions, albeit at different parts of a circuit, and as such supply-side bonding jumpers should be included in these rules.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 01 09:18:59 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8314-NFPA 70-2021

Statement: Editorial corrections were made to clarify this section. Equipment grounding conductors and supply-side bonding jumpers are not always required to be 1/0 AWG or larger.

New language on cross sectional area is not needed. New proposed exception adds no value.

Public Input No. 230-NFPA 70-2019 [Section No. 310.10(G)(1)]

(1) General.

Aluminum, copper-clad aluminum, or copper conductors for each phase, polarity, neutral, ~~or~~ grounded circuit, equipment grounding conductor or supply side bonding jumper shall be permitted to be connected in parallel (electrically joined at both ends) for the purpose of providing an accumlative cross sectional area. Shall be only in sizes 1/0 AWG and larger where installed in accordance with 310.10(G)(2) through (G)(6).

Exception No. 1: Conductors in sizes smaller than 1/0 AWG shall be permitted to be run in parallel to supply control power to indicating instruments, contactors, relays, solenoids, and similar control devices, or for frequencies of 360 Hz and higher, provided all of the following apply:

(1) They are contained within the same raceway or cable.

(2) The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors.

(3) The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected.

Exception No. 2: Under engineering supervision, 2 AWG and 1 AWG grounded neutral conductors shall be permitted to be installed in parallel for existing installations.

Exception No. 3: Supply side bonding jumper installed according to Table 250.102 (C)(1)

Informational Note to Exception No. 2: Exception No. 2 can be used to alleviate overheating of neutral conductors in existing installations due to high content of triplen harmonic currents.

Statement of Problem and Substantiation for Public Input

There is confusion with purpose paralleling conductors. It is important to note the purpose of paralleling is to collectively supply power through the accumulative circular mil area of all the conductors involved. the addition of Supply side bonding jumps is to acknowledge they are also allow to be run in parallel.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrican
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 31 15:51:08 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8314-NFPA 70-2021

Statement: Editorial corrections were made to clarify this section. Equipment grounding conductors and supply-side bonding jumpers are not always required to be 1/0 AWG or larger.

New language on cross sectional area is not needed. New proposed exception adds no value.

Public Input No. 30-NFPA 70-2019 [Section No. 310.10(G)(1)]

(1) General.

Aluminum, copper-clad aluminum, or copper conductors for each ~~phase~~ ungrounded , polarity, neutral, ~~or~~ grounded circuit, or equipment grounding conductor shall be permitted to be connected in parallel (electrically joined at both ends) ~~only in sizes 1~~ . Except for equipment grounding conductors, the conductors shall be size 1 /0 AWG and larger ~~where installed in~~ . The conductors that are connected in parallel shall be installed in accordance with 310.10(G)(2) through (G)(6).

Exception No. 1: Conductors in sizes smaller than 1/0 AWG shall be permitted to be run in parallel to supply control power to indicating instruments, contactors, relays, solenoids, and similar control devices, or for frequencies of 360 Hz and higher, provided all of the following apply:

(1) They are contained within the same raceway or cable.

(2) The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors.

(3) The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected.

Exception No. 2: Under engineering supervision, 2 AWG and 1 AWG grounded neutral conductors shall be permitted to be installed in parallel for existing installations.

Informational Note to Exception No. 2: Exception No. 2 can be used to alleviate overheating of neutral conductors in existing installations due to high content of triplen harmonic currents.

Statement of Problem and Substantiation for Public Input

This Public Input is intended to be primarily an editorial revision and not substantive.
For replacement of "phase" with "ungrounded", the term "ungrounded" is defined in Article 100 and thus will be better understood.
For the addition of "equipment grounding conductor" in the opening paragraph, this is intended that indeed, equipment grounding conductors are permitted to be connected in parallel but are sized as provided in 310.10(G)(5) and 250.122.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Tue Nov 05 17:50:49 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8314-NFPA 70-2021

Statement: Editorial corrections were made to clarify this section. Equipment grounding conductors and supply-side bonding jumpers are not always required to be 1/0 AWG or larger.

New language on cross sectional area is not needed. New proposed exception adds no value.

Public Input No. 3480-NFPA 70-2020 [Section No. 310.10(G)(1)]

(1) General.

Aluminum, copper-clad aluminum, or copper conductors for each phase, polarity, neutral, or grounded circuit shall be permitted to be connected in parallel (electrically joined at both ends) only in sizes 1/0 AWG and larger where installed in accordance with 310.10(G)(2) through (G)(6).

Exception No. 1: Conductors in sizes smaller than 1/0 AWG shall be permitted to be run in parallel ~~to supply control power to indicating instruments , contactors, relays, solenoids, and similar control devices, or for frequencies of 360 Hz and higher,~~ provided all of the following apply:

(1) They are contained within the same raceway or cable.

(2) The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors.

(3) The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected.

Exception No. 2: Under engineering supervision, 2 AWG and 1 AWG grounded neutral conductors shall be permitted to be installed in parallel for existing installations.

Informational Note to Exception No. 2: Exception No. 2 can be used to alleviate overheating of neutral conductors in existing installations due to high content of triplen harmonic currents.

Statement of Problem and Substantiation for Public Input

The current language is unnecessarily restrictive as to the applications that are permitted for parallel conductors smaller than 1/0 AWG. When the conditions specified in the exception are met, there is no safety downside to using parallel conductors in smaller sizes. Thus in keeping with the goal of "Practical Safeguarding" as specified in 90.1(A), there is no reason to restrict paralleling conductors in small sizes when each conductor is protected at its individual ampacity.

Submitter Information Verification

Submitter Full Name: Wayne Whitney
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 16:47:08 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: No substantiation for opening up this exception further. Currently allowed applications are low current.

Public Input No. 3482-NFPA 70-2020 [Section No. 310.10(G)(1)]

(1) General.

Aluminum, copper-clad aluminum, or copper conductors for each phase, polarity, neutral, or grounded circuit shall be permitted to be connected in parallel (electrically and physically joined at both ends) only in sizes 1/0 AWG and larger where installed in accordance with 310.10(G)(2) through (G)(6).

Exception No. 1: Conductors in sizes smaller than 1/0 AWG shall be permitted to be run in parallel to supply control power to indicating instruments, contactors, relays, solenoids, and similar control devices, or for frequencies of 360 Hz and higher, provided all of the following apply:

(1) They are contained within the same raceway or cable.

(2) The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors.

(3) The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected.

Exception No. 2: Under engineering supervision, 2 AWG and 1 AWG grounded neutral conductors shall be permitted to be installed in parallel for existing installations.

Informational Note to Exception No. 2: Exception No. 2 can be used to alleviate overheating of neutral conductors in existing installations due to high content of triplen harmonic currents.

Statement of Problem and Substantiation for Public Input

The NEC uses the phrase "electrically joined" in only a couple places, in contrast to the much more common phrase "electrically connected". It is my understanding that "electrically joined" is meant to convey physical, proximate connection of the conductors to each other, while "electrically connected" simply implies some conductive circuit path between the two points.

With that understanding, the current language does not preclude, e.g., complex circuits with multiple switches in which one configuration would result in two conductors "electrically connected" at each end, when they are not "electrically joined." However, many read "electrically joined" as being synonymous with "electrically connected" and hence read this section to prohibit such circuit configurations.

Therefore, if it is not the intention to prohibit such configurations, I suggest the additional two words to make it clear that this section on parallel conductors only applies to conductors physically and proximately connected at each end, and does not apply to conductors that are just electrically connected via some circuit path, some of the time.

Submitter Information Verification

Submitter Full Name: Wayne Whitney
Organization: [Not Specified]
Street Address:
City:
State:

Zip:
Submittal Date: Tue Sep 08 16:54:56 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Electrically joined conductors will also be physically joined.

Public Input No. 148-NFPA 70-2019 [Section No. 310.10(G)(2)]

(2) Conductor and Installation Characteristics.

The paralleled conductors in each phase, polarity, neutral, grounded circuit conductor, equipment grounding conductor, or equipment bonding jumper shall comply with all of the following:

(1) Be the same length

(2) Consist of the same conductor material

(3) Be the same size in circular mil area

(4) Have the same insulation type

(5) Be terminated in the same manner

Exception to (5): The equipment grounding conductor(s) or equipment bonding jumper(s) shall not be required to be terminated in the same manner or location as long as the termination location meets the requirements of 250.4(A)(4) for grounded systems and 250.4(B)(3) for ungrounded systems.

Additional Proposed Changes

File Name	Description	Approved
XFMREGC.jpg	EGC Parallel Example	

Statement of Problem and Substantiation for Public Input

Greetings CMP,

There seems to be a misconception that the EGC is required to meet all the same characteristics of the ungrounded and grounded conductors. While the sizing of the EGC or EBJ is clear and if installed in separate raceways would need to be of the same size in each raceway. Since we size the EGC full sized based on the OCPD ahead of it does not need the benefits of being treated as a "parallel" set like it is with phase or grounded conductors. With that said, it also would not need to be terminated at both ends IDENTICAL as you would with meeting the parallel conductor rules under 310.10(G) because with the EGC we are not trying to install them in parallel to obtain a larger circular mil. Take a XFMR for example, if the XFMR Enclosure is correctly bonded and grounded then no matter where the EGC's terminate onto the enclosure (assuming metal and terminations in compliance with 250.8) it would serve their role. Requiring the EGC and EBJ to be installed in parallel at their terminations just like the phase and/or grounded conductor is pointless in it's function. Again we are not paralleling the EGC, if that was the case then it would not be installed full size in each raceway. Please see attached image for clarification.

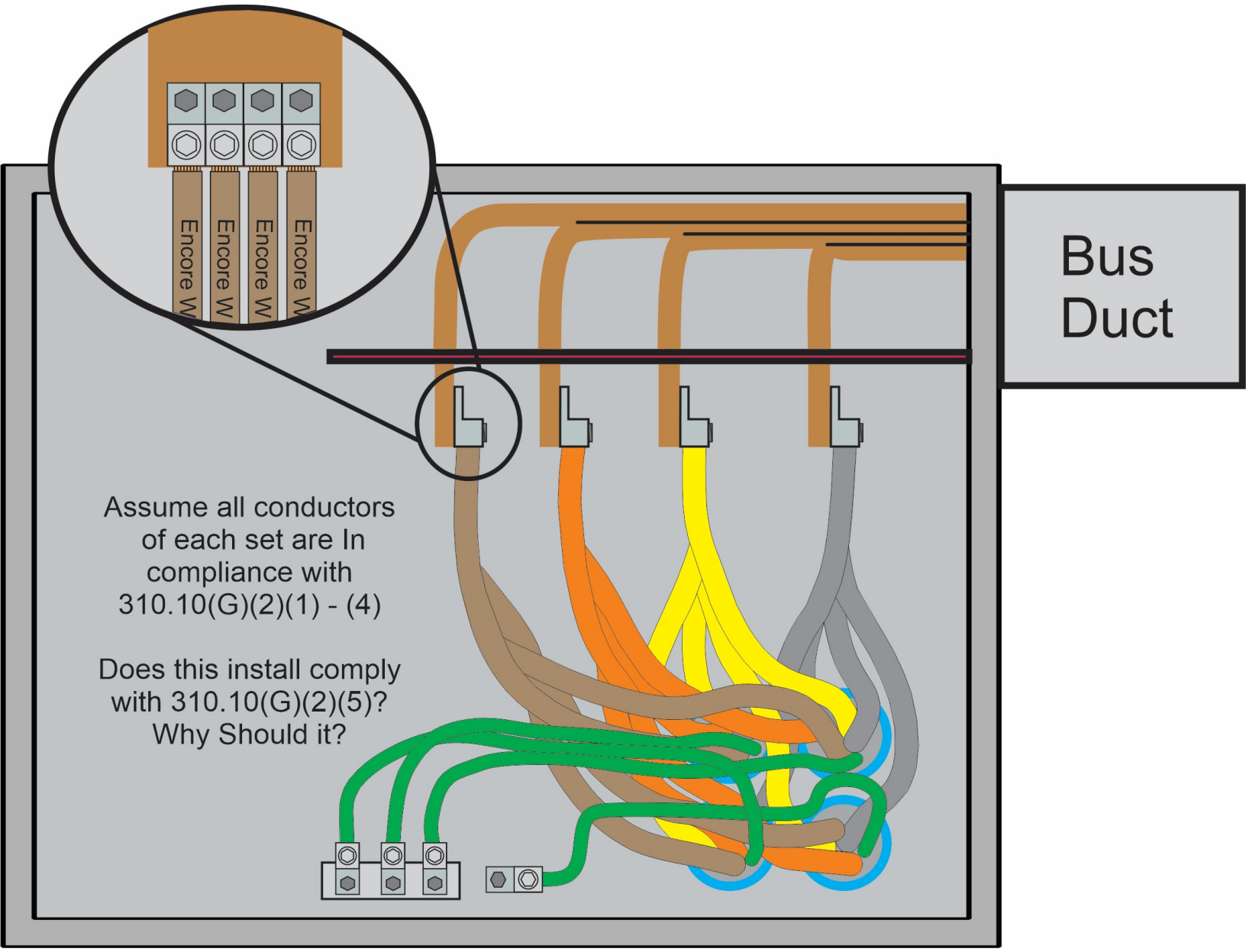
Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: ElectricianLIVE.com
Street Address:
City:
State:
Zip:

Submittal Date: Mon Nov 25 16:33:30 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: This section does not state that the terminations must be in the same location. The figure provided complies with the current section. (Terminations are done in the same manner).


Encore W
Encore W
Encore W
Encore W
Bus
Duct
Assume all conductors
of each set are In
compliance with
310.10(G)(2)(1) - (4)
Does this install comply
with 310.10(G)(2)(5)?
Why Should it?

Public Input No. 229-NFPA 70-2019 [Section No. 310.10(G)(2)]

(2) Conductor and Installation Characteristics.

The paralleled conductors in each phase, polarity, neutral, grounded circuit ~~conductor~~ , equipment grounding conductor, or equipment bonding jumper shall comply with all of the following:

(1) Be the same length

(2) Consist of the same conductor material

(3) Be the same size in circular mil area

(4) Have the same insulation type

(5) Be terminated in the same manner

(6) Identified in the same manner

Statement of Problem and Substantiation for Public Input

when inspecting the parallel conductor installation seeing multiple colors or methods on each phase makes the installation confusing and un-workmen like for consistency the identification of the parallel conductors should be the same. example all blue, red , black, tagged or otherwise identified

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 31 15:22:52 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: There is no indication that such inconsistent marking is actually occurring in the field.

Public Input No. 31-NFPA 70-2019 [Section No. 310.10(G)(4)]

(4) Ampacity Correction or Adjustment.

Conductors installed in parallel shall comply with ~~the provisions of~~ 310.15(~~C~~ B) or (~~1~~ C) as applicable .

Statement of Problem and Substantiation for Public Input

This Public Input is to recognize that conductors that are installed in parallel are subject to all the requirements in 310.15(B) and (C) as applicable and not only those in (C)(1).
This PI also deletes "with the provisions of" which is superfluous.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Tue Nov 05 18:04:16 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8314-NFPA 70-2021
Statement: Editorial corrections were made to clarify this section. Equipment grounding conductors and supply-side bonding jumpers are not always required to be 1/0 AWG or larger.

New language on cross sectional area is not needed. New proposed exception adds no value.

Public Input No. 3417-NFPA 70-2020 [Section No. 310.10(G)(5)]

(5) Equipment Grounding Conductors.

~~Where parallel equipment~~ If equipment grounding conductors are ~~used~~ connected in parallel , they shall be sized in accordance with 250.122. ~~Sectioned equipment~~ Equipment grounding conductors smaller than 1/0 AWG that are sectioned shall be permitted in multiconductor cables, if the combined circular mil area of the sectioned equipment grounding conductors in each cable complies with 250.122.

Statement of Problem and Substantiation for Public Input

This Public Input is intended to be primarily editorial rather than substantive.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 14:21:20 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: New language is no more clear than existing language.

Public Input No. 1401-NFPA 70-2020 [Section No. 310.12]

~~**310.12** Single-Phase Dwelling Services and Feeders.~~

~~For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.12(A) through (D).~~

~~For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of two ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.12(A) through (C).~~

~~**(A)** Services.~~

~~For a service rated 100 amperes through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.~~

~~**(B)** Feeders.~~

~~For a feeder rated 100 amperes through 400 amperes, the feeder conductors supplying the entire load associated with a one-family dwelling, or the feeder conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the feeder rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.~~

~~**(C)** Feeder Ampacities.~~

~~In no case shall a feeder for an individual dwelling unit be required to have an ampacity greater than that specified in 310.12(A) or (B).~~

~~**(D)** Grounded Conductors.~~

~~Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, if the requirements of 220.61 and 230.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.~~

~~Where correction or adjustment factors are required by 310.15(B) or (C), they shall be permitted to be applied to the ampacity associated with the temperature rating of the conductor.~~

> ~~Informational Note No. 1: The service or feeder ratings addressed by this section are based on the standard ampere ratings for fuses and inverse time circuit breakers from 240.6(A).~~
>
> ~~Informational Note No. 2: See Example D7 in Annex D.~~

~~Table 310.12 Single-Phase Dwelling Services and Feeders~~

~~Conductor~~

~~(AWG or kcmil) Service or Feeder Rating~~

~~(Amperes) Copper Aluminum or Copper-Clad Aluminum 100 4 2 110 3 1 125 2 1/0 150 1 2/0 175 1/0 3/0 200 2/0 4/0 225 3/0 250 250 4/0 300 300 250 350 350 350 500 400 400 600~~

~~Note: If no adjustment or correction factors are required, this table shall be permitted to be applied.~~

Statement of Problem and Substantiation for Public Input

Delete all of 310.12. This rule should have never been in the Code. Article 310 address conductors and conductor ampacity not load calculations. How in the world does Article 310 state that a 335A wire (400 kcmil copper at 75ºC) would be permitted on a 400A protection device? Or that a 70A wire (4 AWG at 60ºC) is permitted on a 100A protection device. This table has two cases where the conductor ampacity is not protected in accordance with 240.4(B). If the intent of this rule is to permit smaller conductors for dwelling units because the panel feels that the load calculations in 220 are “way oversized,” then the panel should submit a PI to have residential demand loads adjusted by 83% to size the service, then the conductors would be sized to the service overcurrent protection device. I think Article 310.16 should get out of the business of sizing circuits and ignoring the overcurrent protection requirements of Article 240. In addition, the text also permits this rule to apply to feeder conductors from a generator, where the generator is sized based on the “actual” load, not some “calculated” load that is way larger than reality. If someone measures 90A per 220.87 Ex, the feeder conductor, per this table would permit 4 AWG rated only 70A at 60ºC in accordance with 110.14(C)(1)(a). Again, if the goal is to size the conductor closer to reality, then the 83% factor should be contained in Article 220, not Article 310.

Submitter Information Verification

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Submittal Date: Tue Jun 02 11:37:12 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: No substantiation to show this language is being improperly applied causes confusion or other issues in the field. The Panel encourages the submitter to provide examples from the field where issues have occurred.

Public Input No. 2114-NFPA 70-2020 [Section No. 310.12]

310.12 Single-Phase Dwelling Services and Feeders.

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a ~~single-phase, 120/240-volt system shall be permitted to be sized in accordance with~~ 310.12(A) ~~through (D).For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of two ungrounded conductors and the neutral conductor from a 208Y/120 volt~~ 120/240V or 120/208V single-phase utility system shall be permitted to be sized in accordance with 310.12(A) through (~~C~~ D).

(A) Services.

For a service rated 100 amperes through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.

(B) Feeders.

For a feeder rated 100 amperes through 400 amperes, the feeder conductors supplying the entire load associated with a one-family dwelling, or the feeder conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the feeder rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.

(C) Feeder Ampacities.

In no case shall a feeder for an individual dwelling unit be required to have an ampacity greater than that specified in 310.12(A) or (B).

(D) Grounded Conductors.

Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, if the requirements of 220.61 and 230.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.

Where correction or adjustment factors are required by 310.15(B) or (C), they shall be permitted to be applied to the ampacity associated with the temperature rating of the conductor.

Informational Note No. 1: The service or feeder ratings addressed by this section are based on the standard ampere ratings for fuses and inverse time circuit breakers from 240.6(A).

Informational Note No. 2: See Example D7 in Annex D.

Table 310.12 Single-Phase Dwelling Services and Feeders

Service or Feeder Rating (Amperes)	Conductor (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum
100	4	2
110	3	1
125	2	1/0
150	1	2/0
175	1/0	3/0
200	2/0	4/0
225	3/0	250
250	4/0	300
300	250	350
350	350	500
400	400	600

Note: If no adjustment or correction factors are required, this table shall be permitted to be applied.

Statement of Problem and Substantiation for Public Input

Add text for the feeder rule to specifiy that the feeders are supplied by an electric utility. This means that you can't use 310.12 for feeder conductors from a generator.

Submitter Information Verification

Submitter Full Name: Mike Holt
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Submittal Date: Sat Aug 01 15:01:18 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Section 310.12 applies to feeders from all sources, including utility supply or other sources, such as a generator.

Public Input No. 3323-NFPA 70-2020 [Sections 310.12(A), 310.12(B)]

Sections 310.12(A), 310.12(B)

(A) Services.

For a service rated 100 amperes through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.

(B) Feeders.

For a feeder rated 100 amperes through 400 amperes, the feeder conductors supplying the entire load associated with a one-family dwelling, or the feeder conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the feeder rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.

Exception: In existing installations where a feeder previously supplied the entire load associated with a dwelling unit that met the rules on 310.12(A) or (B), in order to permit a service upgrade to the dwelling unit the 83 percent sizing of the feeder conductors which will no longer supply the entire dewelling unit will still be permitted to apply.

Statement of Problem and Substantiation for Public Input

The conductors are unaware if they contain the entire dwelling unit load or not, therefore sizing their ampacity in such a manner is purely for a safety factor in their sizing.

By only permitting the 83% rule for conductors that supply the entire dwelling, one is disincentivized from adding additional service capacity. As such this may prohibit a move to an electrified house or other electrically demanding installation.

Permitting conductors to be utilized as per their previous ampacity, especially now that dwelling units are required to have external disconnecting means, would permit many installations to reuse existing feeders at their existing ampacity while keeping the load on the previously existing conductors the same or reducing it if portions of that load are replaced with the new electrical installation. Previously this was not the case since most service conductors were only 3-wire feeders, but now a good portion of those are likely to become 4-wire feeders and thus would be applicable for such an exception in the future.

Ideally the requirement to serve 'the entire load' of such dwelling units would be removed entirely, as if these conductors are safe when they carry the entire load, surely they are also safe when they carry less than the entire load.

Submitter Information Verification

Submitter Full Name: Chris Rettger
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Submittal Date: Mon Sep 07 22:55:28 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The proposed language would create many opportunities for misuse that do not exist now.

Public Input No. 18-NFPA 70-2019 [Section No. 310.12 [Excluding any Sub-Sections]]

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.12(A) through (D).

~~For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of two ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.12(A) through (C).~~

Additional Proposed Changes

File Name	Description Approved
See_note_tt_CEC_Copper_ampacity_Table_2nd_half.jpeg	CEC Ampacity Table note tt only allows 2/0 Cu and #6Al to increase, and only 1 ampere when you consider the round up rule
CEC_Copper_Amapcity_Table_1st_half.jpg	CEC Copper Ampacity Table Top Half
CEC_Aluminum_Ampacity_Table.jpg	CEC Aluminum Ampacity Table
nfpapublicinputform_NEC_310_15_B_7_DIA1_and_2.1409247730317.pdf	2017 Proposal Submitters Attachment, that shows three heaters compared to two
1956_Table_1a..pdf	1956 Table 1a 70-418 see first note, this was not for just dwellings, it was because

	there were only two heaters and we were using a 3 heater ampacity table
Proceedings_1956_60th_Aluminum_Conductors..pdf	1956 Proceedings, see last page, 4th to last paragraph, they made allowance because there are only two heaters instead of three
AIEE957_load_diversity_how_many_of_all_the_conductors_are_carrying.15944.pdf	1956 AIEE Report, (showing 3 of 12 pages) see second page 4th paragraph marked "2" and third page "diversity table". This shows the term load diversity applied to the ratio of conductors conducting.
1953_aluminum_ampacity..png	1953, prior to allowance, ampacity table notes had aluminum at 84% of copper
2017_National_Electric_Code_NEC_2018_Phoenix_Amendment.pdf	Phoenix Amendment removing the allowance, I had nothing to do with this.

Statement of Problem and Substantiation for Public Input

The additional allowance made in the 2017 edition for 120/208 3 wire services encourages a fire hazard, the 2017 submitter gave bad information by saying the CEC allows this, it does not, see CEC ampacity table and specifically it's note "tt" (attached), the CEC only increases 2/0cu and #6al and only effectively by 1 amp when you consider the next size up rule, it's only effectively increasing by 1 amp because it currently lands on a standard size ocpd so you wouldn't be able to use the next size up rule.

It appears some of the panel believes this allowance is due to the diversity of the loads served, when it is actually because of load diversity of the conductors. The three-wire single phase 120/240 will only ever be able to see the equivalent of two fully loaded conductors, if both ungrounded conductors are fully loaded the neutral will carry nothing, If one ungrounded conductor and the neutral are fully loaded the other ungrounded conductor is carrying zero amperes. While a 120/208 single phase service from a three-phase system will allow all three conductors to be fully loaded because they are vectorially 120 degrees apart rather than 180 like the 120/240 Edison/Split-Phase. The Submitter for the 17' change even shows these conductor group current differences in his attachment(attached to this PI). When this allowance was originally introduced in the code(1956, see below and attached) it was not limited to residences, it was for all 120/240Edison 3-wire services. In 1978 it was further limited to dwellings for further restriction, this apparently led to a misunderstanding of the reasoning behind the special allowance, leading to an unsafe NEC in 2017.

Table 310.15 is based on 3 conductors fully loaded in a conductor group, the 120/240Edison 3 wire is limited by physics to only ever see the equivalent of 2 fully loaded conductors, while it also benefits from the heat sink properties of the third conductor, so T310.15 is not an accurate ampacity for the specific conductor group of a 120/240 single phase service. Thermal contribution of conductors is base on I2R, with the 120/208 service you are allowing three heaters in an assembly instead of only two like the 120/240 service has, all heaters all being of the same individual BTU output, while also eliminating the heat sink properties of the third conductor.

If you don't want to double check my temperature rise calculations for the difference in conductor groups there is an identical example elsewhere in the code that precisely shows the issue that the 2017 change causes. You can look at the flexible cords and cables ampacity table, it has separate rows for groups of 2 and 3 conductors, T400.5(A)(2) 60degree row specifically (not 75 degree on the cords table), column E is 2 conductors while column F is 3 conductors, the 2 conductor column matches T310.12 +/-1or2 amperes, while the 3 conductor column matches T310.15 75 degree column (not 60 degree for wire table), +/-1or2 amperes. (You get the same ampacity at 60c on cords while 75c on wires because cords are not installed fully immersed in insulating material, cords are essentially in free air, but nonetheless it illustrates the issue I am protesting.)

Below and attached are historical highlights of this allowance to explain the reasoning behind the special allowance of the section. Attached in the "Upload Additional Proposed Changes" section are originals and also the City of Phoenix Amendment removing this allowance, which to be clear I had nothing to do with.

Before 1956 there was no special allowance for the service conductors.
1956
NFPA Proceedings of the sixth annual meeting June 4-8, 1956
Page 52 and 53
Report of Electrical Correlating committee(attached)

“Also in connection with this table, the utility people pointed out that aluminum wire for services was being modified from the 84 per cent value previously given in the Code, that is 84 per cent of the copper carrying capacity, and while they were in agreement with that because the data was the result of a study by the sub-committee, they did want to point out that in a 3-wire single phase, with only one of the wires loaded, it would not be necessary to go to the higher values.

It was proposed that a note be made for 2 to 4/0, the allowable capacity, it would be one, the 84 percent value, and these values were ironed out by the Correlating Committee to values normally used by the Code so that for #2, 100 amperes; #1, 110 amperes; for #0, 120. That, too, was adopted by the Correlating Committee. There were minor editorial changes but those are the changes in substance."

1956 NEC
Table 1A Page(attached)

shows in the note the allowance applied to all Edison feeders and services not just residential, it was later restricted to residential in 78'.

1956 IEEE (AIEE at the time) Paper "The Heating and Mechanical Effects of Installing Insulated Conductors in Steel Raceways" By Brandon, Kline, Geiges and Paradise. https://ieeexplore.ieee.org /document/4499473 (3 of 12 pages attached)
"Purpose
The purpose of the investigation was to compile information, observations, and test data which could be used for analyzing the following:
1. The applicable, current-carrying capacity reduction factors for more than nine conductors.
2. The effect of load diversity in reference to the current-carrying capacity reduction factors and conductor-operating temperatures."

This entire article is available online from IEEE, I am sending a copy of the test findings chart that illustrates the use of the term "load diversity" as not meaning the actual load being served, but the number of conductors conducting in the conductor group. The chart is titled Table VIII. Diversity Tests, column titles are Wire Type, Wire Size AWG, No. of Wires, No. Conducting, Operating Temperature C, Amperes, and Volts. The first row of data is #6 AWG, 12 wires, 4 conducting, operating at 60C, 59.5Amperes and 3.5 Volts. This testing was used for our De-rating table.

Submitter Information Verification

Submitter Full Name: devin hanes
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Affiliation: IEC
Street Address:
City:
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Zip:
Submittal Date: Sat Nov 02 19:21:05 EDT 2019
Committee: NEC-P06

Committee Statement

Resolution: No evidence of a fire hazard has been presented. In addition, full size neutral conductors are required for 208/120 feeders.

Public Input No. 4407-NFPA 70-2020 [Section No. 310.12 [Excluding any Sub-Sections]]

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.12(A) through (D).

~~For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of two ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.12(A) through (C).~~

Statement of Problem and Substantiation for Public Input

The second paragraph allows feeders comprised of two wye-connected phase conductors and the associated neutral conductor to use the same favorable ampacity allowances as those that have been permitted for generations on single phase distributions. The principal substantiation for the change, in the 2017 NEC, was that the Canadian Electrical Code permits this arrangement. The allowance flies in the face of physics and must be removed.

One of the principal reasons the traditional allowance works is that on a single phase distribution the worst case heating occurs with two conductors loaded to their full ampacity. This occurs when the entire load is either line to neutral on one side only, or line to line. The heating declines in proportion to the square of any reductions in current as the load becomes more evenly distributed. Because ampacity tables are based on three conductors operating fully loaded, the result is a justified bonus allowance under conditions that guarantee only two-thirds of the calculated heating will be present.

The NEC now extends this deserved bonus for single phase distributions and applies it equally to a distribution where all three conductors will see essentially full-loading assuming complete line-to-neutral loading, the worst case. The lowest loading will occur when one line conductor is at 100% and the other at 50%, in which case the neutral current is reduced to 86% (½√3) of the higher loaded phase conductor. This is why 310.15(E)(2) requires such neutrals to be taken at 100%, and, indeed, the NEC is not changing that rule in any way. The evident technical validity of that requirement disqualifies the technical validity of the requirement proposed for deletion under this PI. In this case, the Canadian Code has it wrong, not the NEC.

It may be true that there is no loss experience under the CEC approach. However, the CEC, like the NEC, oversizes dwelling feeders. This is why utility supplies to dwellings are, almost without exception, far smaller than their NEC counterparts. Oversized feeders can accommodate systemic undersizing from feeder ampacity calculations. However, CMP 2 is making steady advances with respect to increasing the accuracy of Article 220 load calculations. When Art. 220 starts generating accurate dwelling load profiles, and it will come to pass, then this allowance in the NEC, unsupported by physics, will undoubtedly lead to significant failures. It is time to unravel this recent allowance that contravened the first sixty years of special allowances for dwelling feeders and services. This rule was exclusively applicable to single-phase distributions from 1956 until 2017, and should be again.

Submitter Information Verification

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Affiliation: self
Street Address:
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Submittal Date: Thu Sep 10 12:18:57 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: No evidence of a fire hazard has been presented. In addition, full size neutral conductors are required for 208/120 feeders.

Public Input No. 3425-NFPA 70-2020 [Section No. 310.14(A)(3)]

(3) Temperature Limitation of Conductors.

No conductor shall be used in such a manner that ~~its operating temperature exceeds that designated for the type of insulated conductor involved~~ the operating temperature of the insulation is exceeded . In no case shall conductors be associated together in such a way, with respect to the type of circuit, the wiring method employed, or the number of conductors, that the limiting temperature of any conductor insulation is exceeded.

Informational Note No. 1: The temperature rating of a conductor insulation [see Table 310.4(A) and Table 311.10(A)] is the maximum temperature, at any location along its length, that the conductor insulation can withstand over a prolonged time period without serious degradation. The ampacity tables of Article 310 and the ampacity tables of Informative Annex B, the ambient temperature correction factors in 310.15(B), and the notes to the tables provide guidance for coordinating conductor sizes, insulation types, ampacities, ambient temperatures, and number of associated conductors. The principal determinants of operating temperature are as follows:

(1) Ambient temperature — ambient temperature may vary along the conductor length as well as from time to time.

(2) Heat generated internally in the conductor as the result of load current flow, including fundamental and harmonic currents.

(3) The rate at which generated heat dissipates into the ambient medium. Thermal insulation that covers or surrounds conductors affects the rate of heat dissipation.

(4) Adjacent load-carrying conductors — adjacent conductors have the dual effect of raising the ambient temperature and impeding heat dissipation.

Informational Note No. 2: Refer to 110.14(C) for the temperature limitation of terminations.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

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Organization: Simmons Electrical Services
Street Address:
City:
State:

Zip:

Submittal Date: Tue Sep 08 14:30:06 EDT 2020

Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3429-NFPA 70-2020 [Section No. 310.14(B)]

(B) Engineering Supervision.

Under engineering supervision, conductor ampacities shall be permitted to be calculated by means of Equation 310.14(B).

$$I = \sqrt{\frac{T_c - T_a}{R_{dc}\left(1 + Y_c\right)R_{ca}}} \times 10^3 \text{ amperes} \qquad \textbf{[310.14(B)]}$$

where:

T_C = conductor insulation temperature in degrees Celsius (°C)

T_a = ambient temperature in degrees Celsius (°C)

R_{dc} = dc resistance of 305 mm (1 ft) of conductor in microohms at temperature, T_C

Y_C = component ac resistance resulting from skin effect and proximity effect

R_{ca} = effective thermal resistance between conductor and surrounding ambient

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself can continue to function satisfactorily at a much higher temperature than the insulation system employed.

In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.

The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

Submitter Full Name: Phil Simmons
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Submittal Date: Tue Sep 08 14:38:21 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3430-NFPA 70-2020 [Section No. 310.15(A)]

(A) General.

Ampacities for conductors rated 0 volts to 2000 volts shall be as specified in the Ampacity Table 310.16 through Table 310.21, as modified by 310.15(A) through (F) and 310.12. Under engineering supervision, ampacities of sizes not shown in ampacity tables for conductors meeting the general wiring requirements shall be permitted to be determined by interpolation of the adjacent conductors based on the conductor's circular-mil area.

The temperature correction and adjustment factors shall be permitted to be applied to the ampacity for the temperature rating of the insulated conductor, if the corrected and adjusted ampacity does not exceed the ampacity for the temperature rating of the termination in accordance with the provisions of 110.14(C).

Informational Note No. 1: Table 310.16 through Table 310.19 are application tables for use in determining conductor sizes on loads calculated in accordance with Part II, Part III, Part IV, or Part V of Article 220. Ampacities result from consideration of one or more of the following:

(1) Temperature compatibility with connected equipment, especially the connection points.

(2) Coordination with circuit and system overcurrent protection.

(3) Compliance with the requirements of product listings or certifications. See 110.3(B).

(4) Preservation of the safety benefits of established industry practices and standardized procedures.

Informational Note No. 2: For conductor area see Chapter 9, Table 8, Conductor Properties. Interpolation is based on the conductor circular-mil area and not the conductor overall area.

Informational Note No. 3: For the ampacities of flexible cords and cables, see 400.5. For the ampacities of fixture wires, see 402.5.

Informational Note No. 4: For explanation of type letters used in tables and for recognized sizes of conductors for the various conductor insulations, see Table 310.4(A) and Table 310.4(B). For installation requirements, see 310.1 through 310.14 and the various articles of this *Code*. For flexible cords, see Table 400.4, Table 400.5(A)(1), and Table 400.5(A)(2).

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself can continue to function satisfactorily at a much higher temperature than the insulation system employed.
Table 8 of Chapter 9 provides the circular-mil area of conductors. These sizes should be referred to to ensure the overall conductor area is not used.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

Submitter Full Name: Phil Simmons
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Submittal Date: Tue Sep 08 14:41:17 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 4128-NFPA 70-2020 [Section No. 310.15(A)]

(A) General.

Ampacities for conductors rated 0 volts to 2000 volts shall be as specified in the Ampacity Table 310.16 through Table 310.21, as modified by 310.15(A) through (F) and 310.12. Under engineering supervision, ampacities of sizes not shown in ampacity tables for conductors meeting the general wiring requirements shall be permitted to be determined by interpolation of the adjacent conductors based on the conductor's area.

The temperature correction and adjustment factors shall be permitted to be applied to the ampacity for the temperature rating of the conductor, if the corrected and adjusted ampacity does not exceed the ampacity for the temperature rating of the termination in accordance ~~with the provisions of~~ with 110.14(C).

Informational Note No. 1: Table 310.16 through Table 310.19 are application tables for use in determining conductor sizes on loads calculated in accordance with Part II, Part III, Part IV, or Part V of Article 220. Ampacities result from consideration of one or more of the following:

(1) Temperature compatibility with connected equipment, especially the connection points.

(2) Coordination with circuit and system overcurrent protection.

(3) Compliance with the requirements of product listings or certifications. See 110.3(B).

(4) Preservation of the safety benefits of established industry practices and standardized procedures.

Informational Note No. 2: For conductor area see Chapter 9, Table 8, Conductor Properties. Interpolation is based on the conductor area and not the conductor overall area.

Informational Note No. 3: For the ampacities of flexible cords and cables, see 400.5. For the ampacities of fixture wires, see 402.5.

Informational Note No. 4: For explanation of type letters used in tables and for recognized sizes of conductors for the various conductor insulations, see Table 310.4(A) and Table 310.4(B). For installation requirements, see 310.1 through 310.14 and the various articles of this *Code*. For flexible cords, see Table 400.4, Table 400.5(A)(1), and Table 400.5(A)(2).

Statement of Problem and Substantiation for Public Input

Deleting the words "the provisions of" does not change the meaning of the section.

Submitter Information Verification

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State:
Zip:

Submittal Date: Wed Sep 09 21:36:39 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 96-NFPA 70-2019 [Section No. 310.15(A)]

(A) General.

Ampacities for conductors rated 0 volts to 2000 volts shall be as specified in the Ampacity Table 310.16 through Table 310.21, as modified by 310.15(A) through (F) and 310.12. Under engineering supervision, ampacities of sizes not shown in ampacity tables for conductors meeting the general wiring requirements shall be permitted to be determined by interpolation of the adjacent conductors based on the conductor's area.

The temperature correction and adjustment factors shall be permitted to be applied to the ampacity for the temperature rating of the conductor, if the corrected and adjusted ampacity does not exceed the ampacity for the temperature rating of the termination in accordance with the provisions of 110.14(C).

Informational Note No. 1: Table 310.16 through Table 310.19 are application tables for use in determining conductor sizes on loads calculated in accordance with Part II, Part III, Part IV, or Part V of Article 220. Ampacities result from consideration of one or more of the following:

(1) Temperature compatibility with connected equipment, especially the connection points. See 110.14(C)(1) for ambient temperature correction of terminals.

(2) Coordination with circuit and system overcurrent protection.

(3) Compliance with the requirements of product listings or certifications. See 110.3(B).

(4) Preservation of the safety benefits of established industry practices and standardized procedures.

Informational Note No. 2: For conductor area see Chapter 9, Table 8, Conductor Properties. Interpolation is based on the conductor area and not the conductor overall area.

Informational Note No. 3: For the ampacities of flexible cords and cables, see 400.5. For the ampacities of fixture wires, see 402.5.

Informational Note No. 4: For explanation of type letters used in tables and for recognized sizes of conductors for the various conductor insulations, see Table 310.4(A) and Table 310.4(B). For installation requirements, see 310.1 through 310.14 and the various articles of this *Code*. For flexible cords, see Table 400.4, Table 400.5(A)(1), and Table 400.5(A)(2).

Statement of Problem and Substantiation for Public Input

This is a companion proposal to the proposed revision for 110.14(C)(1). It is editorial in nature to provide guidance for the user of this section. Please see substantiation for proposed revision to 110.14(C)(1).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 94-NFPA 70-2019 [Section No. 110.14(C)(1)]	Ambient temperature adjustments for terminals
Public Input No. 98-NFPA 70-2019 [Section No. 310.15(B)(1)]	

Submitter Information Verification

Submitter Full Name: Paul Guidry
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Affiliation: Associated Builders and Contractors
Street Address:
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Zip:
Submittal Date: Tue Nov 12 15:50:53 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 3433-NFPA 70-2020 [Section No. 310.15(B)(1)]

(1) General.

Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(1) or Table 310.15(B)(2), or shall be permitted to be calculated using Equation 310.15(B).

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[310.15(B)]}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_C = temperature rating of conductor insulation (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself can continue to function satisfactorily at a much higher temperature than the insulation system employed.

In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.

The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

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Zip:
Submittal Date: Tue Sep 08 14:50:37 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 98-NFPA 70-2019 [Section No. 310.15(B)(1)]

(1) General.

Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(1) or Table 310.15(B)(2), or shall be permitted to be calculated using Equation 310.15(B).

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[310.15(B)]}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_C = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

Informational Note: See 110.14(C)(1) for ambient temperature adjustments for terminals.

Statement of Problem and Substantiation for Public Input

This a companion proposal for revision of 110.14(C)(1).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 94-NFPA 70-2019 [Section No. 110.14(C)(1)]	Ambient temperature adjustments for terminals
Public Input No. 96-NFPA 70-2019 [Section No. 310.15(A)]	Ambient temperature adjustments for terminals

Submitter Information Verification

Submitter Full Name: Paul Guidry
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Affiliation: Associated Builders and Contractors
Street Address:
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State:
Zip:
Submittal Date: Tue Nov 12 16:10:25 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: These proposed informational note may discourage readers from looking at all relevant

references. The user needs to understand not just termination limitations, but also equipment ratings, and any other relevant limitations within the system.

Public Input No. 2402-NFPA 70-2020 [Section No. 310.15(B)(2)]

(2) Rooftop.

For raceways or cables exposed to direct sunlight on or above rooftops where the distance above the roof to the bottom of the raceway or cable is less than 23 mm (⅞ in.), a temperature adder of ~~33°C~~ 30°C (~~60°F~~ 86°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Informational Note: One source for the ambient temperatures in various locations is the *ASHRAE Handbook — Fundamentals*.

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (°F)
	60°C	75°C	90°C	150°C	200°C	250°C	
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

Statement of Problem and Substantiation for Public Input

Change the temperature adder in 310.15(B)(2) Rooftop from 33 degrees C to 30 Degrees C and change (60 degrees F) to (86 degrees F) to align with the ambient temperature correction factors in Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30 degrees C (86 degrees F).

Submitter Information Verification

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Submittal Date: Wed Aug 19 10:21:11 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This refers to a temperature adder, not a correction factor associated with the table.

Public Input No. 3435-NFPA 70-2020 [Section No. 310.15(B)(2)]

(2) Rooftop.

For raceways or cables exposed to direct sunlight on or above rooftops where the distance above the roof to the bottom of the raceway or cable is less than 23 mm (**7** ⁄ **8** in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2) .

Exception: *Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.*

Informational Note: One source for the ambient temperatures in various locations is the *ASHRAE Handbook — Fundamentals* .

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor Insulation			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor Insulation						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor Insulation						Ambient Temperature (°F)
	60°C	75°C	90°C	150°C	200°C	250°C	
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

(3) Raceways and Cables Exposed to Sunlight on Rooftops.

If raceways or cables are exposed to direct sunlight on or above rooftops, the adjustments shown in Table 310.15(B)(3) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Informational Note: One source for the ambient temperatures in various locations is the ASHRAE Handbook Fundamentals.

Table 310.15(B)(3) Ambient Temperature Adjustment for Raceways or Cables Exposed to Sunlight on or Above Rooftops

	Temperature Adder	
Distance Above the Roof to Bottom of Raceway or Cable	°C	°F
On roof to 13 mm (0 - ½ in) above	33	60
13 to 90 mm (½ to 3½ in.) above roof	22	40

90 to 300 mm (3½ to 12 in.) above roof	17	30
300 to 900 mm (12 to 36 in.) above roof	14	25

Informational Note to Table 310.15(B)(3): The temperature adders in Table 310.15(B)(3) are based on the measured temperature rise above the local climatic ambient temperatures due to sunlight heating.

Additional Proposed Changes

File Name	Description	Approved
Fact_Finding_Report_final_draft-_Ambient_Temperature_Adjustment_10-10-2011_.pdf		

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.
This Public Input intends to restore Table 310.15(B)(3(c) from the 2014 NEC. It was based on the only valid and scientifically documented study of the actual temperatures that are experienced in raceways that are exposed to direct sunlight on rooftops. This was an unbiased and scientifically defensible Fact-Finding Study performed by Underwriters Laboratories. It is attached for this Code Panel's information.
The documentation for the change made to this section by the previous Code Panel during the 2017 NEC cycle was flawed, illogical and biased. The Task Group that submitted the documentation was not balanced and was populated by a group that set out to defeat the rooftop requirement. It fails the logic test to be almost embarrassing! It is difficult to imagine that anyone could believe, much less endorse, that the temperature adder goes from 60°F to zero below and above 7/8 inch! To comply with the NEC Style Manual, this subdivision needs to have a number in sequence. See the NEC Style Manual Section 2.1. This Comment proposes to number the subdivision as 310.15(B)(3).
It is recognized that CMP-6 has considered the impact of direct sunlight on raceways and cables before. It is hoped that the exhaustive fact-finding study by Underwriters Laboratories will provide the factual documentation needed to restore this accurate table to the NEC,

Submitter Information Verification

Submitter Full Name: Phil Simmons
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Zip:
Submittal Date: Tue Sep 08 14:54:32 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation. There is no adequate substantiation provided to undo the previous work of the panel.

File IN16969
Project 11CA25532

October 10, 2011

Fact-Finding Report on Ambient Temperature Adjustment for Raceway and Cable Systems Exposed to Sunlight on Rooftops

Prepared for Travis Lindsay Consulting Services, Inc.
Las Vegas, Nevada 89146

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EXECUTIVE SUMMARY

The 2011 National Electrical Code® (NEC®) requires for circular raceways exposed to sunlight on rooftops, an adjustment temperature be added to the outdoor temperature when determining ambient temperature and associated correction factors for calculating the ampacity of conductors. This adjustment temperature adder for circular raceways exposed to sunlight on rooftops is to account for solar heating, and is needed to assure that no conductor is used in a manner such that its operating temperature exceeds that for which it is designed.

In preparing for the 2011 NEC, a proposal was submitted to include cables into the scope of this requirement. Although supporting documentation included a report of testing with MC cables, the Code Panel chose to reject this proposal since the term “cables” was too general, and that testing was insufficient since only MC cable in a single size was tested. Some of the Code Panel members also noted the need for a more comprehensive research project to determine the effects of sunlight on wiring systems in general when installed on rooftops.

This is a report of a Fact-Finding Investigation intended to provide technical data and other pertinent facts regarding the safety aspects of installing raceways and cables to direct sunlight on or above rooftops. The investigation included tests on 17 different types and sizes of wiring systems, each of which were installed at four different elevations above the roof at an outdoor test facility in Las Vegas, Nevada. In addition to temperature measurements on the wiring system conductors, outdoor ambient temperature, wind speed, and solar irradiance were also recorded during the summer months of 2011. By calculating the difference between the temperature on the wiring system conductors and the outdoor ambient temperature during the period of peak solar irradiance during selected days of full sun and minimum wind, inferences could be made about the effects of solar heating on these wiring systems.

A statistical analysis of the data also provided insights into how solar heating affects wiring systems in general when installed on or above a rooftop. For all wiring systems mounted directly on the roof, the maximum temperature rise above outdoor ambient with a 95% confidence interval would statistically be 62.2 ^{o}F. For all wiring systems mounted at a distance above the roof (1/2 inch and greater) the maximum temperature rise above outdoor ambient with a 95% confidence interval would statistically be 51.4 ^{o}F.

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GENERAL

A proposal was accepted for the 2008 National Electrical Code® (NEC®), which recommended that for conduits exposed to sunlight on rooftops, an adjustment temperature be added to the outdoor temperature when determining ambient temperature for the correction factors in Tables 310.16 and 310.18. The substantiation for this proposal noted that Section 310.10 required that no conductor shall be used in such a manner that its operating temperature exceeds that designated for the type of insulated conductor involved. It also cited testing that showed the air inside conduits in direct sunlight to be significantly hotter than the surrounding air. This proposal resulted in new Section 310.15(B)(2)(c) and new Table 310.15(B)(2)(c) for the 2008 NEC[1].

For the 2011 NEC, a similar proposal was submitted to include cables into the scope of this requirement. Although supporting documentation included a report of testing with MC cables, the Code Panel chose to reject this proposal since the term “cables” was too general, and that testing was insufficient since only MC cable in a single size was tested. Some of the Code Panel members noted the need for a more comprehensive research project to determine the effects of sunlight on conduits, MC cable, and cable in general when installed on rooftops.

[1] For the 2011 NEC, Sec. 310.10 became Sec. 310.15(A)(3), Sec. 310.15(B)(2)(c) became Sec. 310.15(B)(3)(c), and Table 310.15(B)(2)(c) became Table 310.15(B)(3)(c).

OBJECTIVE

The objective for this Fact-Finding Investigation is to provide technical data and other pertinent facts regarding the safety aspects of installing raceways and cables to direct sunlight on or above rooftops.

Travis Lindsey Consulting Services Inc. proposes to submit a public proposal to revise Section 310.15(B)(3)(c) of the 2011 NEC as follows:

> (c) ~~*Circular*~~ *Raceways and Cables Exposed to Sunlight on Rooftops*. Where conductors ~~or cables~~ are installed in ~~circular~~ raceways or where in cables exposed to direct sunlight on or above rooftops, the adjustments shown in Table 310.15(B)(3)(c) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(2)(a) or 310.15(B)(2)(b).

Table 310.15(B)(3)(c) Ambient Temperature Adjustment for ~~Circular~~ Raceways or Cables Exposed to Sunlight on or Above Rooftops

Distance Above Roof to Bottom of ~~Conduit~~ Raceway or Cable	Temperature Adder	
	°C	°F
0-13 mm (1/2 in.)	33	60
Above 13 mm (1/2 in.) - 90 mm (3-1/2) in.)	22	40
Above 90 mm (3-1/2 in.) - 300 mm (12 in.)	17	30
Above 300 mm (12 in.) - 900 mm (36 in.)	14	25

WIRING SYSTEMS AND ROOFTOPS

NEC Requirements

Wiring methods and materials are described in Chapter 3 of the NEC. Included in Chapter 3 are various Articles for different cable types and raceways for containing conductors for general wiring, including wiring that may be installed on a rooftop and exposed to sunlight. Although the “uses permitted” for these various cables and raceways do not specifically mention rooftops, it could be assumed that if permitted for outdoor use and/or wet locations, and resistant to sunlight, a particular wiring system could be installed on a rooftop exposed to sunlight. Tables 1 and 2 include the various cable and raceway systems from Chapter 3 that could typically be installed on or above rooftops exposed to sunlight as permitted by the NEC. Also included in these tables are the specific NEC Chapter 3 Article, the UL standard, and the range of sizes that would be permitted or could be listed.

Table 1 – Cables Suitable for Installation on Rooftops Exposed to Sunlight

Type	NEC Article	UL Standard	Wire Size		Comment
			Min	Max	
MV	328	1072	8	2000	If identified for use in direct sunlight, or as "MV or MC"
MC	330	1569	18	2000	
MI	332	1581	16	500	Max 4 AWG for 2 & 3 conductor; 6 AWG for 4 conductor; 10 AWG for a 7 conductor
UF	340	493	14	4/0	For use with PV (rooftop) systems; Max 6 AWG for multiple conductors. This can also include single conductor cable listed as PV wire.
TC	336	1277	18	1000	When marked "Sunlight Resistant"
SE	338	854	14	unspecified	

Table 2 – Conduits and Raceways Suitable for Installation on Rooftops Exposed to Sunlight

Type	NEC Article	UL Standard	Trade Size		Comment
			Min	Max	
IMC	342	1242	1/2	4	
RMC	344	6/6A	3/8	6	
LFMC	350	360	3/8	4	
PVC	352	651	1/2	6	
LFNC	356	1660	3/8	4	When listed as suitable for outdoors
EMT	358	797/797A	1/2	4	
Auxiliary Gutters	366	870			When listed for exposure to sunlight and wet locations
Cable Bus	370				When identified for outdoor use
Metal Wireways	376	870			When listed for wet locations
Nonmetallic Wireways	378	879/5A			When listed for wet locations

COMPREHENSIVE TEST PROGRAM TO ADDRESS WIRING SYSTEMS EXPOSED TO SUNLIGHT ON ROOFTOPS

Test Sample Selection

Various test samples were chosen because of their expected use on rooftops exposed to sunlight, and their similarity to other raceway and cable systems that were not tested, but considered to be representative of these other wiring systems for test purposes. For cables, Type MC cable was chosen to represent metal clad and metal sheathed cables and conduits (e.g. Type MC, MI, LFMC, etc.). Sizes 12 AWG, 1/0 AWG, and 500 kcmil were chosen to represent cables of the smaller, medium, and larger sizes. Type SE and TC cable was also chosen in the 1/0 AWG size to represent jacketed cables (e.g. Type SE, TC, MV, UF, etc.) For conduits and tubings, Type RMC and EMT were chosen to represent circular metal raceways (e.g. RMC, IMC, EMT, etc.). To represent the smaller sizes, trade size ½ was chosen for RMC, and trade size ¾ was chosen for EMT. For the medium and larger sizes, trade sizes 1-1/2 and 4 respectively were chosen. Type PVC was chosen to represent nonmetallic conduits and raceways. To represent the smaller sizes, trade size ¾ was chosen, and for the medium and larger sizes, trade sizes 1-1/2 and 4 respectively were chosen. For other metal wiring systems (e.g. metal wireways, gutters, etc.), metal raceway was chosen in the 4x4 inch and 8x8 inch sizes to represent smaller and larger raceways in general.

Table 3 is a summary of the proposed testing to consider a comprehensive research program to determine the effects of direct sunlight when conduit, MC cable, and wiring systems in general are installed on or above a rooftop.

Table 3 – Summary of Test Samples

Raceway/ Cable Type	Conductor Size*	Trade Size	Installed Conductor Size*	Number of Conductors
MC	12			3
MC	1/0			3
MC	500			3
SE	1/0			3
TC	1/0			3
RMC		1/2	12	7
RMC		1-1/2	1/0	4
RMC		4	500	3
PVC		3/4	12	3
PVC		1-1/2	1/0	3
PVC		4	500	3
EMT		3/4	12	3
EMT		1-1/2	1/0	5
EMT		4	500	3
Metal Raceway		4x4 in.	1/0	3
Metal Raceway		8x8 in.	500	3

* - AWG or kcmil (copper), Type THHN/THWN.

Test Considerations

Laboratory Site – The testing was conducted at an outdoor laboratory site located in Las Vegas, Nevada. This area was chosen for its broad range of days with higher solar radiation intensity.



Fig. 1 – Las Vegas, Nevada Outdoor Test Site

Roof - To support Table 310.15(B)(3)(c) from the 2011 NEC, each wiring system was tested directly on the roof, and at distances of 1/2, 3-1/2, and 12 inches above the roof[2]. For wiring systems tested directly on the roof and at 1/2 inch above the roof, the roof was asphalt painted black in color to account for additional heating from solar absorption on the roof. For wiring systems tested at distances greater than 1/2 inch above the roof, the roof surface was asphalt painted white in color to account for additional heating from solar reflection from the roof. Each roof structure was flat, approximately five feet off the ground, and measured 13-1/2 by 10 feet, with R19 fiberglass batt insulation under the roof deck.



Fig. 2 – Samples Mounted Directly on Black Roof



Fig. 3 – Samples Mounted 12 Inches off White Roof

Test Samples – Each test sample was 10 feet long exposed along the horizontal length of the roof surface. A thermocouple was secured to each conductor insulation midway along the length of the sample. The thermocouples were type T, No. 24 AWG, with welded junctions. For the Type MC cable samples, the thermocouple was secured near the conductor. For samples with more than three conductors, a maximum of three thermocouples were used. See Appendix A for a thorough description of each test sample. The ends of each wiring system were closed with surgical cotton to restrict air flow. The wires were not energized during the testing since the object of the testing was to obtain a measurement of the wiring system temperature increase due to the influence of exposure to the sun.

[2] Although the breakpoints in Table 310.15(B)(3)(c) are for distances of above (greater than) ½, 3-1/2, and 12 inches above the roof, the test samples were located at these breakpoint distances to represent a worst-case test condition.



Fig. 4 – Thermocouples Installed on Conductors



Fig. 5 – Cotton Used to Close Ends of Wireways

Data Measurements - Temperatures were measured at 1 minute increments throughout the day, and the maximum of the 1 minute increments for a 5 minute time period was recorded. This resulted in 12 recorded measurements per hour. In addition to the measurement of temperature of the conductor insulation of each test sample, the near-by outdoor air temperature was measured in two aspirated enclosures located approximately 8 feet and 13 feet above grade level in the vicinity of the roofs and test samples. Wind speed was similarly measured in the same vicinity using two anemometers. Solar irradiance was measured using a pyranometer located in the same plane as the roof surface.



Fig. 6 – Aspirated Enclosure for Outdoor Temperature



Fig. 7 – Anemometer for Wind Speed Measurement

Solar irradiance and wind speed was recorded along with the test sample temperatures. Measurements were recorded during the months of June, July and August of 2011. Sufficient data was recorded to enable supportable and statistical inferences regarding expected ambient temperatures for raceway and cable systems exposed to sunlight on rooftops.

Solar Irradiance - Solar irradiance, or radiation from the sun, is measured as power density in Watts per square meter (W/m^2). This solar radiation reaching the earth can vary depending on several factors, including as time-of-day, time-of-year, atmospheric conditions such as clouds, haze, rain, etc., as well as geographical location. The maximum solar radiation reaching the earth's atmosphere can approach 1400 W/m^2, however, 1000 – 1200 W/m^2 is more typical of maximum surface irradiance on a sunny day in many parts of the United States, and can be less during the winter, and much less on cloudy days.

Solar photovoltaic (PV) modules are tested and rated under what is referred to as standard test conditions, or STC for short. These standard test conditions are solar irradiance of 1000 W/m^2 and air temperature of 25 ^oC.[3] In the NEC, PV system components, such as wire size and overcurrent protection, are based on these standard test conditions, with adjustment factors for periods of time where the maximum solar irradiance can exceed 1000 W/m^2.[4]

Figure 8 shows a graph of the solar irradiance at the test site incident to the test roofs on June 22, 2011. The day was full sun, maximum outdoor ambient temperature of 110 ^oF, and near the time of summer solstice. The solar irradiance that day exceeded 1000 W/m^2 for a three-hour period beginning at 11:10 am. The NEC defines in Article 100 a "continuous load" as a load where the maximum current is expected to continue for 3 hours or more.

[3] Underwriters Laboratories Inc., *UL Standard for Safety for Flat-Plate Photovoltaic Modules and Panels*, UL 1703. See Glossary Section 2.17 for definition of Standard Test Conditions.

[4] As an example, see NEC Sec. 690.8 where calculations for maximum circuit current and conductor ampacity involve multipliers of 125%.

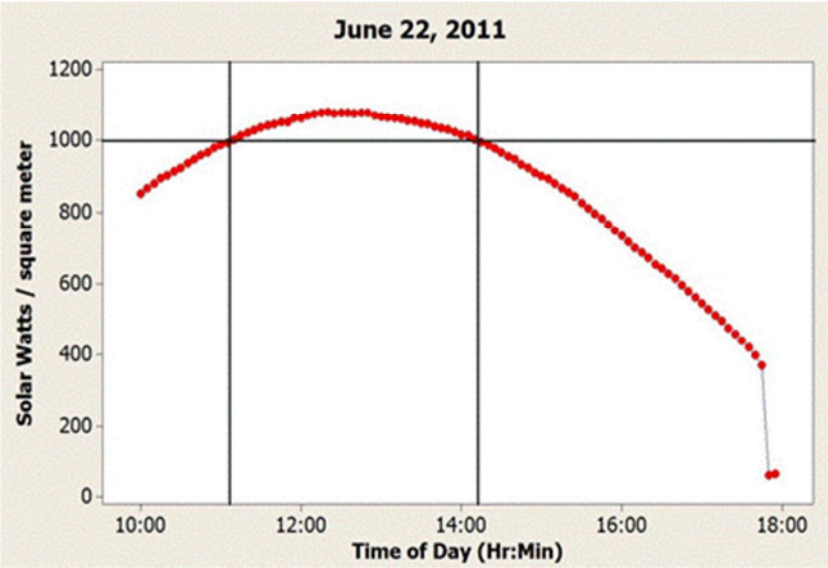


Fig. 8 – Solar Irradiance for June 22, 2011 at Las Vegas Test Site

Test Results

Data measurements were recorded during the months of June, July and August of 2011. This time of the year also produced many days of large amounts of solar radiation for the longest periods of time. During these months there were many days of full sun throughout the day where outside temperature exceeded 100 ^{o}F, and solar irradiance exceeded 1000 W/m^2. The solar irradiance for days of prolonged full sun peaked near solar noon, which occurred at about 12:45 pm in Las Vegas that time of year (daylight savings time). For analysis of results purposes, 10 days were chosen during this time period where that solar irradiance exceeded 1000 W/m^2 for a prolonged period of time. Although wind speed could not be controlled, these days were also chosen where the wind speed was minimized. This resulted in 5 days in late June, and 5 days in early August as shown in Table 4. For each of these 10 days, the temperature data were analyzed for the period of time that day were the solar irradiance was greater than or equal to 1000 W/m^2. Depending upon the day, this resulted in elapsed times of 3 hours and 5 minutes to 2 hours and 15 minutes as shown in the table. This table also includes the average wind speed and maximum outdoor ambient temperature for that period of time. See Appendix C for complete graphs of the daily outdoor ambient temperature, solar irradiance, and wind speed.

Table 4 – 10 Days of Analyzed Data

	Period of Solar Radiation ≥ 1000 W/m^2 (Hours:Minutes)			Avg Wind Speed	Outdoor Ambient
Day (2011)	Beginning	End	Elapsed Time	(MPH)	Deg F
June 21	11:15	14:05	2 hr 50 min	2.8	101
June 22	11:10	14:10	3 hr 00 min	3.1	109
June 23	11:20	14:15	2 hr 55 min	4.4	108
June 25	11:05	14:10	3 hr 05 min	3.1	103
June 26	11:10	14:15	3 hr 05 min	2.7	103
August 4	11:35	14:00	2 hr 25 min	6.0	105
August 5	11:30	14:05	2 hr 35 min	6.4	103
August 6	11:35	13:50	2 hr 15 min	5.7	102
August 8	11:35	14:00	2 hr 25 min	6.3	106
August 9	11:45	14:00	2 hr 15 min	5.5	106

For each test sample, the rise above outdoor ambient temperature for the three thermocouple temperatures were averaged for each five-minute increment to record the temperature rise above outdoor ambient of the test sample for that time measurement increment. An analysis of the variance for the three thermocouple readings of each test sample typically showed a variance of less than 1 ^{o}F, except for the tray cable (TC) samples, where the variance was greater because of the orientation of the three thermocouples around the circumference of the cable. For that reason, the maximum temperature of the three thermocouple readings for the tray cable was used for this test sample because of the importance of recording the hottest temperature being experienced by the cable.

For each of the ten chosen days, the maximum, minimum, 90th, 75th, and 50th percentile temperatures were calculated for each test sample at each elevation for the period of time that day when the solar irradiance was greater than or equal to 1000 W/m^2. For the accumulated ten days, the overall maximum, minimum, and averages of the 90th, 75th and 50th percentile temperatures were then tabulated. The tables below show that complied data.

Table 5

Maximum Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	42.9	39.2	48.0	62.9
	1/2" RMC	34.2	35.1	38.7	66.5
	1-1/2" EMT	34.9	36.1	37.4	51.2
	1-1/2" RMC	48.5	47.0	34.8	55.7
	4" EMT	35.2	38.9	35.3	43.8
	4" RMC	45.7	48.1	40.9	47.5
Circular Raceway - Plastic	3/4" PVC	42.2	46.5	42.3	63.6
	1-1/2" PVC	43.1	47.3	43.9	58.5
	4" PVC	46.3	48.4	43.0	52.3
Square Raceway - Metal	4" DUCT	51.1	54.9	46.1	59.9
	8" DUCT	46.7	46.3	38.7	52.1
Cables	#12 MC	45.4	53.0	47.8	71.4
	#1/0 MC	52.8	55.1	50.7	66.6
	#1/0 SE	39.7	43.0	43.5	58.3
	Tray 1/0 SE	36.6	39.4	40.1	47.8
	Tray 1/0 TC	59.6	65.0	53.3	60.3
	#500 MC	55.1	58.3	51.8	62.2
	NEC Adder	25	30	40	60

Table 6

Minimum Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	26.3	22.1	28.4	42.0
	1/2" RMC	21.2	22.3	23.2	39.8
	1-1/2" EMT	22.8	25.6	24.7	31.7
	1-1/2" RMC	30.9	31.3	20.1	31.0
	4" EMT	23.2	25.7	21.7	25.9
	4" RMC	29.3	30.3	23.4	25.7
Circular Raceway - Plastic	1/2" RMC	21.2	22.3	23.2	39.8
	1-1/2" PVC	29.9	33.7	27.0	35.7
	4" PVC	28.2	28.8	23.0	26.1
Square Raceway - Metal	4" DUCT	33.3	37.5	27.6	36.3
	8" DUCT	31.0	31.0	22.0	23.7
Cables	#12 MC	31.1	34.6	27.9	41.5
	#1/0 MC	36.9	39.5	33.8	42.7
	#1/0 SE	27.6	30.9	29.0	37.2
	Tray 1/0 SE	24.8	28.0	26.5	31.3
	Tray 1/0 TC	40.3	47.9	36.9	41.5
	#500 MC	36.3	37.9	31.2	35.3
	NEC Adder	25	30	40	60

Table 7

90th Percentile Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	36.3	30.9	40.9	55.8
	1/2" RMC	29.2	29.9	33.0	56.0
	1-1/2" EMT	29.4	31.2	32.1	43.3
	1-1/2" RMC	40.0	39.5	28.3	45.0
	4" EMT	29.7	33.2	29.9	36.5
	4" RMC	38.7	40.7	33.9	39.9
Circular Raceway - Plastic	3/4" PVC	37.0	40.8	35.5	53.3
	1-1/2" PVC	37.4	41.3	36.9	49.4
	4" PVC	38.5	40.2	35.3	42.9
Square Raceway - Metal	4" DUCT	43.5	47.2	38.6	50.3
	8" DUCT	39.7	39.9	31.8	43.8
Cables	#12 MC	40.3	45.2	40.2	60.1
	#1/0 MC	46.3	48.5	43.7	56.8
	#1/0 SE	34.9	38.0	37.8	49.8
	Tray 1/0 SE	31.5	34.6	34.4	41.1
	Tray 1/0 TC	51.0	59.1	46.9	53.0
	#500 MC	47.6	50.6	43.9	52.7
	NEC Adder	25	30	40	60

Table 8

75th Percentile Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	35.1	29.9	39.7	54.5
	1/2" RMC	28.3	29.0	32.0	54.7
	1-1/2" EMT	28.9	30.7	31.5	42.6
	1-1/2" RMC	39.4	38.8	27.7	44.3
	4" EMT	29.1	32.5	29.3	35.8
	4" RMC	38.0	40.1	33.1	39.2
Circular Raceway - Plastic	3/4" PVC	36.2	39.9	34.5	52.1
	1-1/2" PVC	36.7	40.6	36.2	48.7
	4" PVC	37.9	39.6	34.6	42.2
Square Raceway - Metal	4" DUCT	42.7	46.5	37.8	49.6
	8" DUCT	39.0	39.2	31.0	43.1
Cables	#12 MC	39.2	44.2	39.1	58.9
	#1/0 MC	45.5	47.8	43.0	56.1
	#1/0 SE	34.2	37.3	37.2	49.1
	Tray 1/0 SE	30.9	34.0	33.7	40.4
	Tray 1/0 TC	50.0	58.3	46.3	52.3
	#500 MC	46.9	49.9	43.1	52.0
	NEC Adder	25	30	40	60

Table 9

50th Percentile Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	33.6	28.0	37.6	52.1
	1/2" RMC	27.1	27.9	30.6	52.3
	1-1/2" EMT	27.9	29.7	30.6	41.6
	1-1/2" RMC	38.2	37.7	26.8	43.1
	4" EMT	28.1	31.5	28.3	34.6
	4" RMC	36.6	38.6	31.7	37.1
Circular Raceway - Plastic	3/4" PVC	34.9	38.4	33.1	50.1
	1-1/2" PVC	35.6	39.6	35.2	47.4
	4" PVC	36.5	38.1	33.1	40.0
Square Raceway - Metal	4" DUCT	41.1	44.9	36.4	48.2
	8" DUCT	37.9	38.1	30.0	41.3
Cables	#12 MC	37.9	42.7	37.3	56.2
	#1/0 MC	44.2	46.6	41.8	54.8
	#1/0 SE	33.1	36.3	36.0	47.9
	Tray 1/0 SE	29.9	32.9	32.7	39.3
	Tray 1/0 TC	48.5	56.8	44.7	50.7
	#500 MC	45.5	48.2	41.7	50.0
	NEC Adder	25	30	40	60

Data Analysis

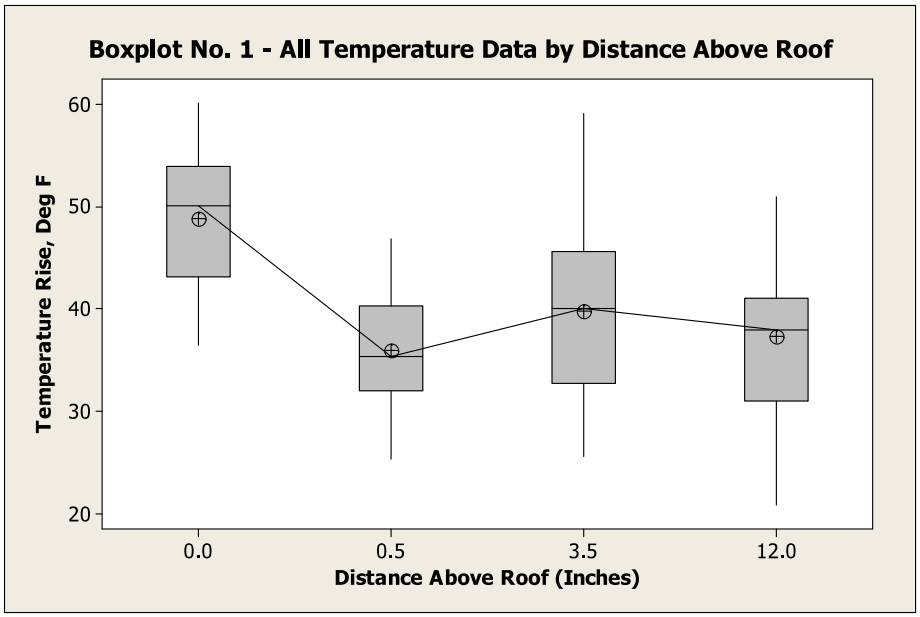
To analyze the differences between wiring systems at different distances from the roof, a compilation of all of the wiring system 90th percentile temperature rises (Table 7)[5] for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was made for each of the four elevations. This analysis is shown in Boxplot[6] No.1. Note that for the wiring systems at distances 0.0 and 0.5 inches above the roof, the roof color was black, and for distances 3.5 and 12.0 inches above the roof, the roof color was white. Previous research[7] had shown that at the 0.5 inch distance, there was no significant difference between the black and white roof colors affecting the temperature of the wiring systems. For that reason black was chosen for the color of the roof at that distance. However, this previous research was only conducted with smaller size raceways and cable. It is possible that larger size raceways and cables could have absorbed more of the reflected solar radiation off the roof had the roof been white. This could explain why the mean temperature rise for the wirings systems at 0.5 inches above the roof were less than those at 3.5 and 12.0 inches above the roof.

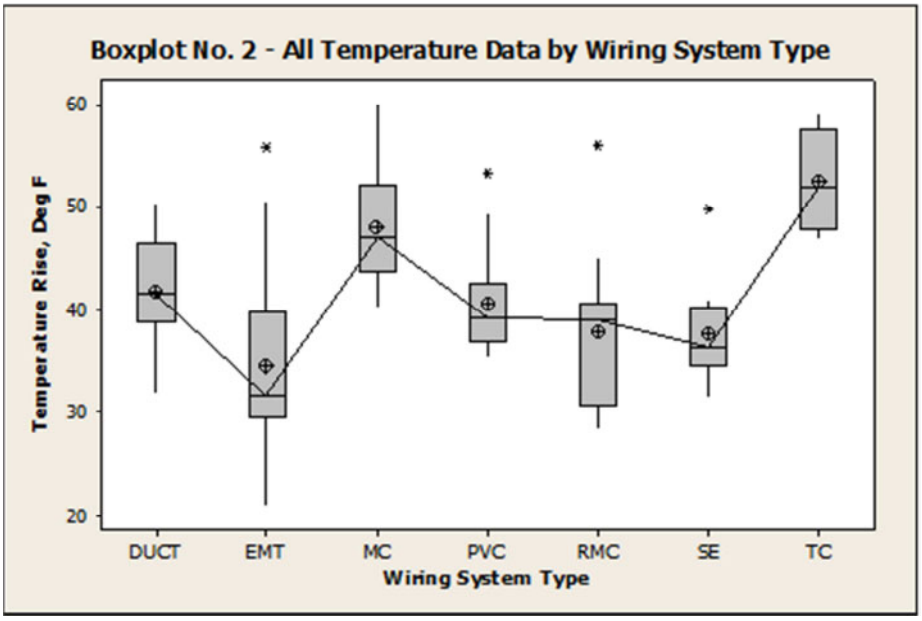
To analyze the differences between the different individual wiring systems, a compilation of all of the different wiring system 90th percentile temperature rises for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was made. This analysis is shown in Boxplot No.2. Note that the MC and TC cables were black in color, and the SE cable was light gray in color.

[5] The 90th percentile values were used to eliminate the maximum temperatures that were only being experienced for a very short period of time when the solar irradiance peaked for that day. Note however, there was typically only a few degrees F or less difference between the 90th and 75th percentile values. See Tables 7 and 8.

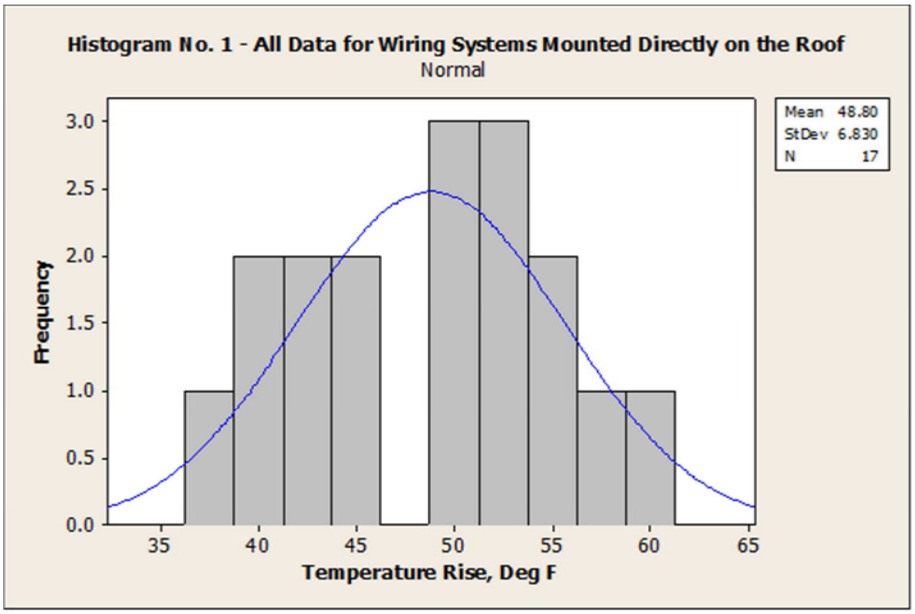
[6] See Appendix D for a description of boxplots.

[7] "*Effect of Rooftop Exposure on Cable Temperatures*," November 2008, by Travis C. Lindsey. Available for review at the National Fire Protection Association (NFPA) Headquarters, Quincy, MA. Reference Report on Proposals – June 2010, Proposal 6-66, Log #2751, NEC-P06. See Fig. 3, Temperature Rise as Function of Roof Color.

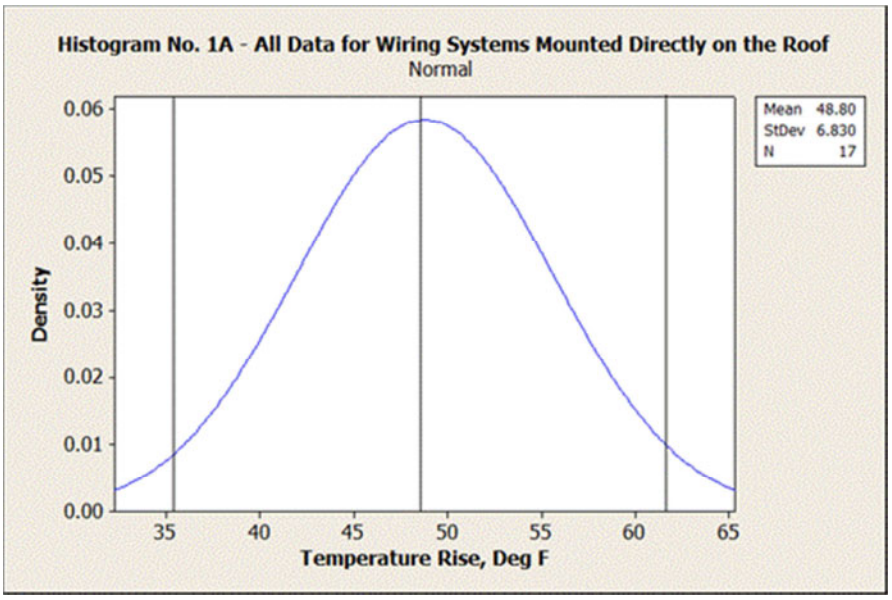

Boxplot No. 1 - All Temperature Data by Distance Above Roof
Temperature Rise, Deg F
60
50
40
30
20
0.0
0.5
3.5
12.0
Distance Above Roof (Inches)


Boxplot No. 2 - All Temperature Data by Wiring System Type
Temperature Rise, Deg F
60
50
40
30
20
DUCT
EMT
MC
PVC
RMC
SE
TC
Wiring System Type

Histogram No. 1 shows the 90th percentile temperature rise data for wiring systems directly on the roof for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2.



This analysis shows that for all of the 17 test samples of wiring systems mounted directly on the roof, the mean (average) temperature rise was 48.8 °F with a standard deviation of 6.83 °F. Confidence intervals (C.I) are often used as a statistical estimate to bracket data parameters with a known degree of certainty. A 95% C.I. is suggested as an appropriate safety factor to represent the true population of the data from the sampled population (tested samples). A 95% C.I. is calculated (two-sided) as the mean plus/minus 1.96 times the standard deviation. For this case, maximum temperature rise for all wiring systems mounted directly on the roof with a 95% C.I. would be 62.2 °F. Histogram 1A shows a representation of this with vertical lines at the mean and 95% C.I. points.



An observation from Boxplot No. 1 appears to show that there is little difference between mean temperature rises for test samples of wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof. Neglecting any heat convection or reradiation from the surface of the roof, this would be expected since the distance from the sun to the surface of the earth is large as compared to the distance between the three wiring systems. To verify this, an analysis of variance (ANOVA) was conducted with this data for the three distances from the roof. This analysis, shown in Fig. 9, demonstrates there is little difference between the mean temperature rises for all test data from each of the three wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof. This is exemplified by the low value for R_{sq}, which shows that varying the distance from the roof between 0.5 and 12.0 inches does not have any significant effect on the temperature rise within the raceway or cable. It is expected that distances greater than 12.0 inches will also show this minimal difference.

One-way ANOVA: 90th Percentile Data versus Distance from Roof (0.5, 3.5, and 12.0 inches)

Source	DF	SS	MS	F	P
Distance	2	137.6	68.8	1.62	0.209
Error	48	2043.1	42.6		
Total	50	2180.8			

S = 6.6 R-Sq = 6.31% R-Sq(adj) = 2.41%

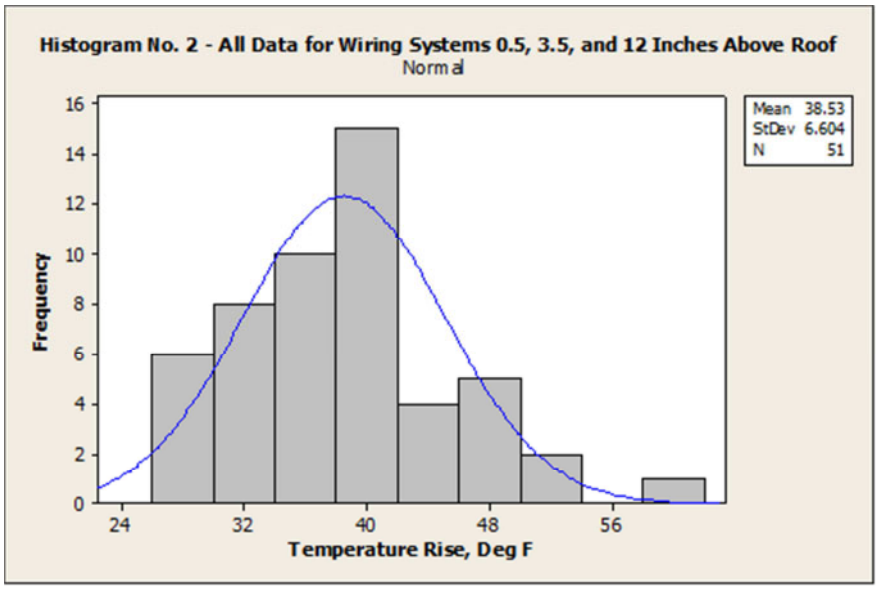
DF = Degrees of Freedom
SS = Sum of squares
MS = Mean square
S = Standard deviation
F = F ratio
P = p-value
R = Correlation coefficient

Individual 95% C.I.s for Mean Based on Pooled Standard Deviation of 6.6

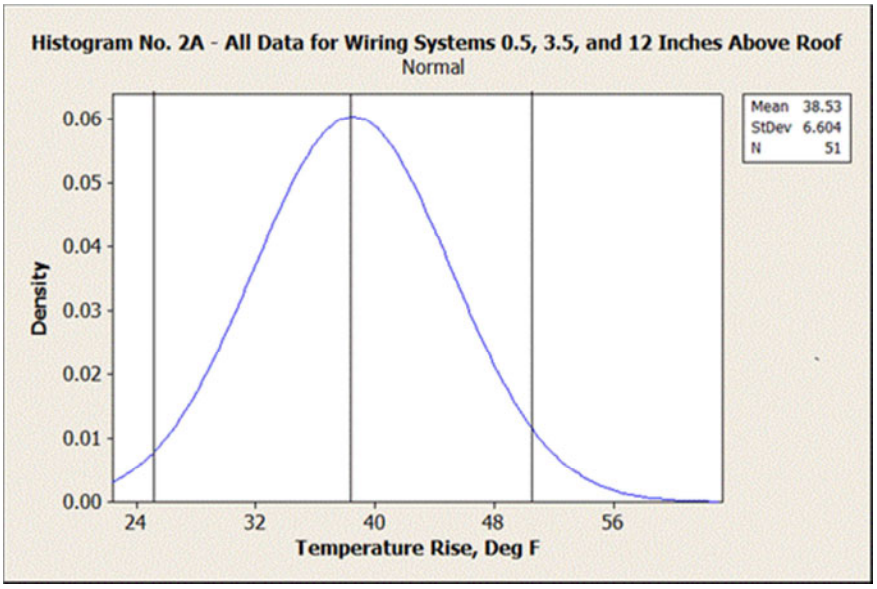
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Level   N    Mean  StDev  --------+---------+---------+---------+-
 0.5   17  36.640  5.186  (---------*----------)
 3.5   17  40.644  7.769               (---------*----------)
12.0   17  38.297  6.359       (----------*---------)
                          --------+---------+---------+---------+-
                               36.0      39.0      42.0      45.0
```

Fig. 9 – Analysis of Variance for Wiring Systems Mounted Off Roof

Histogram No. 2 shows the 90th percentile temperature rise data for all wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2.



This analysis shows that for all of the 51 test samples of wiring systems mounted off the roof (0.5, 3.5, and 12.0 inches), the mean temperature rise was 38.5 °F with a standard deviation of 6.60 °F. The maximum temperature rise for all wiring systems mounted off on the roof with a 95% C.I. would be 51.4 °F. Histogram 2A shows a representation of this with vertical lines at the mean and 95% C.I. points.



SUMMARY

1. Of the 17 different wiring systems tested, nine are currently addressed by the 2011 NEC Sec. 310.15(B)(3)(c) requirement for circular raceways exposed to sunlight on rooftops, *e.g.*, EMT, RMC, and PVC, and eight are not, *e.g.*, square raceway and cables. Using the maximum temperature rises from Table 5:
    a. All of the wiring systems mounted 12 inches from the roof and 3-1/2 inches from the roof exceeded the NEC Table 310.(B)(3)(c) temperature adders of 25 ^{o}F and 30 ^{o}F respectively. For wiring systems mounted 12 inches from the roof, this ranged from 34.2 to 59.6 ^{o}F, and for wiring systems 3-1/2 inches from the roof this ranged from 35.1 to 65.0 ^{o}F.
    b. For wiring systems mounted ½ inch off the roof, all of the cables, and the 4 inch square metal duct exceeded the 40 ^{o}F NEC temperature adder. Five of the nine circular raceways also exceeded this 40 ^{o}F adder. The range in temperature rises for wiring systems mounted ½ inch off the roof was 34.8 to 53.3 ^{o}F.
    c. For wiring systems mounted on the roof, four of the cables exceeded the 60 ^{o}F temperature adder, and three of the circular raceways also exceeded this 60 ^{o}F adder. The range in temperature rises for wiring systems mounted on the roof was 43.8 to 71.4 ^{o}F.

2. In general, the smaller size wiring systems reached a hotter temperature than wiring systems of the same type but larger. This was especially true of the metallic wiring systems, and when the wiring systems were mounted directly on the roof. This was expected because the larger wiring systems had a larger ratio of surface area to mass, and thus took longer to heat up and cool down. This greater mass could also absorb the radiated heat from the sun (and the conducted heat from the roof) over a greater volume. See Tables 5 – 9.

3. The 1/0 SE cable operated much cooler than the similar sized 1/0 MC and 1/0 TC cables. This was expected due to the black outer jacked of the 1/0 MC and 1/0 TC cables having greater absorption properties, *e.g.*, higher emissivity, than the lighter colored SE cable. See Boxplot No. 2.

4. Wiring systems mounted 3-1/2 inches off the white roof usually operated hotter than similar wiring systems mounted ½ inch off the black roof. This was likely because of the solar reflection off the white roof producing additional solar power that could be absorbed by the underside of the wiring system 3-1/3 inches from the roof. These results may have been different had the wiring systems mounted ½ inch off the roof been tested with a white roof. However, wiring systems mounted directly on the roof most always operated significantly hotter than wiring systems of the same type mounted off the roof. See Boxplot No. 1.

5. For all wiring systems mounted directly on the roof, the 90th percentile mean temperature rise above outdoor ambient for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was 48.8 ^oF with a standard deviation 6.8. For this case, maximum temperature rise above outdoor ambient for all wiring systems mounted directly on the roof with a 95% confidence interval (C.I.) would be 62.2 ^oF.

6. A statistical analysis of variance of the data for temperature rise above outdoor ambient showed that all test data from wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof were not affected significantly by distance. Therefore, distances greater than 0.5 inches above the roof can be considered far from the roof and roof distance does not need to be a consideration in calculating temperature rise. For all wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof, the 90th percentile mean temperature rise above outdoor ambient for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was 38.5 ^oF with a standard deviation 6.6. For this case, maximum temperature rise above outdoor ambient for all wiring systems mounted off on the roof with a 95% confidence interval (C.I.) would statistically be 51.4 ^oF.

Report by:

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APPENDIX A

Test Samples

1. Metal-Clad Cable, Type MC, No. 12 AWG/3 with No. 12 AWG ground. Aluminum interlocked armor with black PVC jacket. Copper THHN/THWN conductors.

2. Rigid Metal Conduit, Type RMC, Trade Size ½. Metallic silver in color. Seven No. 12 AWG copper conductors, Type THHN/THWN installed.

3. Rigid Polyvinyl Chloride Conduit, Type PVC, Trade ¾. Natural gray in color. Three No. 12 AWG copper conductors, Type THHN/THWN installed.



Fig. A1 – No. 12 MC (1), ½ RMC (2), ¾ PVC (3)

4. Electrical Metallic Tubing, Type EMT, Trade Size ¾. Metallic silver in color. Three No. 12 AWG copper conductors, Type THHN/THWN installed.

5. Metal-Clad Cable, Type MC, No. 1/0 AWG/3 with No. 6 AWG ground. Aluminum interlocked armor with black PVC jacket. Copper THHN/THWN conductors.

6. Service-Entrance Cable, Type SE, No. 1/0 AWG/3 with No. 2 AWG ground. Sunlight resistant with light gray jacket. Copper THHN/THWN conductors.

7. Rigid Metal Conduit, Type RMC, Trade Size 1-½. Metallic silver in color. Four No. 1/0 AWG copper conductors, Type THHN/THWN installed.

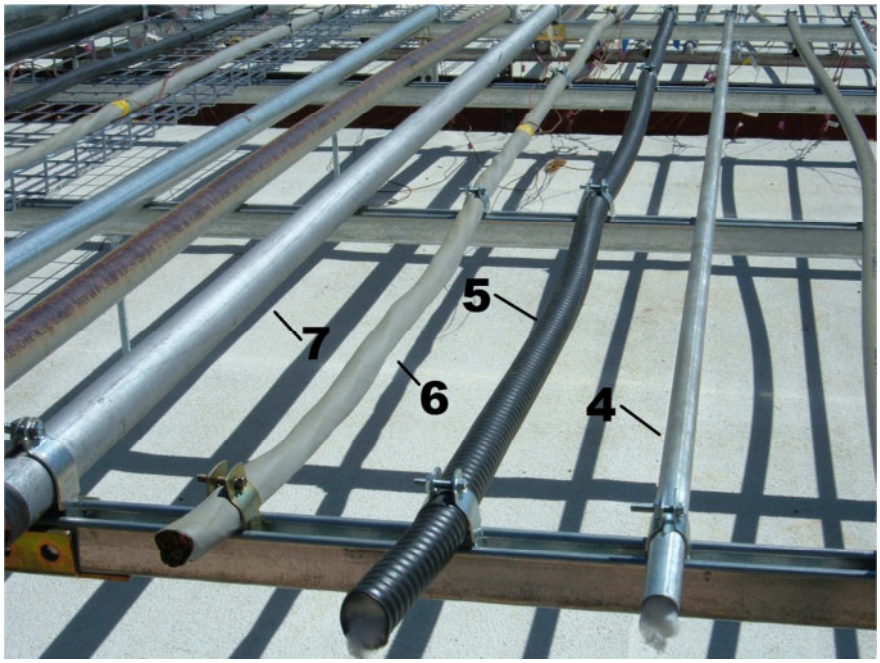


Fig. A2 – ¾ EMT (4), No. 1/0 MC (5), No. 1/0 SE (6), 1-1/2 RMC (7)

8. Rigid Polyvinyl Chloride Conduit, Type PVC, Trade1-1/2. Natural gray in color. Three No. 1/0 AWG copper conductors, Type THHN/THWN installed.

9. Electrical Metallic Tubing, Type EMT, Trade Size 1-1/2. Metallic silver in color. Five No. 1/0 AWG copper conductors, Type THHN/THWN installed.



Fig. A3 – 1-1/2 PVC (8), 1-1/2 EMT (9)

10. Service-Entrance Cable, Type SE, No. 1/0 AWG/3 with No. 2 AWG ground. Sunlight resistant with light gray jacket. Copper THHN/THWN conductors. Installed in a cable tray, basket type.

11. Power and Control Tray Cable, Type TC, No. 1/0 AWG/3 with No. 6 AWG bare ground. Sunlight resistant with black jacket. Copper THHN/THWN conductors. Installed in a cable tray, basket type.



Fig. A4 – No. 1/0 SE (10), No. 1/0 TC (11), Installed in Cable Tray

12. Metal-Clad Cable, Type MC, No. 500 kcmil/3 with No. 2 AWG ground. Aluminum interlocked armor with black PVC jacket. Copper THHN/THWN conductors.

13. Rigid Metal Conduit, Type RMC, Trade Size 4. Metallic silver in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.



Fig. A5 – No. 500 MC (12), 4 RMC (13)

14. Rigid Polyvinyl Chloride Conduit, Type PVC, 4. Natural gray in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.

15. Electrical Metallic Tubing, Type EMT, Trade Size 4. Metallic silver in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.



Fig. A6 – 4 PVC (14), 4 EMT (15)

16. Metal Wireway, 4 in. by 4 in., 16 gauge steel. Gray in color. Three No. 1/0 AWG copper conductors, Type THHN/THWN installed.

17. Metal Wireway, 8 in. by 8 in., 14 gauge steel. Gray in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.

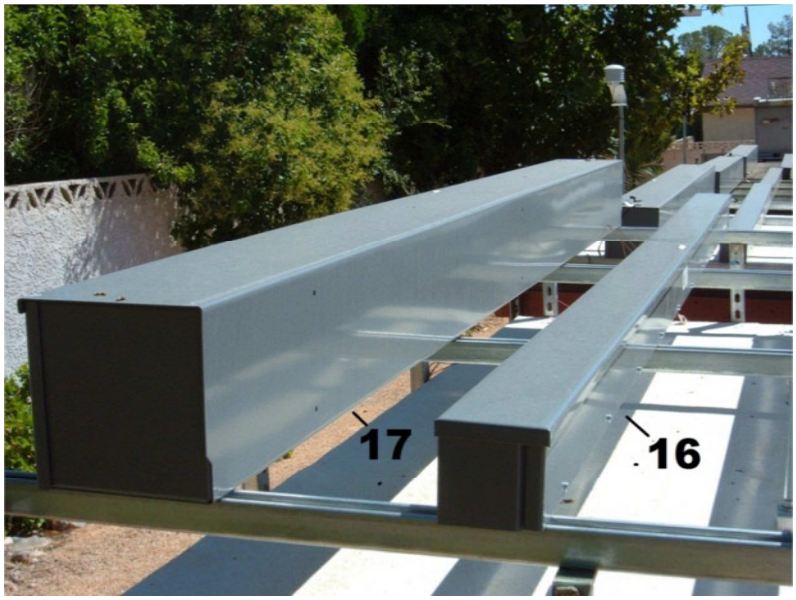


Fig. A7 – 4 In. Duct (16), 8 In. Duct (17)

APPENDIX B

Test Instrumentation

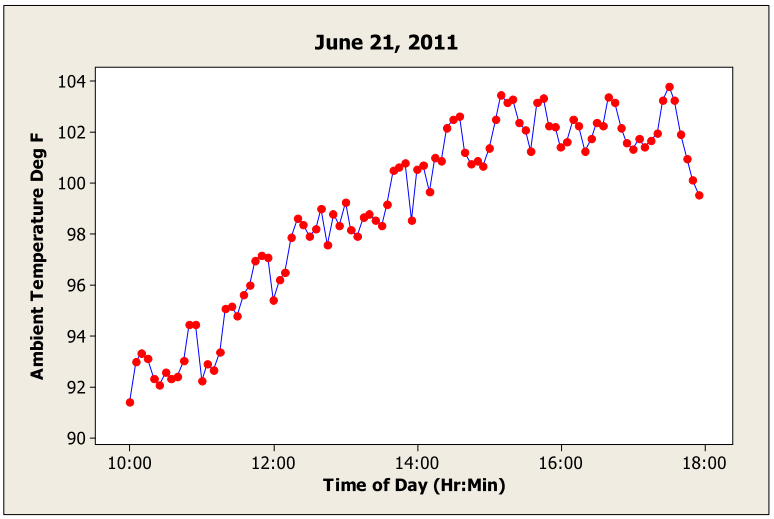
Pyranometer – Campbell Scientific, CS300 apogee silicon pyranometer.

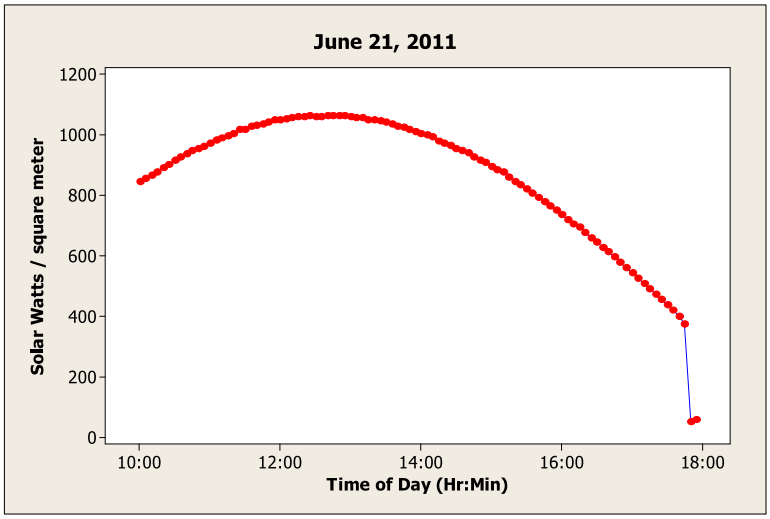
Anemometer - Campbell Scientific, 03101 three-cup anemometer.

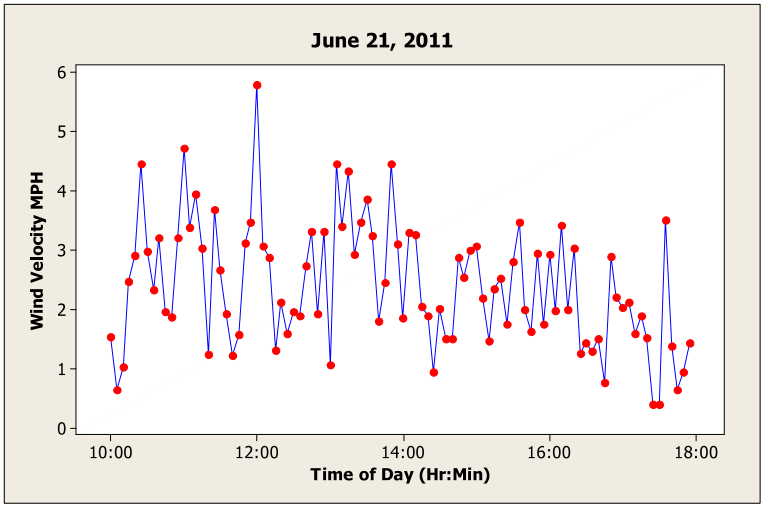
Data Acquisition System - Campbell Scientific, CR5000 Measurement and Control System. Serial No. 1315. Date of last calibration, April 15, 2011, by Campbell Scientific (A2LA accredited).

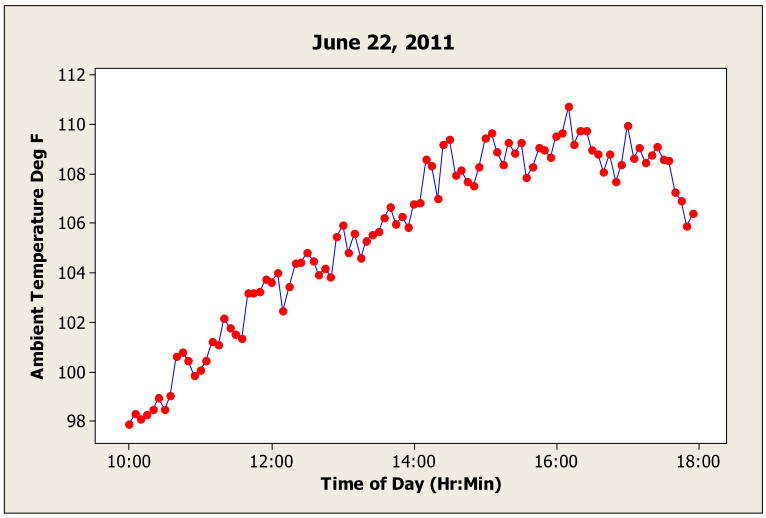
APPENDIX C

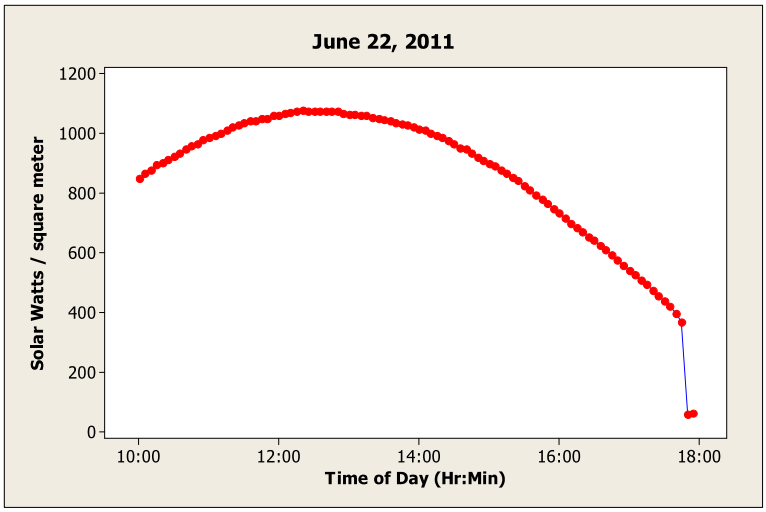
Graphs of Daily Outdoor Ambient Temperature, Solar Irradiance, and Wind Speed

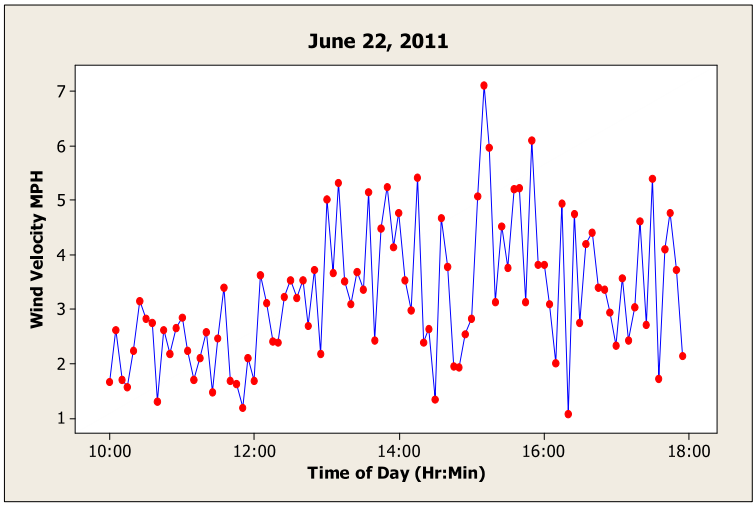

June 21, 2011
Ambient Temperature Deg F
104
102
100
98
96
94
92
90
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

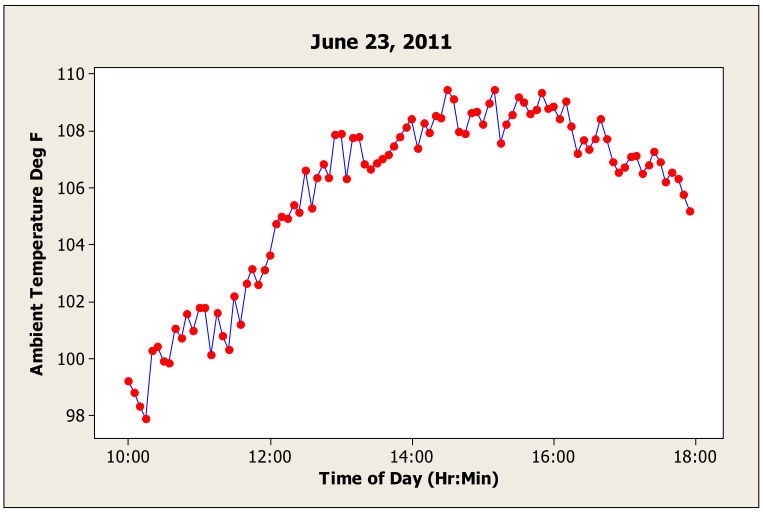

June 21, 2011
Solar Watts / square meter
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800
600
400
200
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

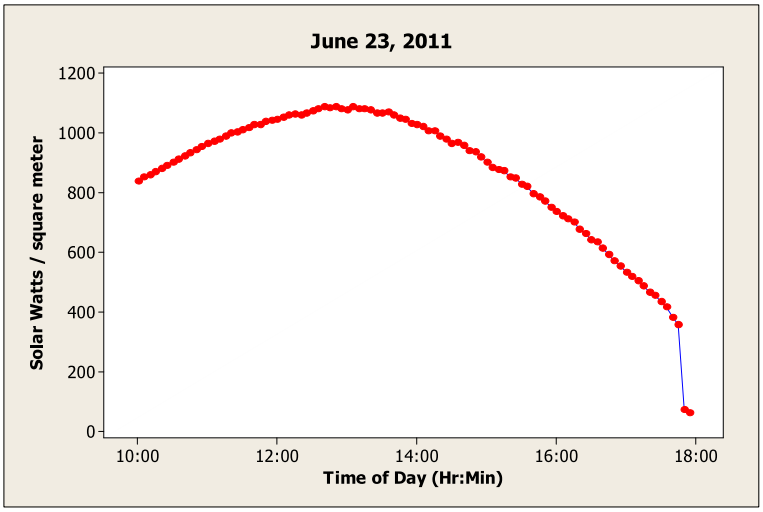

June 21, 2011
Wind Velocity MPH
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4
3
2
1
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

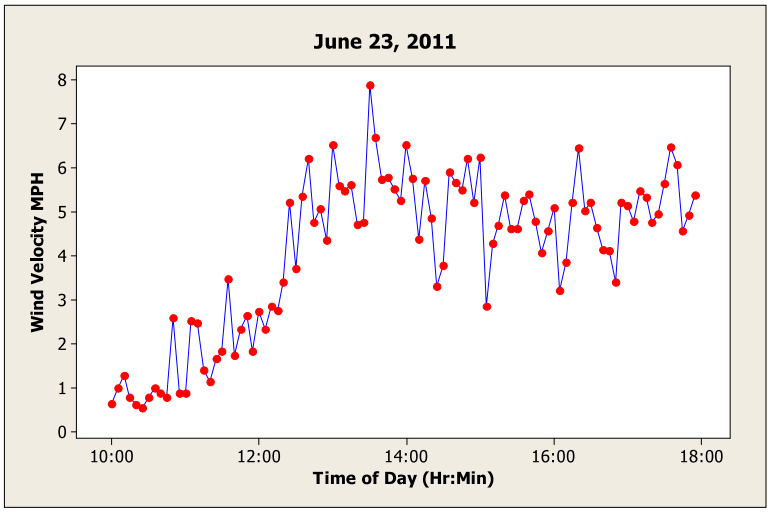

June 22, 2011
Ambient Temperature Deg F
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102
100
98
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

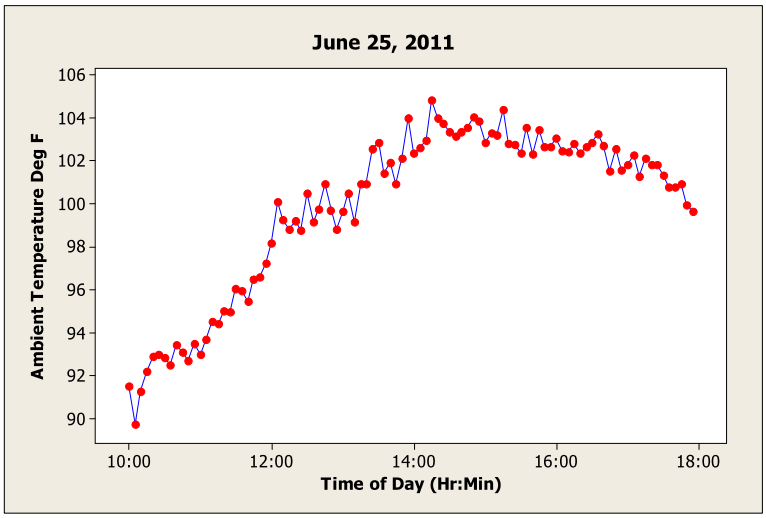

June 22, 2011
Solar Watts / square meter
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800
600
400
200
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

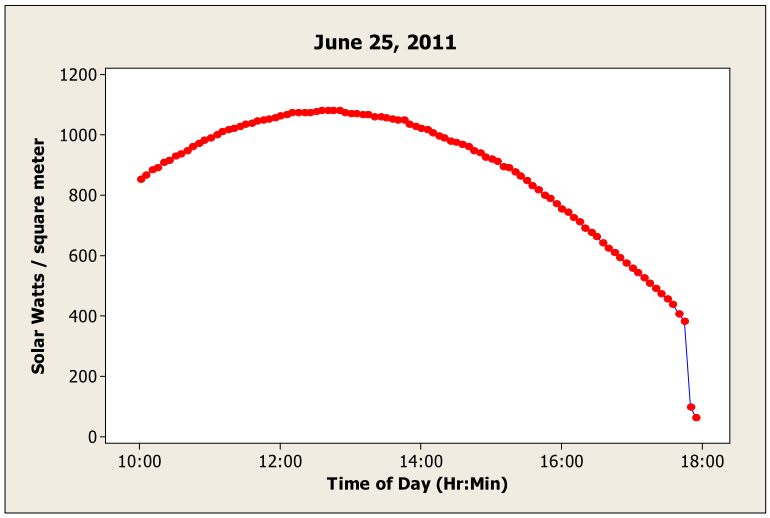

June 22, 2011
Wind Velocity MPH
7
6
5
4
3
2
1
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

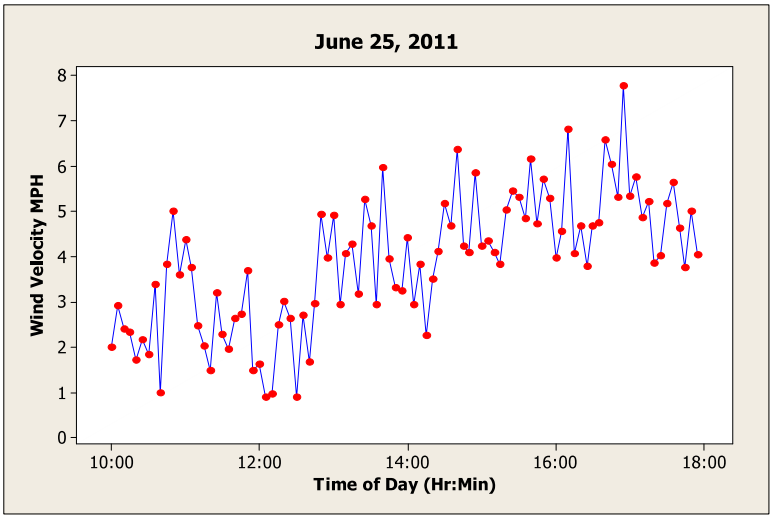

June 23, 2011
Ambient Temperature Deg F
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108
106
104
102
100
98
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

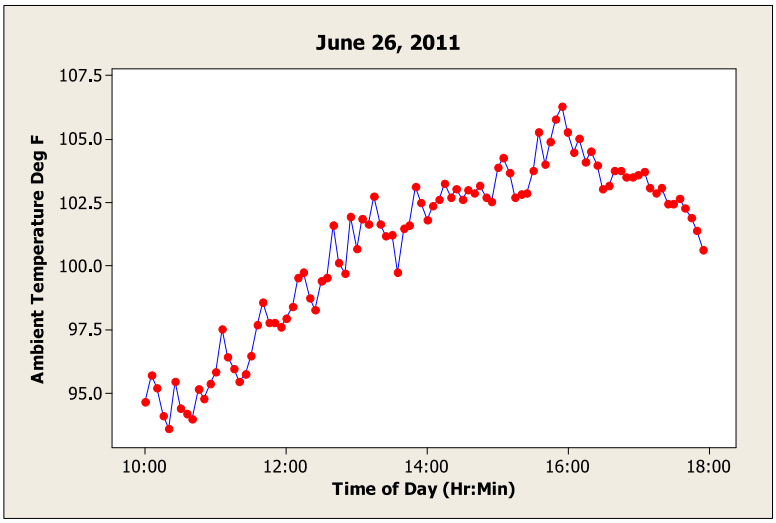

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Solar Watts / square meter
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800
600
400
200
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14:00
16:00
18:00
Time of Day (Hr:Min)

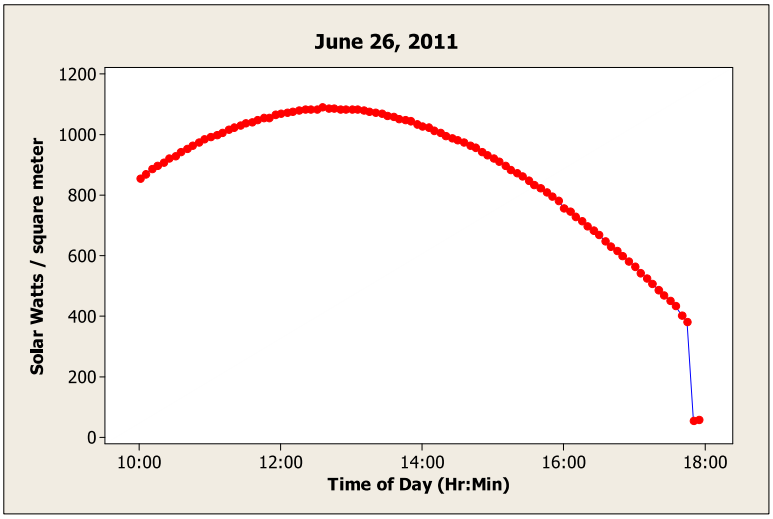

June 23, 2011
Wind Velocity MPH
8
7
6
5
4
3
2
1
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

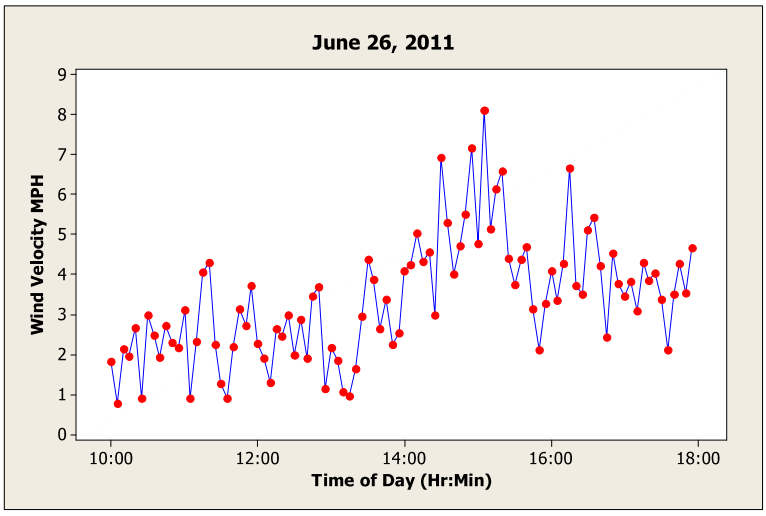

June 25, 2011
Ambient Temperature Deg F
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102
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98
96
94
92
90
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14:00
16:00
18:00
Time of Day (Hr:Min)

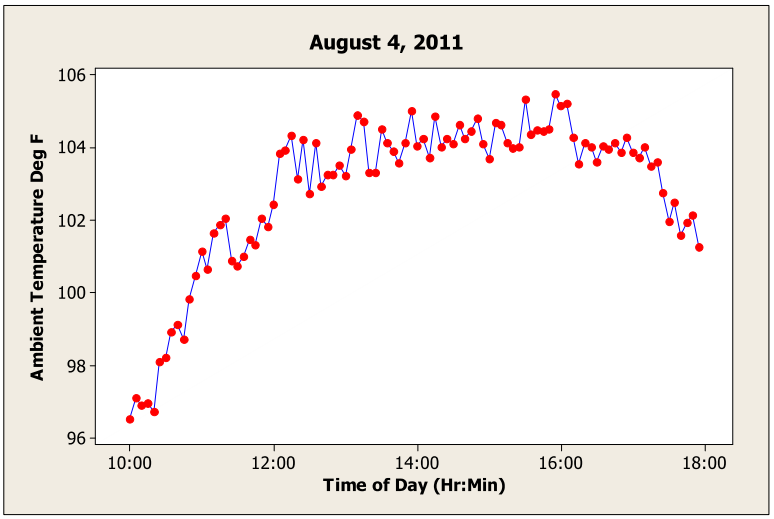

June 25, 2011
Solar Watts / square meter
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800
600
400
200
0
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12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

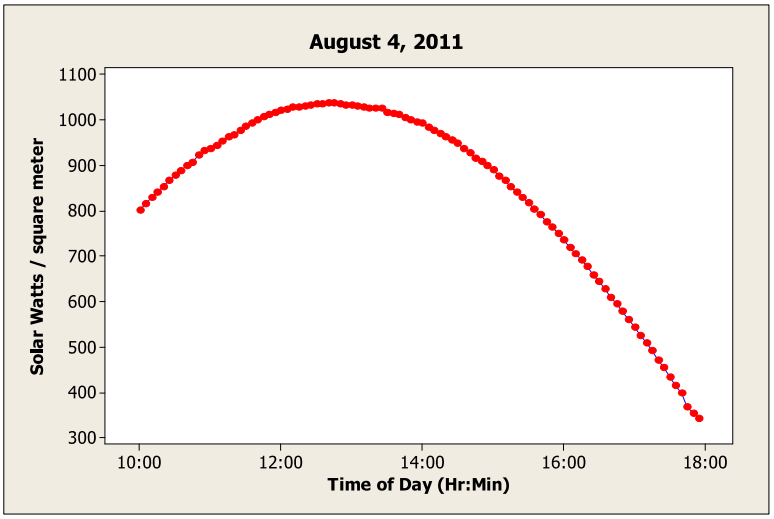

June 25, 2011
Wind Velocity MPH
8
7
6
5
4
3
2
1
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

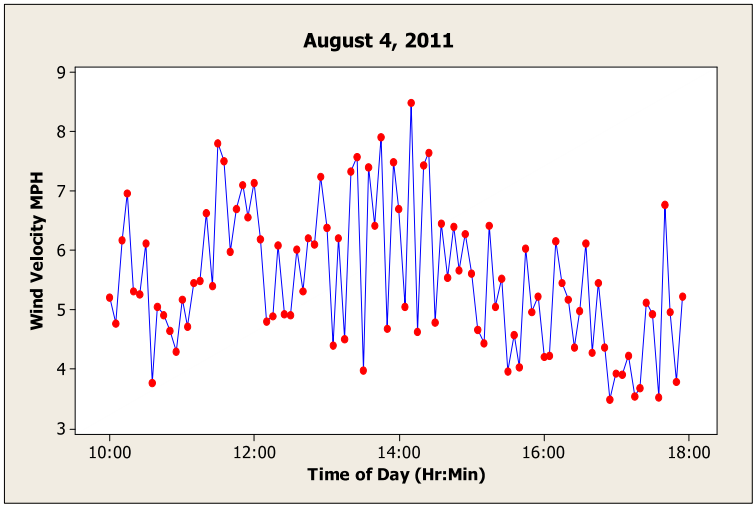

June 26, 2011
Ambient Temperature Deg F
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102.5
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97.5
95.0
10:00
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14:00
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18:00
Time of Day (Hr:Min)

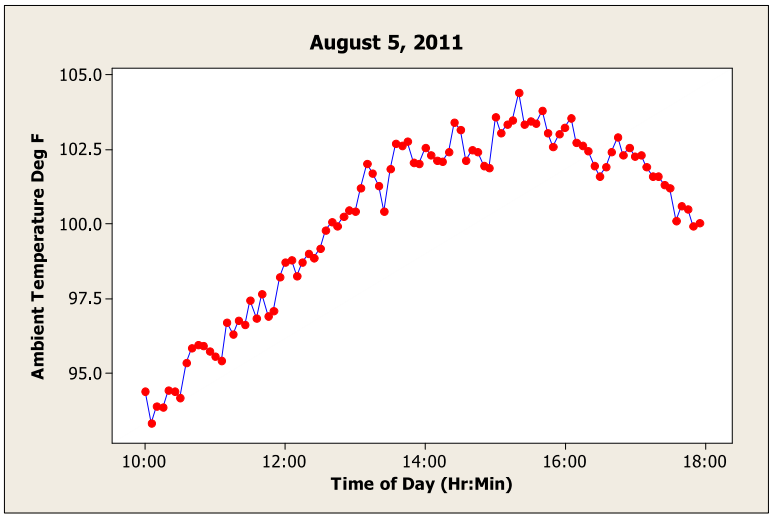

June 26, 2011
Solar Watts / square meter
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16:00
18:00
Time of Day (Hr:Min)

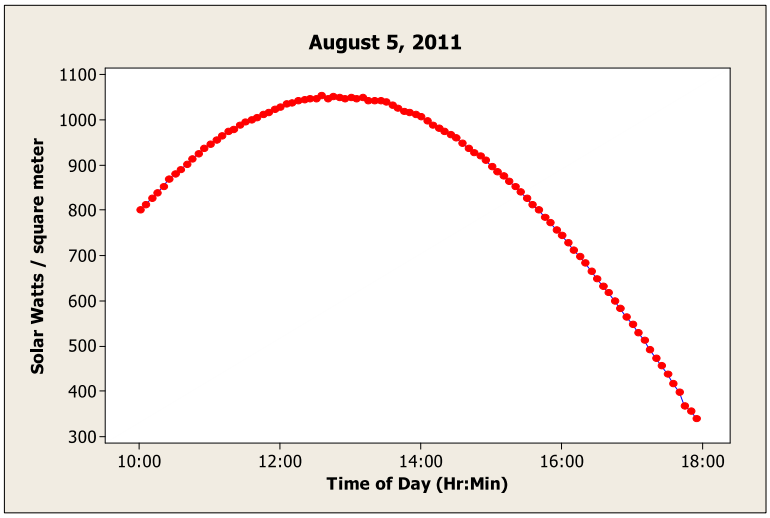

June 26, 2011
Wind Velocity MPH
9
8
7
6
5
4
3
2
1
0
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16:00
18:00
Time of Day (Hr:Min)

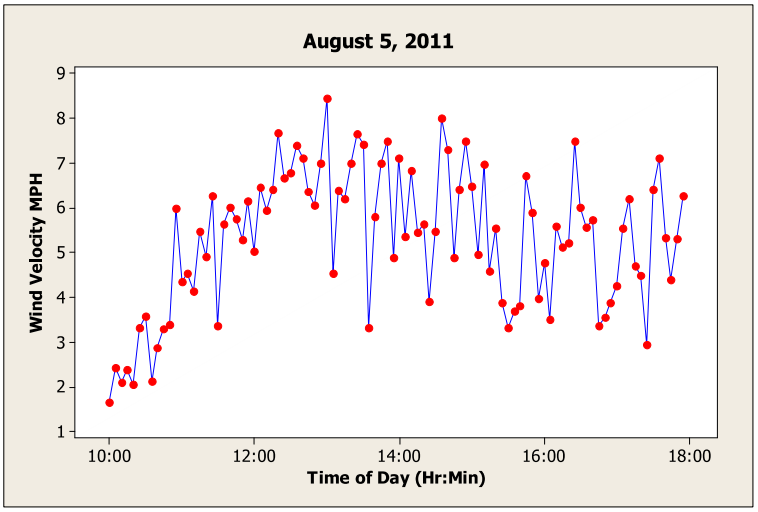

August 4, 2011
Ambient Temperature Deg F
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102
100
98
96
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

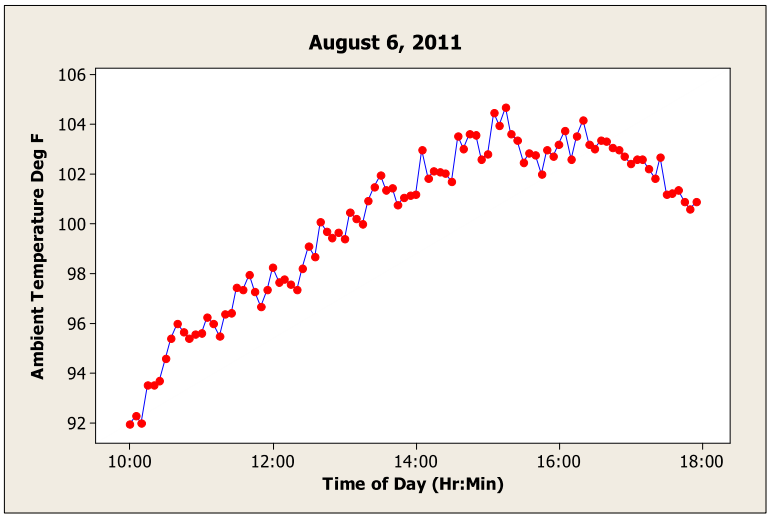

August 4, 2011
Solar Watts / square meter
1100
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900
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700
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500
400
300
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

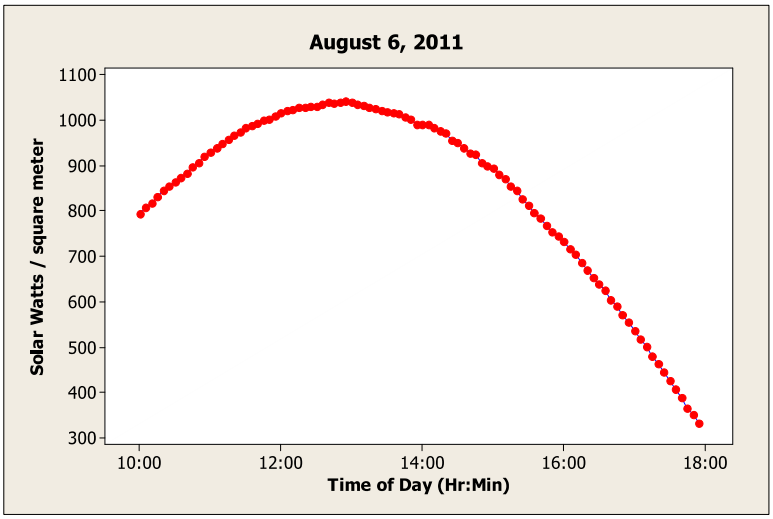

August 4, 2011
Wind Velocity MPH
9
8
7
6
5
4
3
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

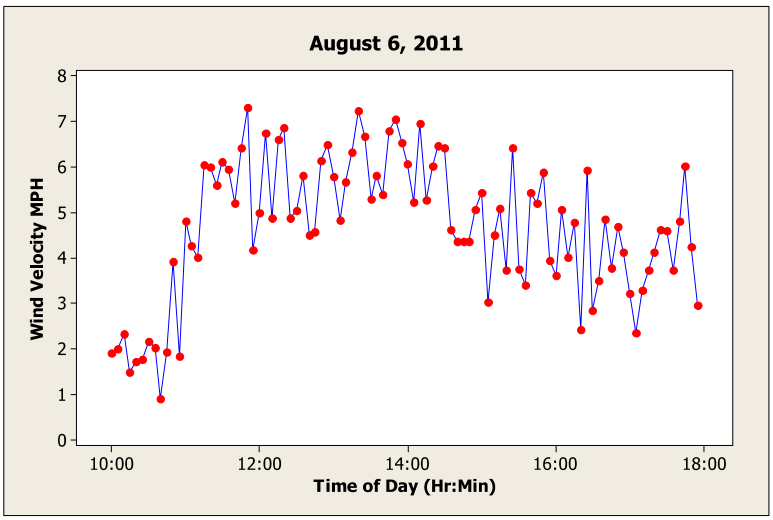

August 5, 2011
Ambient Temperature Deg F
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97.5
95.0
10:00
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14:00
16:00
18:00
Time of Day (Hr:Min)

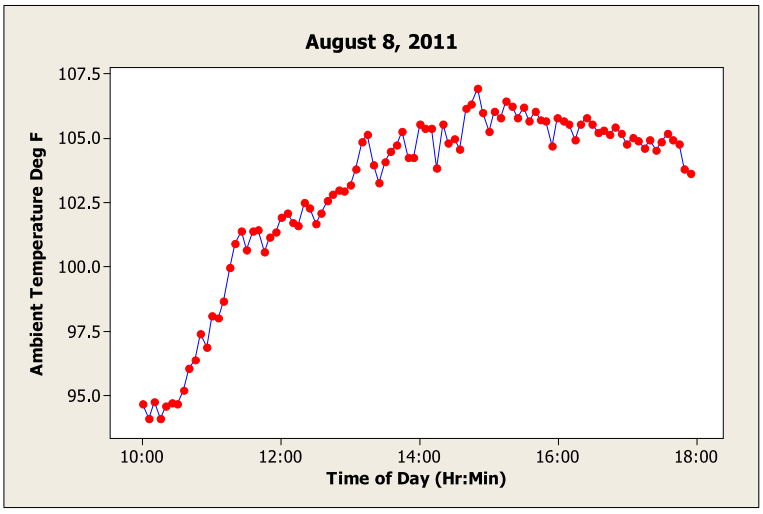

August 5, 2011
Solar Watts / square meter
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500
400
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10:00
12:00
14:00
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18:00
Time of Day (Hr:Min)

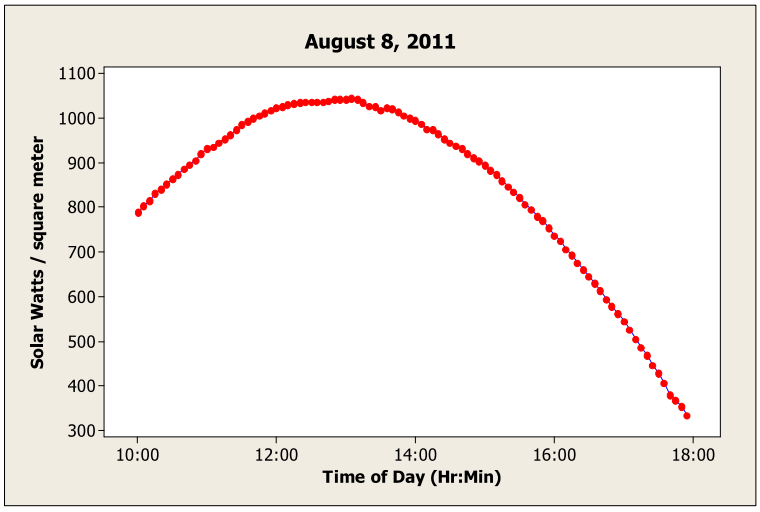

August 5, 2011
Wind Velocity MPH
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8
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5
4
3
2
1
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

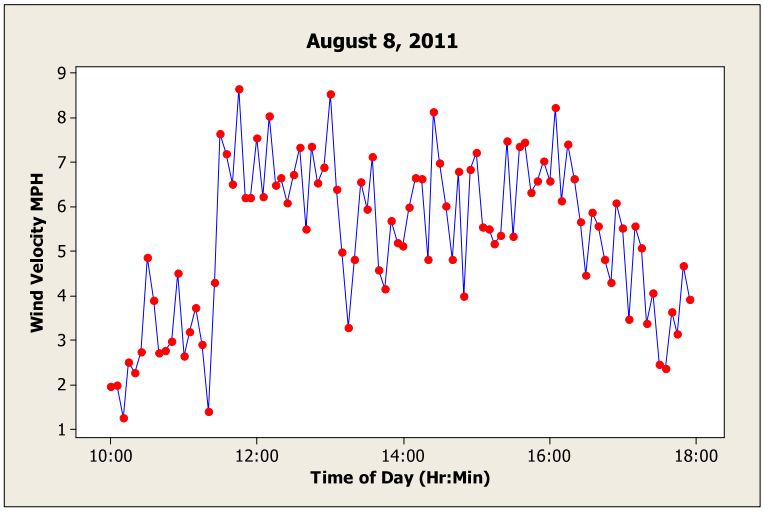

August 6, 2011
Ambient Temperature Deg F
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98
96
94
92
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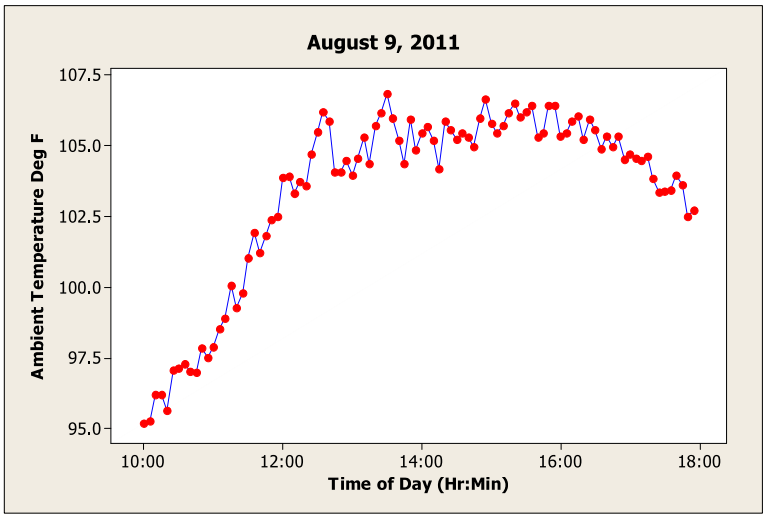

August 6, 2011
Solar Watts / square meter
1100
1000
900
800
700
600
500
400
300
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

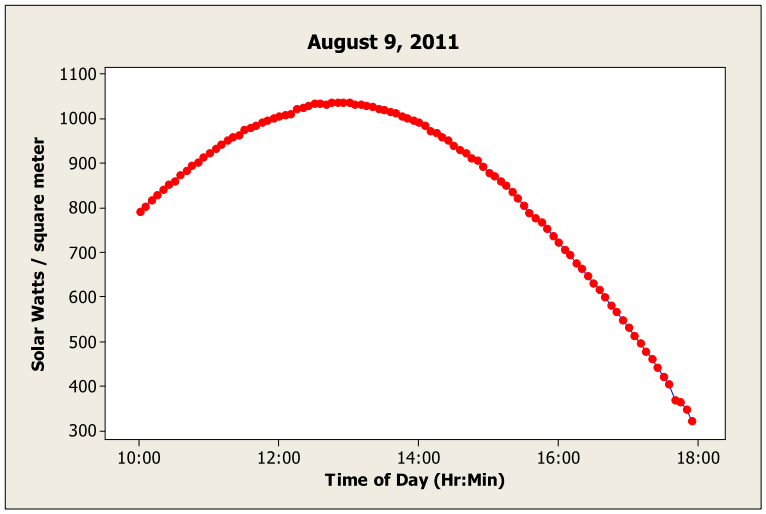

August 6, 2011
Wind Velocity MPH
8
7
6
5
4
3
2
1
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

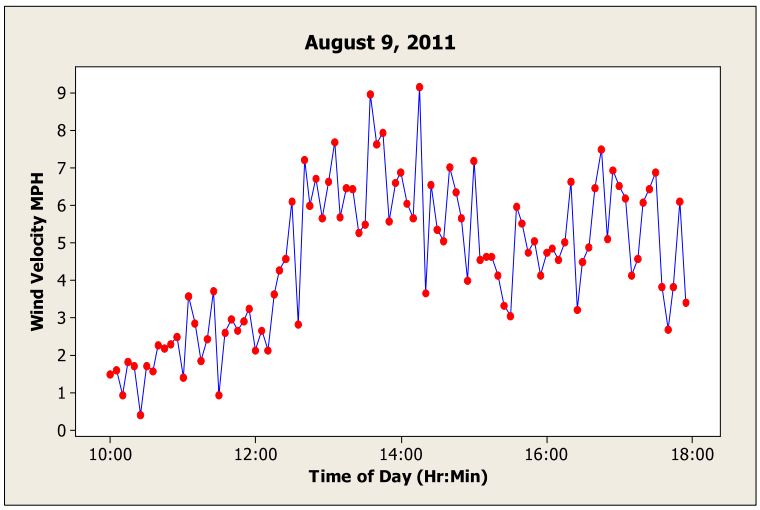

August 8, 2011
Ambient Temperature Deg F
107.5
105.0
102.5
100.0
97.5
95.0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)


August 8, 2011
Solar Watts / square meter
1100
1000
900
800
700
600
500
400
300
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)


August 8, 2011
Wind Velocity MPH
9
8
7
6
5
4
3
2
1
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

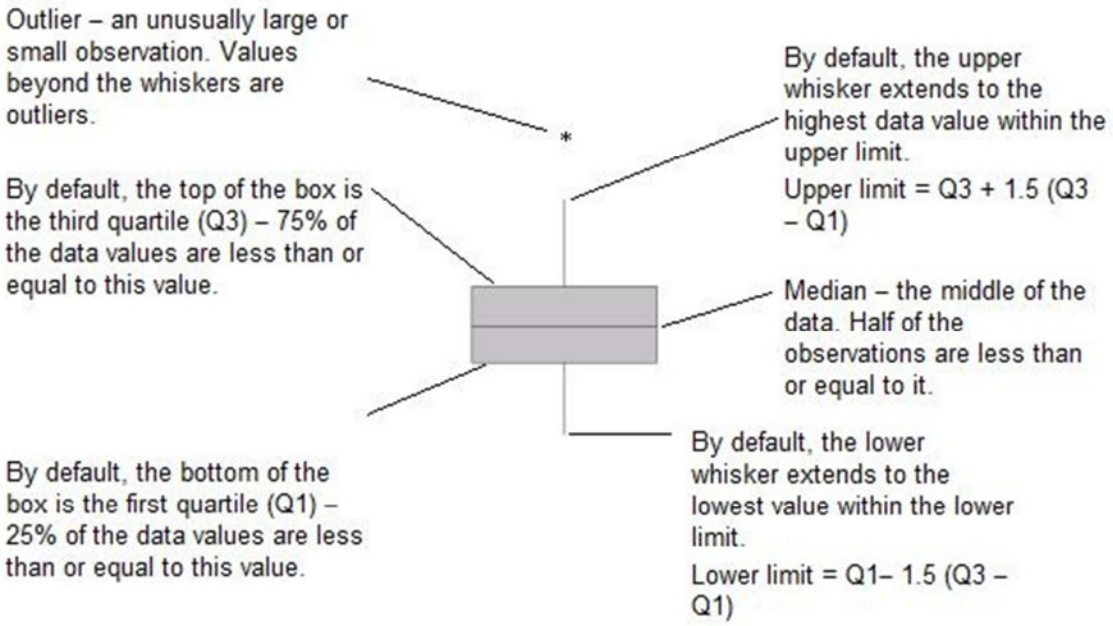

August 9, 2011
Ambient Temperature Deg F
107.5
105.0
102.5
100.0
97.5
95.0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)


August 9, 2011
Solar Watts / square meter
1100
1000
900
800
700
600
500
400
300
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)


August 9, 2011
Wind Velocity MPH
9
8
7
6
5
4
3
2
1
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)

APPENDIX D

Description of Boxplot Diagrams for Data Analysis



Note – A crosshairs within a box also represents the mean (average) of the data.

Public Input No. 4427-NFPA 70-2020 [Section No. 310.15(B)(2)]

(2) Rooftop.

For raceways or cables exposed to direct sunlight on or above rooftops where the distance above the roof to the bottom of the raceway or cable is less than ~~23 mm (~~ **7** ⁄ **8** ~~-~~ 19 mm (¾ in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Informational Note: One source for the ambient temperatures in various locations is the *ASHRAE Handbook — Fundamentals*.

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (°F)
	60°C	75°C	90°C	150°C	200°C	250°C	
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

Statement of Problem and Substantiation for Public Input

The choice of dimension was obviously made to allow for standard shallow strut configurations. Howev-er, although it corresponds to one major brand (Unistrut), it inadvertently excludes most others. For example, B-Line and Superstrut use 13/16-inch, and Kindorf uses ¾ inch.

Submitter Information Verification

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Submittal Date: Thu Sep 10 12:53:24 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 4558-NFPA 70-2020 [Section No. 310.15(B)(2)]

(2) Rooftop.

For raceways or cables exposed to direct sunlight on or above rooftops where the distance above the roof to the bottom of the raceway or cable is less than ~~23 mm (~~ ~~7~~/~~8~~ - 19 mm (3/4 in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Informational Note: One source for the ambient temperatures in various locations is the *ASHRAE Handbook — Fundamentals*.

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86

For ambient temperatures other than 40°C (104°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (°F)
	60°C	75°C	90°C	150°C	200°C	250°C	
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

Statement of Problem and Substantiation for Public Input

Change 7/8 inch to 3/4inch. I believe the original information from the task group indicated that if there was a space (no contact) between the wiring method and the roof then using the ampacity tables without an additional temperature correction factor was acceptable. It is my understanding that CMP6 chose 7/8 inch to match strut dimensions. All structural members including some strut are not 7/8 inch. Changing the value to 3/4 inch allows those struts to be used without large (fender) washers and also allows nominal 1 inch (3/4 inch finished) treated lumber to be used.

Submitter Information Verification

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Submittal Date: Thu Sep 10 15:08:42 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 1631-NFPA 70-2020 [Section No. 310.15(C)]

(C) Adjustment Factors.

~~**(1)** More than Three Current-Carrying Conductors.~~

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors (Articles 210, 215, 220, and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(a) Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	**Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary**
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

~~**(2)** Raceway Spacing.~~

~~Spacing between raceways shall be maintained.~~

Statement of Problem and Substantiation for Public Input

Delete (2) about maintaining raceway spacing. What the heck was that about? There is no rule in the NEC to space raceways a given distance apart and if there was, why would we have to 'maintain' the spacing?

Submitter Information Verification

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Submittal Date: Wed Jun 24 15:45:38 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This section requires separation, without specifying the distance. Spacing is required for heat dissipation and may not be consistent throughout the run. Specific requirements are referenced in wiring method Articles such as 392.

Public Input No. 2105-NFPA 70-2020 [Section No. 310.15(C)(1)]

(1) More than Three Current-Carrying Conductors.

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors (Articles 210, 215, 220, and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(a) Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be

simultaneously energized. Where two or more conductors are protected by the same overcurrent device, and their currents are additive at the overcurrent device, they may be counted as a single conductor.

Statement of Problem and Substantiation for Public Input

Presently, when a single circuit splits into multiple subcircuits, adjustment factors apply to those subcircuits when they are carried within the same cable or raceway. This can lead to the illogical requirement of large conductors downstream of the splitting point than upstream of the splitting point. This is the case even though the total current is same, and after the split the current is spread among more conductors, so the resistive heating effect will be less overall.

For example, suppose a 2-wire 20A circuit feeds a lighting controller, and 10 individual 2-wire subcircuits run from the lighting controller to 10 different lights. If the lighting subcircuits start off in a single conduit run, at present an adjustment factor of 50% applies to each of them. So while the 2-wire supply to the lighting controller might be #12 copper conductors, the lighting subcircuits are currently required to be at a minimum #10 copper with 90C insulation. This is a completely unnecessary increase in size, as the resistive heating effect per unit length in the 20 subcircuit conductors will be less in total than it is in the #12 copper conductors supply the lighting controller.

The proposed text would allow these 20 conductors to be counted as only 2 conductors for the purpose of adjustment factors. As this is similar to the clause on non-simultaneously energized conductors, I have proposed expanding the table footnote. However, for stylistic reasons it may be preferable to create a new subsection (G) with both clauses.

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Submittal Date: Thu Jul 30 16:56:46 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Loading and overcurrent protection could be changed in the future based on installed conductor sizes.

Public Input No. 32-NFPA 70-2019 [Section No. 310.15(C)(1)]

(1) More than Three Current-Carrying Conductors.

~~The~~ If installed in a continuous length longer than 600 mm (24 in), the ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) ~~where~~ if:

(a) the number of current-carrying conductors in a raceway or cable exceeds ~~three, or where~~ three

(b) single conductors or multiconductor cables that are not installed in raceways are installed without maintaining spacing ~~for a continuous length longer than 600 mm (24 in.).~~ .

Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors ~~(Articles 210 , 215 , 220 , and 230)~~ .

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

Exception No. 1: Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

- ~~Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).~~

Exception No. 2: Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(a) *Exception No. 3: Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:*

(2) *The cables do not have an overall outer jacket.*

(3) *Each cable has not more than three current-carrying conductors.*

(4) *The conductors are 12 AWG copper.*

(5) *Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on "bridle rings."*

~~Exception to (4):~~

If cables meeting the requirements in 310.15(C)(1) (d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

Statement of Problem and Substantiation for Public Input

This PI is intended to be editorial rather than substantive.
The revision to (C)(1) creates a list so the 24 inch length rule clearly applies to both conductors or cables in raceways as well as to conductors and multiconductor cables that are not installed in raceways.
The existing reference in (b) to conductors in raceways is unnecessary because this is covered in the opening paragraph.
While exceptions are generally discouraged, this seems to be a set of paragraphs that the readibility will be improved if the exceptions to the general rule are shown as exceptions.
The reference to Articles 210, 215, 220 and 230 seems inappropriate as there are many more articles that cover lighting and power conductors. There are too many to list here.

Submitter Information Verification

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Submittal Date: Tue Nov 05 18:19:17 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 3851-NFPA 70-2020 [Section No. 310.15(C)(1)]

(1) More than Three Current-Carrying Conductors.

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors ~~(Articles 210 , 215 , 220 , and 230)~~ .

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(a) Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be

simultaneously energized.

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to an entire article, other than Article 100. As such, it is proposed to eliminate the reference to Article 210, 215, 220, and 230 as it doesn't add anything to the requirement. Alternatively, a reference to the scope of these articles could be included in an informational note worded in accordance with Section 4.1.3 of the NEC(r) Style Manual if the CMP so desires.

Submitter Information Verification

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Submittal Date: Wed Sep 09 13:59:55 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 4130-NFPA 70-2020 [Section No. 310.15(C)(1)]

(1) More than Three Current-Carrying Conductors.

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors (Articles 210, 215, 220, and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(a) Where conductors are installed in cable trays, ~~the provisions of~~ _ 392.80 shall apply.

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be

simultaneously energized.

Statement of Problem and Substantiation for Public Input

Deleting the words "the provisions of" does not change the meaning of the section.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
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Submittal Date: Wed Sep 09 21:39:34 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 2036-NFPA 70-2020 [Section No. 310.15(C)(2)]

~~(2)~~ ~~Raceway Spacing.~~

~~Spacing between raceways shall be maintained.~~

Statement of Problem and Substantiation for Public Input

This language is so ambiguous that it is unenforceable. Unenforceable rules do not belong in the code.
If this is a real need, the panel needs to provide enforceable language and specify what "maintain spacing" actually means.

Submitter Information Verification

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Street Address:
City:
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Submittal Date: Sun Jul 26 12:48:23 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This section requires separation, without specifying the distance. Removing this section would remove the ability of an AHJ to require spacing where they deem it necessary.

Public Input No. 1715-NFPA 70-2020 [Section No. 310.15(E)]

(E) Neutral Conductor.

~~Neutral conductors shall be considered current carrying in accordance with any of the following:A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to be counted~~

(1) The neutral conductor in a 2-wire circuit consisting of one phase conductor and a neutral conductor shall not be considered a current carrying conductor when applying the provisions of 310.15(C)(1) .

(2) The neutral conductor in a 3-wire circuit consisting of two phase conductors and a neutral conductor of a 3-wire, 1-phase system shall not be considered a current carrying conductor when applying the provisions of 310.15(C)(1) .

~~In a 3~~

(3) The neutral conductor in a 4 -wire circuit consisting of

~~two phase~~

(4) three phase conductors and

~~the~~

(5) a neutral conductor of a 4-wire, 3-phase

~~, wye-connected system, a common conductor carries approximately the same current as the line-to-neutral load currents of the other conductors and shall be counted when applying the provisions of~~

(6) system shall not be considered a current carrying conductor when applying the provisions of 310.15(C)(1) .

(7) The neutral conductor in a 3-wire circuit consisting of two phase conductors and a neutral conductor of a 4-wire, 3-phase system shall be considered a current carrying conductor when applying the provisions of 310.15(C)(1) .

~~On~~

(8) The neutral conductor of a 4-wire

~~, 3-phase wye circuit~~

(9) circuit consisting of three phase conductors and a neutral conductor, where the major portion of the load consists of nonlinear loads,

~~harmonic currents are present in the neutral conductor; the neutral conductor~~

(10) shall

~~therefore~~

(11) be considered a current

-

(12) carrying conductor when applying the provisions of 310 . 15(C)(1) .

Statement of Problem and Substantiation for Public Input

The revision to this rule is to make it easier to understand when a neutral conductor is considered a current carrying conductor.The way it's written, a neutral conductor from a two wire circuit would not be considered a current carrying conductor when apply the provisions of 310.15(C)(1); we know that is not the intent of th rule.

Submitter Information Verification

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Submittal Date: Thu Jun 25 14:53:22 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The current language accurately reflects the application of a neutral when applying the adjustment factors for the number of current carrying conductors.

Public Input No. 2037-NFPA 70-2020 [Section No. 310.15(E)]

(E) Neutral Conductor.

Neutral conductors shall be considered current carrying in accordance with any of the following:

(1) A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to be counted when applying the provisions of 310.15(C)(1).

(2) In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, ~~a common~~ the neutral conductor carries approximately the same current as the line-to-neutral load currents of the other conductors and shall be counted when applying the provisions of 310.15(C)(1).

(3) On a 4-wire, 3-phase wye circuit where the major portion of the load consists of nonlinear loads, harmonic currents are present in the neutral conductor; the neutral conductor shall therefore be considered a current-carrying conductor.

Statement of Problem and Substantiation for Public Input

The term "common neutral" is very similar to the term "common conductor" and that similarity makes the use of "common conductor" confusing to the code user. A neutral used with only two ungrounded conductors of a 3 phase wye system is still a neutral conductor per the Article 100 definition.
The term "common neutral" as used elsewhere in this code applies to a neutral conductor used with two or more ungrounded conductors where there is no potential between those ungrounded conductors

Submitter Information Verification

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Submittal Date: Sun Jul 26 12:51:43 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 931-NFPA 70-2020 [Section No. 310.15(E)]

(E) Neutral Conductor.

Neutral conductors shall be considered current carrying in accordance with any of the following:

(1) A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to be counted when applying the provisions of 310.15(C)(1).

(2) In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, ~~a common conductor~~ the neutral conductor carries approximately the same current as the ~~line~~ line -to-neutral load currents of the other conductors and shall be counted when ~~applying the provisions of~~ applying 310.15(C)(1).

(3) On a 4-wire, 3-phase wye circuit where the major portion of the load consists of nonlinear loads, harmonic currents are present in the neutral conductor; the neutral conductor shall therefore be considered a current-carrying conductor.

Statement of Problem and Substantiation for Public Input

The first change is from "common" to "neutral conductor." I am speculating that "common" came from the days when the article 100 definition of "neutral conductor" was changed to match the IEEE usage of the phrase. Now that the article 100 definition has changed, the use of "neutral conductor" is more appropriate.
The second change is to delete the phrase "provisions of." This is an ongoing change in all articles of the Code.

Submitter Information Verification

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Submittal Date: Sat May 02 11:11:04 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8336-NFPA 70-2021

Statement: Editorial changes have been made throughout 310.15 to align with the style manual and revised to use industry terminology. The circular-mil area clarification could help some avoid confusion. The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

The intent of the requirement in 310.15(B)(2) is to mandate some degree of separation, and the proposed limit accomplishes that without limiting options. The proposed

informational note for 310.15(A) may discourage readers from looking at all relevant references. The user needs to understand not just termination limitations but also equipment ratings and any other relevant limitations within the system.

These added table notes will provide clarity to the Code user about the use of these tables.

Public Input No. 3437-NFPA 70-2020 [Section No. 310.16]

310.16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried).

The ampacities shall be as specified in Table 310.16 ~~where~~ if all of the following conditions apply:

(1) ~~Conductors are rated~~ Conductor insulation is rated 0 volts through 2000 volts.

(2) ~~Conductors are~~ Conductor insulation is rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a voltage or temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself does not have a voltage rating and can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

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City:
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Submittal Date: Tue Sep 08 15:00:26 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3441-NFPA 70-2020 [Section No. 310.17]

310.17 Ampacities of Single-Insulated Conductors in Free Air.

The ampacities shall be as specified in Table 310.17 ~~where~~ if all of the following conditions apply:

(1) ~~Conductors are rated~~ Conductor insulation is rated 0 volts through 2000 volts.

(2) ~~Conductors are rated~~ Conductor insulation is rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a voltage or temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself does not have a voltage rating and can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

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Submittal Date: Tue Sep 08 15:05:38 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3451-NFPA 70-2020 [Section No. 310.18]

310.18 Ampacities of Insulated Conductors in Raceway or Cable.

The ampacities shall be as specified in Table 310.18 ~~where~~ if all of the following conditions apply:

(1) ~~Conductors are~~ Conductor insulation is are rated 0 volts through 2000 volts.

(2) ~~Conductors are rated~~ Conductor insulation is rated 150°C (302°F), 200°C (392°F), or 250°C (482°F).

(3) Wiring is installed in a 40°C (104°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a voltage or temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself does not have a voltage rating and can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

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Submittal Date: Tue Sep 08 15:21:50 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3453-NFPA 70-2020 [Section No. 310.19]

310.19 Ampacities of Single-Insulated Conductors in Free Air.

The ampacities shall be as specified in Table 310.19 ~~where~~ if all of the following conditions apply:

(1) ~~Conductors are rated~~ Conductor insulation is rated 0 volts through 2000 volts.

(2) ~~Conductors are rated~~ Conductor insulation is rated up to 250°C (482°F).

(3) Wiring is installed in a 40°C (104°F) ambient temperature.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a voltage or temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself does not have a voltage rating and can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

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Submittal Date: Tue Sep 08 15:24:58 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3461-NFPA 70-2020 [Section No. 310.20]

310.20 Ampacities of Insulated Conductors Supported on a Messenger.

The ampacities shall be as specified in Table 310.20 ~~where~~ if all of the following conditions apply:

(1) ~~Conductors are rated~~ Conductor insulation is rated 0 volts through 2000 volts.

(2) ~~Conductors are rated~~ Conductor insulation is rated 75°C (167°F) or 90°C (194°F).

(3) Wiring is installed in a 40°C (104°F) ambient temperature.

(4) There are not more than three single-insulated conductors.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a voltage or temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself does not have a voltage rating and can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

Submitter Full Name: Phil Simmons
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Submittal Date: Tue Sep 08 15:53:41 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 2770-NFPA 70-2020 [New Section after 310.21]

Part III. Construction Specification
310.104

Statement of Problem and Substantiation for Public Input

Relocate Part II construction specifications to 310.104 and make it Part III construction specification. This will provide consistency with other articles in chapter 3

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2768-NFPA 70-2020 [Sections Part II., 310.4, 310.6, 310.8]	relocated

Submitter Information Verification

Submitter Full Name: Jon Coulimore
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City:
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Submittal Date: Mon Aug 31 15:12:07 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Article 310 is unique in that it does not contain specific installation instructions, so it does not need to match the other articles.

Public Input No. 1400-NFPA 70-2020 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The ampacities shall be as specified in Table 310.21 where all of the following conditions apply:

(1) Wind velocity is 610 mm/sec (2 ft/sec).

(2) Conductors are 80°C (176°F) total conductor temperature.

(3) Wiring is installed in a 40°C (104°F) ambient temperature.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	—	—	18	—	—	—	—
14*	15	20	25	—	—	—	—
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800

900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

~~*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.~~

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14*	25	30	35	—	—	—	—
12*	30	35	40	25	30	35	12*
10*	40	50	55	35	40	45	10*
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250
300	375	445	500	290	350	395	300

350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.17 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

Table 310.18 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway or Cable

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3
2	160	171	191	124	2
1	186	197	215	145	1
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient

temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.18 shall be referenced for conditions of use.

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).

2. Section 310.19 shall be referenced for conditions of use.

Table 310.20 Ampacities of Conductors on a Messenger

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6
4	101	117	78	91	4

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.20 shall be referenced for conditions of use.

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors				AAC Aluminum Conductors			
Bare		Covered		Bare		Covered	
AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
8	98	8	103	8	76	8	80
6	124	6	130	6	96	6	101
4	155	4	163	4	121	4	127
2	209	2	219	2	163	2	171
1/0	282	1/0	297	1/0	220	1/0	231

Copper Conductors				AAC Aluminum Conductors			
Bare		Covered		Bare		Covered	
AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
2/0	329	2/0	344	2/0	255	2/0	268
3/0	382	3/0	401	3/0	297	3/0	312
4/0	444	4/0	466	4/0	346	4/0	364
250	494	250	519	266.8	403	266.8	423
300	556	300	584	336.4	468	336.4	492
500	773	500	812	397.5	522	397.5	548
750	1000	750	1050	477.0	588	477.0	617
1000	1193	1000	1253	556.5	650	556.5	682
—	—	—	—	636.0	709	636.0	744
—	—	—	—	795.0	819	795.0	860
—	—	—	—	954.0	920	—	—
—	—	—	—	1033.5	968	1033.5	1017
—	—	—	—	1272	1103	1272	1201
—	—	—	—	1590	1267	1590	1381
—	—	—	—	2000	1454	2000	1527

Note: Section 310.21 shall be referenced for conditions of use.

Statement of Problem and Substantiation for Public Input

Remove the * and its associated note from Table 310.16. Rules for overcurrent protection are addressed in Article 240 and there is no reason for Table 310.16 to include the reference to 210.4(D) when there are many cases when 240.4(D) does not apply such as in the case of tap rules, secondary conductors, motors, and air-conditioning. This *note causes some to think that 210.4(D) always applies to these conductors.

Submitter Information Verification

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Organization: Mike Holt Enterprises Inc
Street Address:
City:
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Submittal Date: Tue Jun 02 11:33:02 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This would remove information that is useful to users of the code.

Public Input No. 3464-NFPA 70-2020 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The ampacities shall be as specified in Table 310.21 ~~where~~ if all of the following conditions apply:

(1) Wind velocity is 610 mm/sec (2 ft/sec).

(2) Conductors are 80°C (176°F) total conductor temperature.

(3) Wiring is installed in a 40°C (104°F) ambient temperature.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor Insulation [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	—	—	18	—	—	—	—
14*	15	20	25	—	—	—	—
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750

800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors ~~where the~~ if the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor Insulation [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14*	25	30	35	—	—	—	—
12*	30	35	40	25	30	35	12*
10*	40	50	55	35	40	45	10*
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250

300	375	445	500	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors ~~where the~~ if the ambient temperature is other than 30°C (86°F).

2. Section 310.17 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

Table 310.18 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway or Cable

Size AWG or kcmil	Temperature Rating of Conductor Insulation [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3
2	160	171	191	124	2
1	186	197	215	145	1
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors ~~where the~~ if the ambient temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.18 shall be referenced for conditions of use.

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor Insulation [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors ~~where the~~ if the ambient temperature is other than 40°C (104°F).

2. Section 310.19 shall be referenced for conditions of use.

Table 310.20 Ampacities of Conductors on a Messenger

Size AWG or kcmil	Temperature Rating of Conductor Insulation [See Table 310.4(A)]				Size AWG or kcmil
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6

Size AWG or kcmil	Temperature Rating of Conductor Insulation [See Table 310.4(A)]				Size AWG or kcmil
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
4	101	117	78	91	4
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors ~~where the~~ if the ambient temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.20 shall be referenced for conditions of use.

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors				AAC Aluminum Conductors			
Bare		Covered		Bare		Covered	
AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
8	98	8	103	8	76	8	80
6	124	6	130	6	96	6	101
4	155	4	163	4	121	4	127
2	209	2	219	2	163	2	171

Copper Conductors				AAC Aluminum Conductors			
Bare		Covered		Bare		Covered	
AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
1/0	282	1/0	297	1/0	220	1/0	231
2/0	329	2/0	344	2/0	255	2/0	268
3/0	382	3/0	401	3/0	297	3/0	312
4/0	444	4/0	466	4/0	346	4/0	364
250	494	250	519	266.8	403	266.8	423
300	556	300	584	336.4	468	336.4	492
500	773	500	812	397.5	522	397.5	548
750	1000	750	1050	477.0	588	477.0	617
1000	1193	1000	1253	556.5	650	556.5	682
—	—	—	—	636.0	709	636.0	744
—	—	—	—	795.0	819	795.0	860
—	—	—	—	954.0	920	—	—
—	—	—	—	1033.5	968	1033.5	1017
—	—	—	—	1272	1103	1272	1201
—	—	—	—	1590	1267	1590	1381
—	—	—	—	2000	1454	2000	1527

Note: Section 310.21 shall be referenced for conditions of use.

Statement of Problem and Substantiation for Public Input

The first and perhaps most important reason this and related Public Inputs are important and must be accepted is to correct a longstanding error in the National Electrical Code. It is the insulation of conductors that is required to have a voltage or temperature rating to withstand ambient or environmental temperatures as well as to provide protection against short-circuits and unintended ground faults. The conductor material itself does not have a voltage rating and can continue to function satisfactorily at a much higher temperature than the insulation system employed.
In spite of the statement to the contrary in 90.1(A), the NEC is studied by many students who are learning the electrical trade or electrical engineering profession. Many, many textbooks are written to assist in this educational process.
The NEC should be technically correct to provide the high level of integrity that is needed for understanding and application of this most important safety standard.

Submitter Information Verification

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Submittal Date: Tue Sep 08 15:59:48 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The term insulated conductor is defined in Article 100 and clearly understood to mean the conductor and insulation.

Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The ampacities shall be as specified in Table 310.21 where all of the following conditions apply:

(1) Wind velocity is 610 mm/sec (2 ft/sec).

(2) Conductors are 80°C (176°F) total conductor temperature.

(3) Wiring is installed in a 40°C (104°F) ambient temperature.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

—

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	—	—	18	—	—	—	—
14*	15	20	25	—	—	—	10** 15** 20** 14*
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300

350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

** Applicable only to copper-clad aluminum conductors

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14*	25	30	35	—	—	—	—
12*	30	35	40	25	30	35	12*
10*	40	50	55	35	40	45	10*
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3

2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250
300	375	445	500	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.17 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

Table 310.18 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway or Cable

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
2	160	171	191	124	2
1	186	197	215	145	1
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.18 shall be referenced for conditions of use.

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient

temperature is other than 40°C (104°F).

2. Section 310.19 shall be referenced for conditions of use.

Table 310.20 Ampacities of Conductors on a Messenger

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6
4	101	117	78	91	4
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.20 shall be referenced for conditions of use.

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors		AAC Aluminum Conductors	
Bare	Covered	Bare	Covered

AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
8	98	8	103	8	76	8	80
6	124	6	130	6	96	6	101
4	155	4	163	4	121	4	127
2	209	2	219	2	163	2	171
1/0	282	1/0	297	1/0	220	1/0	231
2/0	329	2/0	344	2/0	255	2/0	268
3/0	382	3/0	401	3/0	297	3/0	312
4/0	444	4/0	466	4/0	346	4/0	364
250	494	250	519	266.8	403	266.8	423
300	556	300	584	336.4	468	336.4	492
500	773	500	812	397.5	522	397.5	548
750	1000	750	1050	477.0	588	477.0	617
1000	1193	1000	1253	556.5	650	556.5	682
—	—	—	—	636.0	709	636.0	744
—	—	—	—	795.0	819	795.0	860
—	—	—	—	954.0	920	—	—
—	—	—	—	1033.5	968	1033.5	1017
—	—	—	—	1272	1103	1272	1201
—	—	—	—	1590	1267	1590	1381
—	—	—	—	2000	1454	2000	1527

Note: Section 310.21 shall be referenced for conditions of use.

Additional Proposed Changes

File Name	Description	Approved
Proposed_Table_310.16_Ampacity_2023_Draft_Fnl.docx	Word file to show added ampacities for 14 AWG copper-clad aluminum and note at bottom of table. Attachment provided for table changes and substantiation since Terra will not allow clear changes in tables.	
NSF_Final_Report_J-00265162_Copperweld_FFR-_CCA-Cu_Revised_10-27-17.pdf	NSF Test Report 14 AWG copper-clad aluminum conductor temperatures at various current levels specific pages cited in substantiation	
Terminal_and_Conductor_Temperature_Testing_Part_I_Fnl.pdf	Terminal temperature Static Heating Test Report, testing as requested by Task Group	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Changes

The changes made in this public input were to Table 310.16 to add a set of ampacities for 14 AWG Copper-Clad Aluminum conductors. In addition, "14" was added to the conductor sizes in the far-right column. The ampacity values were added along with a double asterisk (**) to a new note at the bottom of the table to indicate that the ampacities at this AWG size apply to Copper-Clad Aluminum conductors only and do not apply to single-metal aluminum conductors. In the far-right hand column, a single asterisk (*) was added to the "14" reference the existing note that section 240.4(D) would need to be checked for applicable overcurrent protection device when 14 AWG Copper-Clad Aluminum is installed. For clarity a separate attachment is provided of the legislatively revised table.

Technical Substantiation

What is ampacity? The definition in Article 100 states that ampacity is:
"The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. (CMP-6)"
From 310.16 the conditions of use are:

310.16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried). The ampacities shall be as specified in Table 310.16 where all of the following conditions apply:

(1) Conductors are rated 0 volts through 2000 volts.
(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).
(3) Wiring is installed in a 30°C (86°F) ambient temperature.
(4) There are not more than three current-carrying conductors.
The conclusion then is that ampacity is about temperature and, under the specified conditions of use, the amount of current that can be carried without exceeding the identified insulation temperatures of 60, 75 and 90ºC.

What is "ampacity" from the tables vs. the actual current that can be applied as provided in the rest of the Code? The wire ampacity is the current limit set for the conductor and its respective insulation based on the temperature class of the insulation at 60, 75 and 90ºC for most of the applications. Other parts of the Code then revise the "allowed current" to fit with the testing of equipment, equipment terminals, device terminals, and splicing connectors. When the overall testing is completed, the item with the lowest allowed temperature then sets at what current the conductor is allowed to carry.

For example, considering all of the Section 310.16 conditions of use are met, 10 AWG copper THHN wire has an ampacity from Table 310.16 of 40 Amps. A 30 Amp circuit breaker that this conductor could be terminated on is typically limited to 75ºC or possibly 60ºC. The wiring device, such as a conventional receptacle (that the other end of the conductor is connected to) of configurations having ampere ratings less than 100 Amps, typically is standardized at a temperature limit of 60ºC. Therefore, considering the aggregate of the circuit's components, the overall current allowed on this conductor is 30 amps as indicated in the 60ºC column of Table 310.16 and also set in 240.4(D)(7). In short, the receptacle is the limiting component in this case. But, at the conclusion of all this, the "ampacity" of this 10 AWG THHN conductor unto itself is still 40 Amps.

What testing was done to determine the ampacity of 14 AWG Copper-Clad Aluminum at 60, 75, 90ºC? Following the historical path, as discussed below, that determined ampacities for different sizes of conductors, laboratory temperature testing of multiple samples of 14 AWG THHN Copper-Clad Aluminum was completed. In summary, the samples were connected in series so that whatever test current was set was the same current applied to all conductors. Where testing was of cable assemblies (NM-B) or individual conductors in conduit, all conductors in the cable or conduit had current applied.

Calibrated thermocouples were attached to the core conductor material and to the insulation. The ambient temperature in the testing laboratory was also recorded along with the temperature on the test samples. All data was recorded using a data-logger, that was downloaded into a spreadsheet for analysis. The initial test current was set at 5 Amps and held until temperature equilibrium was attained, approximately 30 minutes for each current level. After temperature equilibrium was reached, the test current was raised in steps of 5 Amps and held again until temperature equilibrium was attained.

The raw data from the multiple samples at each test current level was temperature-corrected to the ambient of 30ºC based on the conditions of use in the Code ampacity tables. The resultant temperature values were then averaged to determine the average conductor core temperature and the average surface insulation temperature. The values proposed in the table are based on the core average temperature, which was found slightly higher than the insulation temperature and is a more conservative value. The selection was also based on which condition, cable or conduit had the higher temperature result. As seen below the conductors in conduit were found to have the greater temperature conditions.

The summary of 14 AWG Copper-Clad Aluminum ambient-temperature-corrected average core temperature and average insulation surface temperature is provided below. This table summarizes the test values from both the testing of NM-B cable as well as conductors in conduit.

Current (Amps)	14-2 w/G NM-B		14 AWG THHN in ½ Inch EMT	
	Average Core (Degrees C)	Average Insulation Surface (Degrees C)	Average Core (Degrees C)	Average Insulation Surface (Degrees C)
5	32.92	32.86	34.55	33.86
10	38.05	38.13	43.12	42.64
15	45.13	45.22	59.84	56.57
20	54.78	55.89	80.16	74.60
25	69.61	71.60	124.41	111.52

[Ref. NSF Report pages: (NMB) 22 – 25 and (EMT) 33]

The following are the worst-case conductor core temperatures for not more than three current carrying conductors in a cable or raceway at a 30ºC ambient.
The ampacity of 10 Amps for 60ºC insulations would have a core temperature of 44.12ºC
The ampacity of 15 Amps for 75ºC insulations would have a core temperature of 59.84ºC
The ampacity of 20 Amps for 90ºC insulations would have a core temperature of 80.16ºC

Additional testing for "Static Heating Test of Push-in Wire Connectors on CCA Conductors in accordance with Clause 9.12 Spring-action sequence per UL 486C" was completed including 14 AWG Copper-Clad Aluminum by Intertek (ETL). At a test value of 20 Amps, twice the proposed ampacity, the temperatures recorded for the three reference conductors showed a maximum conductor temperature of 56.91ºC in a 30ºC ambient. These results are in line with the values shown in the table

above.

How does this compare to 14 AWG copper at 60, 75, and 90ºC? While the ampacity for a conductor with a given insulation should stand alone, testing was completed simultaneously with 14 AWG copper THHN conductors using the same procedure as summarized above. The comparison results are:

Insulation Temperature Rating	14 AWG Copper Clad Aluminum Proposed Ampacity	Core Temperature at Proposed Ampacity (Degrees C)	14 AWG Copper Ampacity from Table	Core Temperature at Table Ampacity (Degrees C)
60ºC	10	43.12	15	47.98
75ºC	15	59.84	20	59.56
90ºC	20	80.16	25	82.77

[Ref. NSF Report pages: (CCA in EMT) 33 and (Cu in EMT) 36]

This testing demonstrates that, for the proposed ampacities, the Copper-Clad Aluminum conductor will operate at a lower temperature than the copper conductor operating at the presently allowed ampacity for a specific insulation class.

How were the existing ampacity values determined? The current carrying capacity of a conductor has appeared in every National Electrical Code® since 1897 edition, which replaced local electrical codes from the New York Board of Fire Underwriters, the Underwriters Association of the Middle Department, and others. Initial current carrying values were being determined by different groups as early as the 1880s with one of the first published tables in 1889. The first Code was also based on work from the National Underwriters Association which became Underwriters Laboratories in 1901.

In the late 1890s and early 1900s a consultant, Ira Henry, employed by National Underwriters Association developed requirements for rubber insulated wire which was replacing the various versions of cotton covered wire. These values remained stable for almost 30 years. In the late 1920s research was undertaken by several entities to update these current values because of improvements in rubber insulating material.

For one investigation, started in 1931, aging testing was done on multiple samples, using three wire sizes ranging from 14 AWG to 4/0 AWG of “code grade rubber insulation”, initially from nine different manufacturers. These aging tests were done at a set temperature in an oven over various periods of time, much as insulation aging testing is done today. After the first round showed excessive deterioration, a second set of tests (with of the same sizes and two additional manufacturers contributing samples) was completed at a lower oven temperature. These tests were to find out how much temperature over time caused the rubber to deteriorate as measured by tensile strength and elongation. The result was that the insulation could withstand 50ºC for the expected life. The second part of the investigation then completed temperature testing at different currents was conducted to see how much current could be carried by each size wire and stay under 50ºC. This resulted in an AIEE paper published in 1938 and updates to the National Electrical Code® allowable current (ampacity) tables.

Later when thermoplastic insulation was introduced the current values were again updated to reflect the superior performance of thermoplastic compounds and the different insulation temperature values of 60, 75 and 90ºC were introduced based on the performance of the different insulation compound formulas. Later still, thermo-set insulations were introduced and again temperature testing was completed for current values for these insulations. The testing completed was based on how much current a given size and material of conductor could carry before the insulation was impacted to deteriorate. To complete the tables, mathematical formulas were developed from the 1930s into the late 1990s to account for the different conductor sizes and different installation conditions. The most widely used formulas were from or based on the work of Neher-McGrath, which were mostly used to address underground installations. This is what we call today “ampacity” as reflected in the Article 310 tables.

From the first Code edition allowing aluminum until the 1956 NEC®, the permitted current for aluminum was fixed at 84% of the table values for copper. The 1956 Code created the first separate tables, Tables 1A and 1B in Chapter 10, where aluminum conductors had values set, but a note still limited aluminum conductors to 84% of copper. The 84% limit was dropped in later Codes. Copper-Clad Aluminum was introduced in the 1971 NEC® in the second stage of code-making activities. This

introduction was to provide an alternative to the problems being seen with the use of the 1350 alloy aluminum conductors in branch circuits.

The 1975 NEC® cycle added 18 AWG and 16 AWG copper conductors with values of 21 and 22 amps respectfully to Table 310-16. The proposal was from the code panel itself. The panel's substantiation for these additions was that these values were taken from the 1971 edition of NFPA 79, the standard for industrial electric machinery. The 1981 Code changed these ampacity values to 14 and 18 Amps in Table 310-16. These ampacity values are only in the 90ºC column and there are no values provided for 60 or 75ºC through up to and including the 2020 NEC®.

The ampacity adjustment that happened in the 2011 NEC® cycle was from a coordinated effort to align the National Electrical Code® and the Canadian Electrical Code, Part I. This activity had been underway for over 10 years. The basis for these changes was for an application of a temperature adjustment formula using the ampacities of existing size conductors at 75ºC. This temperature value was selected since both the NEC® and CEC were in essential agreement on the ampacity at this temperature and the working binational task group agreed with this as the starting point to apply the adjustment formula.

Presently there are no UL standards or UL-published test procedures to determine ampacity. The UL standards for wire and cable are primarily evaluating the insulation and how it performs in normal and abnormal conditions, as stated in the UL standards' Scopes "in accordance with NFPA Standard 70, National Electrical Code® (NEC®)". For most testing completed, the "ampacity" of the conductor is taken directly from the Code. Present IEEE standards utilize extensive tables, IEEE 835 has over 3000 pages of ampacity tables, with formulas to determine a different ampacity based on specific installation conditions. These tables address conductors for voltages from 600 volts to 500,000 volts. There is no formula or process to establish an ampacity for a new size conductor.

Testing laboratory qualifications. The NSF laboratory that completed the main temperature testing is an OSHA recognized electrical testing laboratory with 36 electrical UL standards that require the capability to test temperature for equipment, equipment terminals and conductors. They are also accredited by the Standards Council of Canada and have ISO registration for quality controls. The NSF report provided complete details of their recognitions.

Intertek (ETL) that completed the static heating test of push-in wire connectors also an OSHA Nationally Recognized Testing laboratory for numerous electrical standards including wire and cable standards.

References:

National Electrical Code® – 1897 (replica), 1915, 1956, 1971, 1975, 1981, 2011, 2020 and related proposals, comments and panel statements as available.
Behind the Code – NEC® History by W. Creighton Schwan and David E. Shapiro, third edition
The National Electrical Code and Free Enterprise (A History), Merwin Brandon 1971 Published by the National Fire Protection Association
The Current-Carrying Capacity of Rubber-Insulated Conductors, S.J. Rosch, AIEE Transactions, Vol. 57, March 1938
J.H. Neher and M.H. McGrath, "The Calculation of the Temperature Rise and Load Capability of Cable Systems ", AIEE Transactions Part III - Power Apparatus and Systems, Vol. 76, October 1957, pp. 752-772.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	Branch Circuit AFCI protection added 10 amps
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	Branch circuit ratings added 10 amps

Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	Individual branch circuit receptacle applications and limitations
Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]	Branch circuit applications and limitations added 10 amps
Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]	Summary branch circuit applications and limitations added 10 amps
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	Branch circuit OCPD for 14 AWG copper-clad aluminum set at 10 amps
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	10 amperes added as standard OCPD device rating
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	Branch circuit conductor ratings include 14 AWG copper-clad aluminum
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]	14 AWG copper-clad aluminum added for cables at 10 amps
Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]	Applications and limitations for snap switches
Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]	Applications and limitations for receptacles
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	
Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	
Public Input No. 3237-NFPA 70-2020 [Section No. 210.52(B)(1)]	
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	
Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]	
Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]	
Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]	

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Submittal Date: Wed Sep 09 16:20:01 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8427-NFPA 70-2021

Statement: The minimum conductor sizes for copper and copper-clad aluminum are being reduced to 16 AWG copper and 14 AWG copper-clad aluminum. These revisions are based on testing submitted in support of the use of copper-clad aluminum conductors for 10 amp circuits, and the decades of successful use of 16 AWG copper conductors in fixture wire, motor wiring, control wiring, and other current-carrying applications as permitted in the NEC.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPERCLAD ALUMINUM			
18*	-	-	14	-	-	-	-
16*	-	-	18	-	-	-	-
14*	15	20	25	- 10**	- 15**	- 20**	- 14*
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:
1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).
2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.
3. Section 310.16 shall be referenced for conditions of use.

* Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

** Applicable only to copper-clad aluminum conductors

Substantiation

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Changes

The changes made in this public input were to Table 310.16 to add a set of ampacities for 14 AWG Copper-Clad Aluminum conductors. In addition, "14" was added to the conductor sizes in the far-right column. The ampacity values were added along with a double asterisk (**) to a new note at the bottom of the table to indicate that the ampacities at this AWG size apply to Copper-Clad Aluminum conductors only and do not apply to single-metal aluminum conductors. In the far-right hand column, a single asterisk (*) was added to the "14" reference the existing note that section 240.4(D) would need to be checked for applicable overcurrent protection device when 14 AWG Copper-Clad Aluminum is installed. For clarity a separate attachment is provided of the legislatively revised table.

Technical Substantiation

What is ampacity? The definition in Article 100 states that ampacity is:

> "The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. (CMP-6)"

From 310.16 the conditions of use are:

> **310.16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried)**. The ampacities shall be as specified in Table 310.16 where all of the following conditions apply:
>
> (1) Conductors are rated 0 volts through 2000 volts.

(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

The conclusion then is that ampacity is about temperature and, under the specified conditions of use, the amount of current that can be carried without exceeding the identified insulation temperatures of 60, 75 and 90ºC.

What is "ampacity" from the tables vs. the actual current that can be applied as provided in the rest of the Code? The wire ampacity is the current limit set for the conductor and its respective insulation based on the temperature class of the insulation at 60, 75 and 90ºC for most of the applications. Other parts of the Code then revise the "allowed current" to fit with the testing of equipment, equipment terminals, device terminals, and splicing connectors. When the overall testing is completed, the item with the lowest allowed temperature then sets at what current the conductor is allowed to carry.

For example, considering all of the Section 310.16 conditions of use are met, 10 AWG copper THHN wire has an ampacity from Table 310.16 of 40 Amps. A 30 Amp circuit breaker that this conductor could be terminated on is typically limited to 75ºC or possibly 60ºC. The wiring device, such as a conventional receptacle (that the other end of the conductor is connected to) of configurations having ampere ratings less than 100 Amps, typically is standardized at a temperature limit of 60ºC. Therefore, considering the aggregate of the circuit's components, the overall current allowed on this conductor is 30 amps as indicated in the 60ºC column of Table 310.16 and also set in 240.4(D)(7). In short, the receptacle is the limiting component in this case. But, at the conclusion of all this, the "ampacity" of this 10 AWG THHN conductor unto itself is still 40 Amps.

What testing was done to determine the ampacity of 14 AWG Copper-Clad Aluminum at 60, 75, 90ºC? Following the historical path, as discussed below, that determined ampacities for different sizes of conductors, laboratory temperature testing of multiple samples of 14 AWG THHN Copper-Clad Aluminum was completed. In summary, the samples were connected in series so that whatever test current was set was the same current applied to all conductors. Where testing was of cable assemblies (NM-B) or individual conductors in conduit, all conductors in the cable or conduit had current applied.

Calibrated thermocouples were attached to the core conductor material and to the insulation. The ambient temperature in the testing laboratory was also recorded along with the temperature on the test samples. All data was recorded using a data-logger, that was downloaded into a spreadsheet for analysis. The initial test current was set at 5 Amps and held until temperature equilibrium was attained, approximately 30 minutes for each current level. After temperature equilibrium was reached, the test current was raised in steps of 5 Amps and held again until temperature equilibrium was attained.

The raw data from the multiple samples at each test current level was temperature-corrected to the ambient of 30ºC based on the conditions of use in the Code ampacity tables. The resultant temperature values were then averaged to determine the average conductor core temperature and the average surface insulation temperature. The values proposed in the table are based on the core average temperature, which was found slightly higher than the insulation temperature and is a more conservative value. The selection was also based on which condition, cable or

conduit had the higher temperature result. As seen below the conductors in conduit were found to have the greater temperature conditions.

The summary of 14 AWG Copper-Clad Aluminum ambient-temperature-corrected average core temperature and average insulation surface temperature is provided below. This table summarizes the test values from both the testing of NM-B cable as well as conductors in conduit.

Current (Amps)	14-2 w/G NM-B		14 AWG THHN in ½ Inch EMT	
	Average Core (Degrees C)	Average Insulation Surface (Degrees C)	Average Core (Degrees C)	Average Insulation Surface (Degrees C)
5	32.92	32.86	34.55	33.86
10	38.05	38.13	43.12	42.64
15	45.13	45.22	59.84	56.57
20	54.78	55.89	80.16	74.60
25	69.61	71.60	124.41	111.52

[Ref. NSF Report pages: (NMB) 22 – 25 and (EMT) 33]

The following are the worst-case conductor core temperatures for not more than three current carrying conductors in a cable or raceway at a 30ºC ambient.

The ampacity of 10 Amps for 60ºC insulations would have a core temperature of 44.12ºC

The ampacity of 15 Amps for 75ºC insulations would have a core temperature of 59.84ºC

The ampacity of 20 Amps for 90ºC insulations would have a core temperature of 80.16ºC

Additional testing for “Static Heating Test of Push-in Wire Connectors on CCA Conductors in accordance with Clause 9.12 Spring-action sequence per UL 486C” was completed including 14 AWG Copper-Clad Aluminum by Intertek (ETL). At a test value of 20 Amps, twice the proposed ampacity, the temperatures recorded for the three reference conductors showed a maximum conductor temperature of 56.91ºC in a 30ºC ambient. These results are in line with the values shown in the table above.

How does this compare to 14 AWG copper at 60, 75, and 90ºC? While the ampacity for a conductor with a given insulation should stand alone, testing was completed simultaneously with 14 AWG copper THHN conductors using the same procedure as summarized above. The comparison results are:

Insulation Temperature Rating	14 AWG Copper Clad Aluminum		14 AWG Copper	
	Proposed Ampacity	Core Temperature at Proposed Ampacity (Degrees C)	Ampacity from Table	Core Temperature at Table Ampacity (Degrees C)
60ºC	10	43.12	15	47.98
75ºC	15	59.84	20	59.56

90ºC	20	80.16	25	82.77

[Ref. NSF Report pages: (CCA in EMT) 33 and (Cu in EMT) 36]

This testing demonstrates that, for the proposed ampacities, the Copper-Clad Aluminum conductor will operate at a lower temperature than the copper conductor operating at the presently allowed ampacity for a specific insulation class.

How were the existing ampacity values determined? The current carrying capacity of a conductor has appeared in every National Electrical Code® since 1897 edition, which replaced local electrical codes from the New York Board of Fire Underwriters, the Underwriters Association of the Middle Department, and others. Initial current carrying values were being determined by different groups as early as the 1880s with one of the first published tables in 1889. The first Code was also based on work from the National Underwriters Association which became Underwriters Laboratories in 1901.

In the late 1890s and early 1900s a consultant, Ira Henry, employed by National Underwriters Association developed requirements for rubber insulated wire which was replacing the various versions of cotton covered wire. These values remained stable for almost 30 years. In the late 1920s research was undertaken by several entities to update these current values because of improvements in rubber insulating material.

For one investigation, started in 1931, aging testing was done on multiple samples, using three wire sizes ranging from 14 AWG to 4/0 AWG of “code grade rubber insulation”, initially from nine different manufacturers. These aging tests were done at a set temperature in an oven over various periods of time, much as insulation aging testing is done today. After the first round showed excessive deterioration, a second set of tests (with of the same sizes and two additional manufacturers contributing samples) was completed at a lower oven temperature. These tests were to find out how much temperature over time caused the rubber to deteriorate as measured by tensile strength and elongation. The result was that the insulation could withstand 50ºC for the expected life. The second part of the investigation then completed temperature testing at different currents was conducted to see how much current could be carried by each size wire and stay under 50ºC. This resulted in an AIEE paper published in 1938 and updates to the National Electrical Code® allowable current (ampacity) tables.

Later when thermoplastic insulation was introduced the current values were again updated to reflect the superior performance of thermoplastic compounds and the different insulation temperature values of 60, 75 and 90ºC were introduced based on the performance of the different insulation compound formulas. Later still, thermo-set insulations were introduced and again temperature testing was completed for current values for these insulations. The testing completed was based on **how much current a given size and material of conductor could carry before the insulation was impacted to deteriorate**. To complete the tables, mathematical formulas were developed from the 1930s into the late 1990s to account for the different conductor sizes and different installation conditions. The most widely used formulas were from or based on the work of Neher-McGrath, which were mostly used to address underground installations. This is what we call today “ampacity” as reflected in the Article 310 tables.

From the first Code edition allowing aluminum until the 1956 NEC®, the permitted current for aluminum was fixed at 84% of the table values for copper. The 1956 Code created the first separate tables, Tables 1A and 1B in Chapter 10, where aluminum conductors had values set,

but a note still limited aluminum conductors to 84% of copper. The 84% limit was dropped in later Codes. Copper-Clad Aluminum was introduced in the 1971 NEC® in the second stage of code-making activities. This introduction was to provide an alternative to the problems being seen with the use of the 1350 alloy aluminum conductors in branch circuits.

The 1975 NEC® cycle added 18 AWG and 16 AWG copper conductors with values of 21 and 22 amps respectfully to Table 310-16. The proposal was from the code panel itself. The panel's substantiation for these additions was that these values were taken from the 1971 edition of NFPA 79, the standard for industrial electric machinery. The 1981 Code changed these ampacity values to 14 and 18 Amps in Table 310-16. These ampacity values are only in the 90ºC column and there are no values provided for 60 or 75ºC through up to and including the 2020 NEC®.

The ampacity adjustment that happened in the 2011 NEC® cycle was from a coordinated effort to align the National Electrical Code® and the Canadian Electrical Code, Part I. This activity had been underway for over 10 years. The basis for these changes was for an application of a temperature adjustment formula using the ampacities of existing size conductors at 75ºC. This temperature value was selected since both the NEC® and CEC were in essential agreement on the ampacity at this temperature and the working binational task group agreed with this as the starting point to apply the adjustment formula.

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Report Date: October 27, 2017

Description:	CCA –Cu Ampacity Comparison
Type of Evaluation	Fact Finding Investigation
Job Number	J-00265162
Project Number	0225-104
Project Manager	Don Tottingham
Location	789 Dixboro Road, Ann Arbor
Inspection Dates	August 7- August 18, 2017
Total # of Pages	125 Pages

Evaluated By: Anas Alaghazali

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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

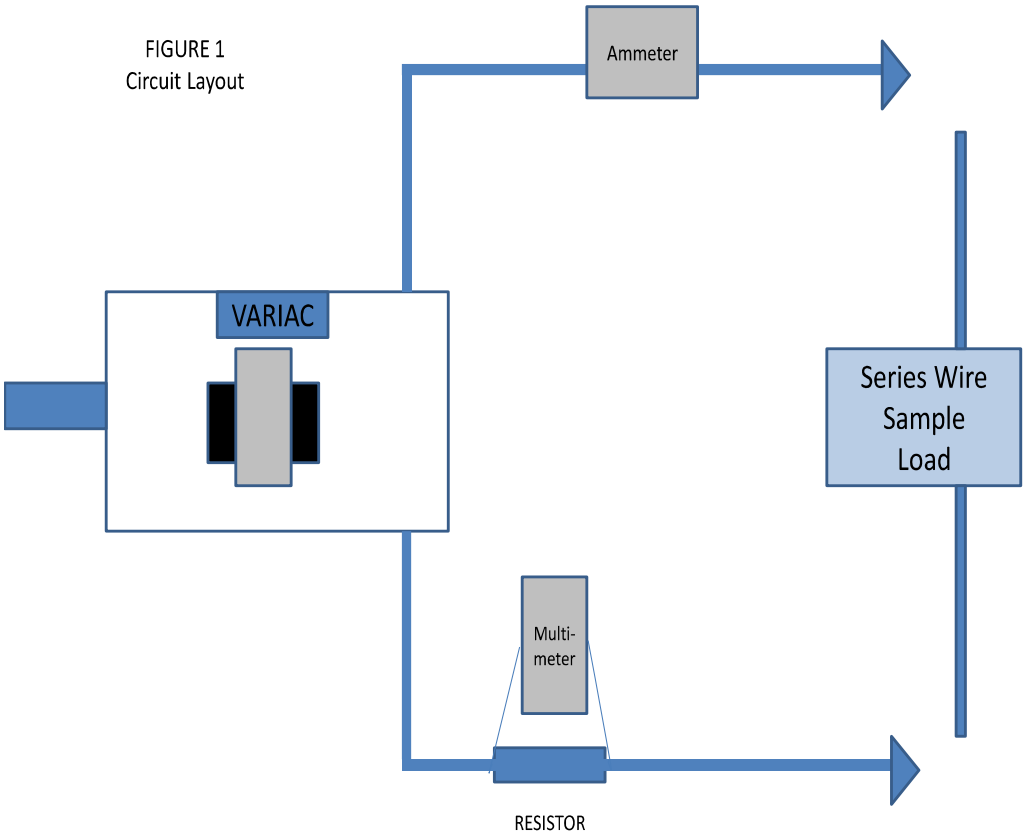
Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

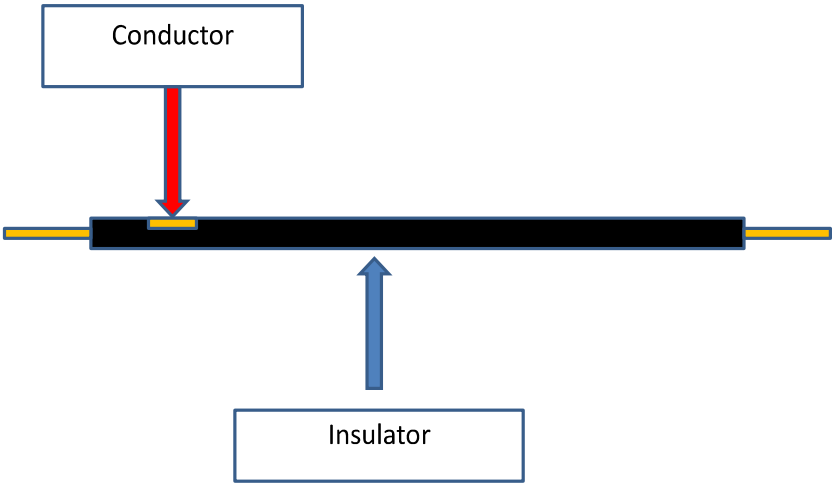
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FIGURE 1
Circuit Layout



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FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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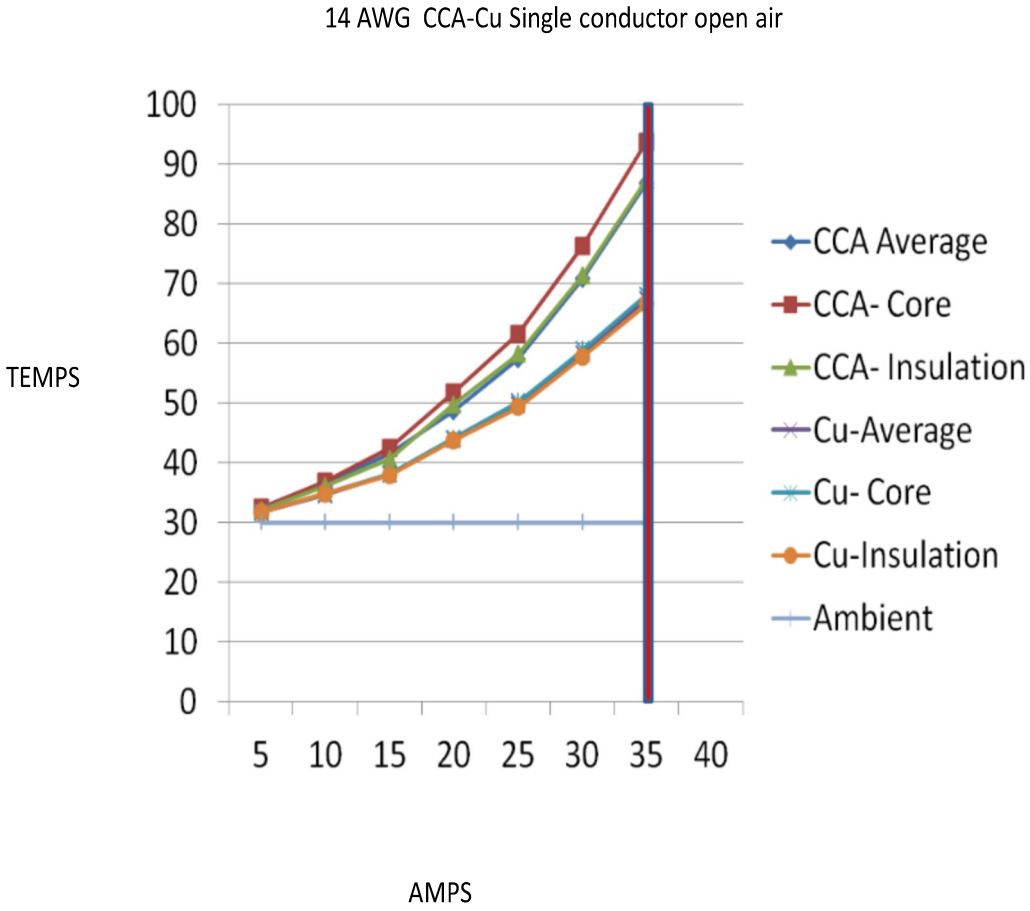
14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

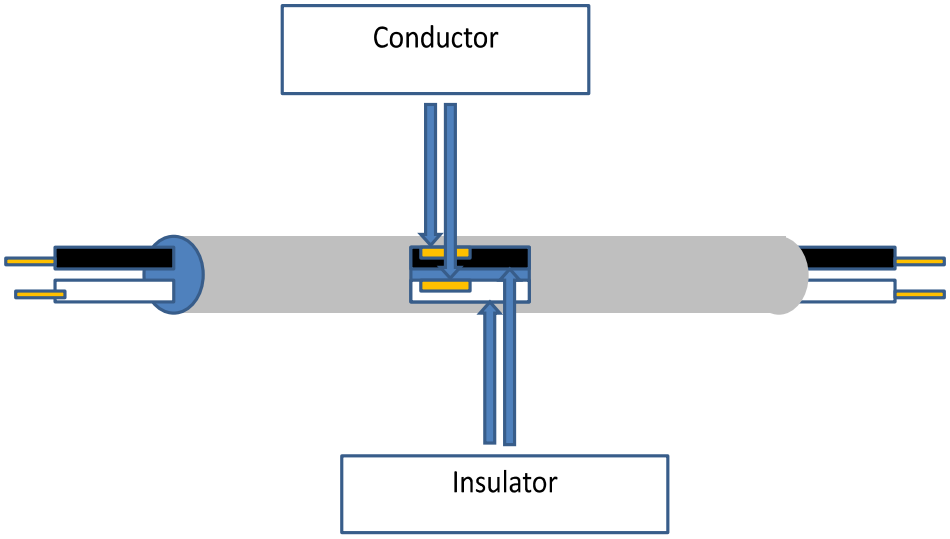
Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

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Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air
(Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air
(Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air
Page (2/2)

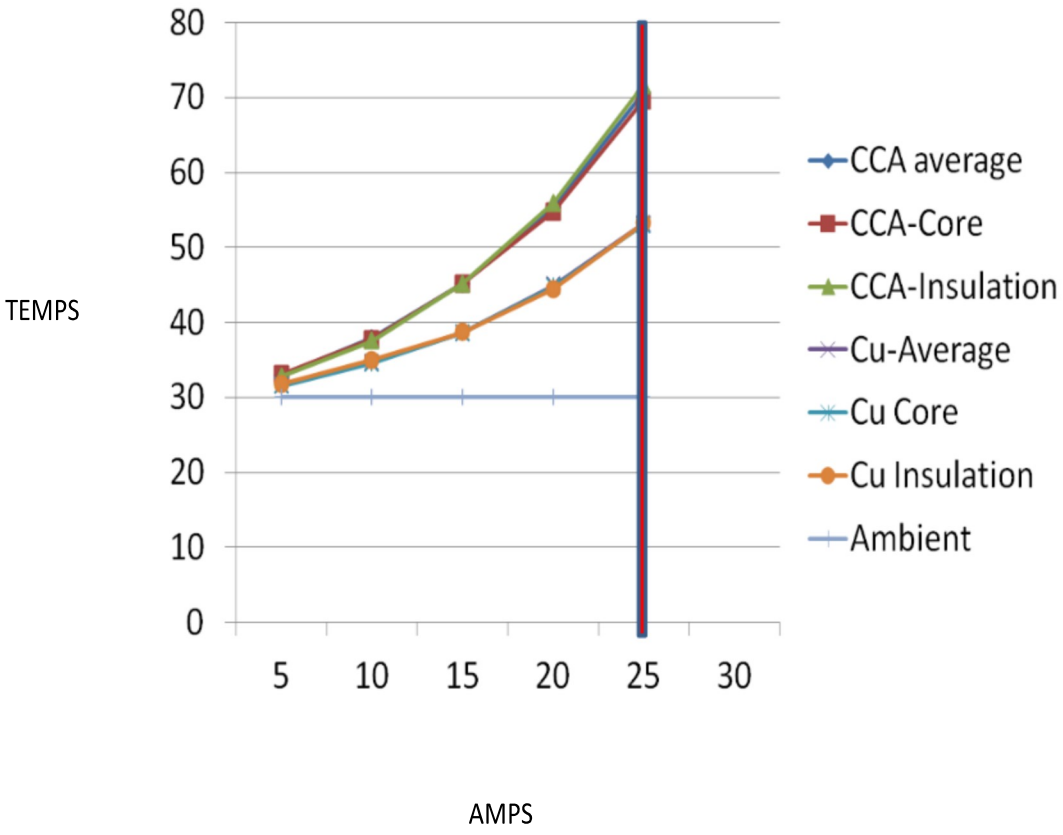
302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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14 AWG CCA-Cu NM Cable Open Air



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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

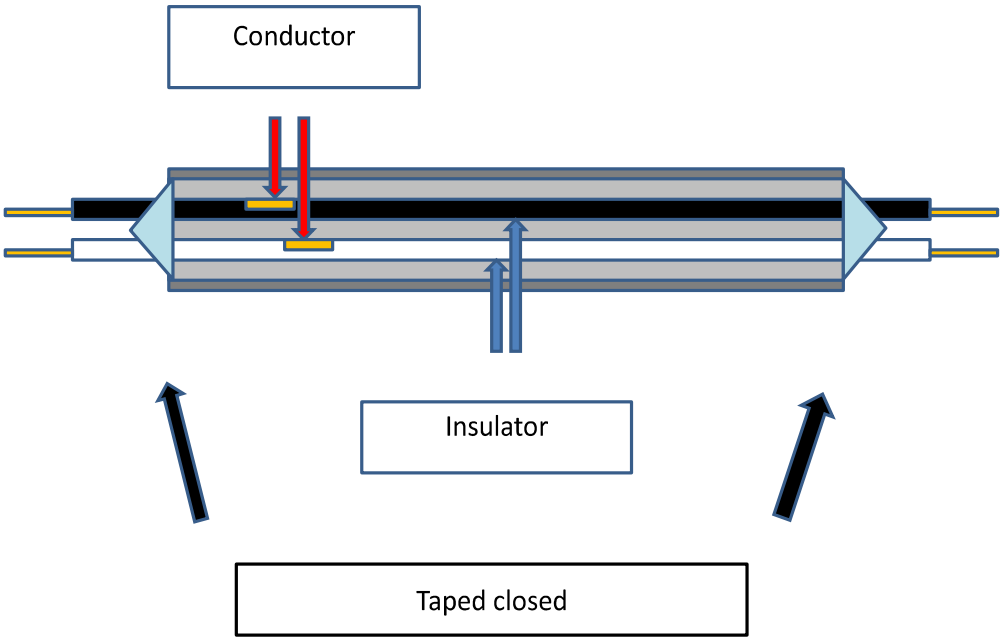
Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
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	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit
Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit
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211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit
Page 1/2)

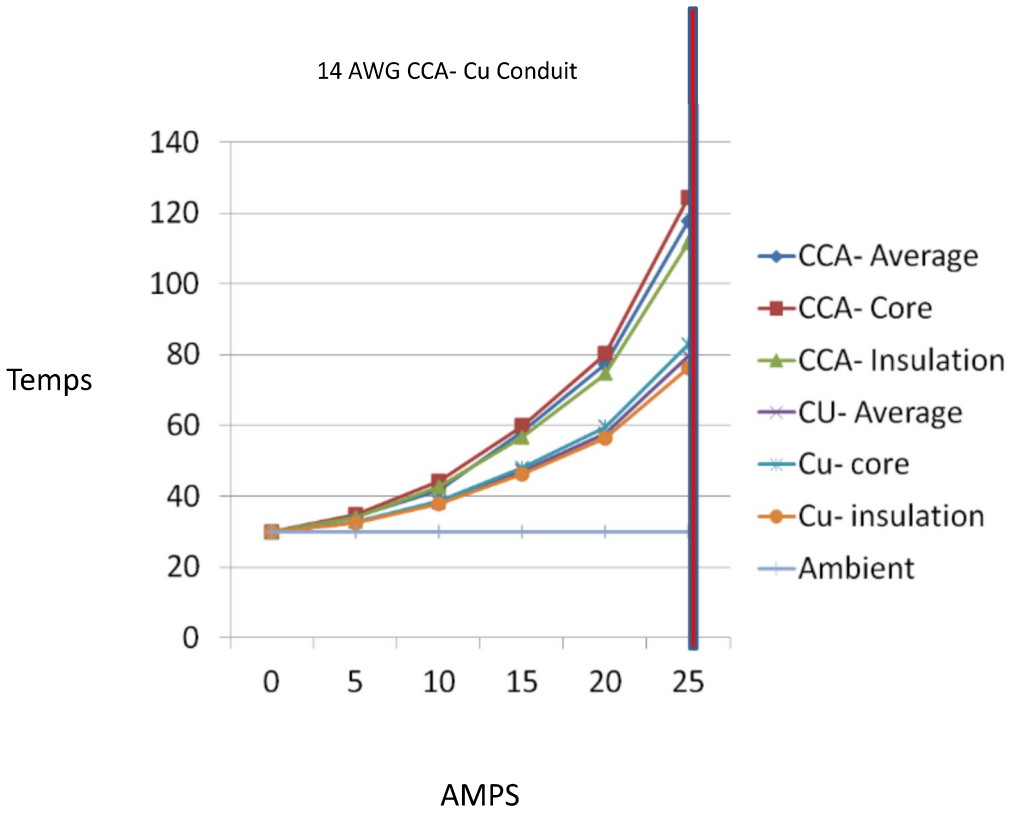
	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
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318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
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Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
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112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

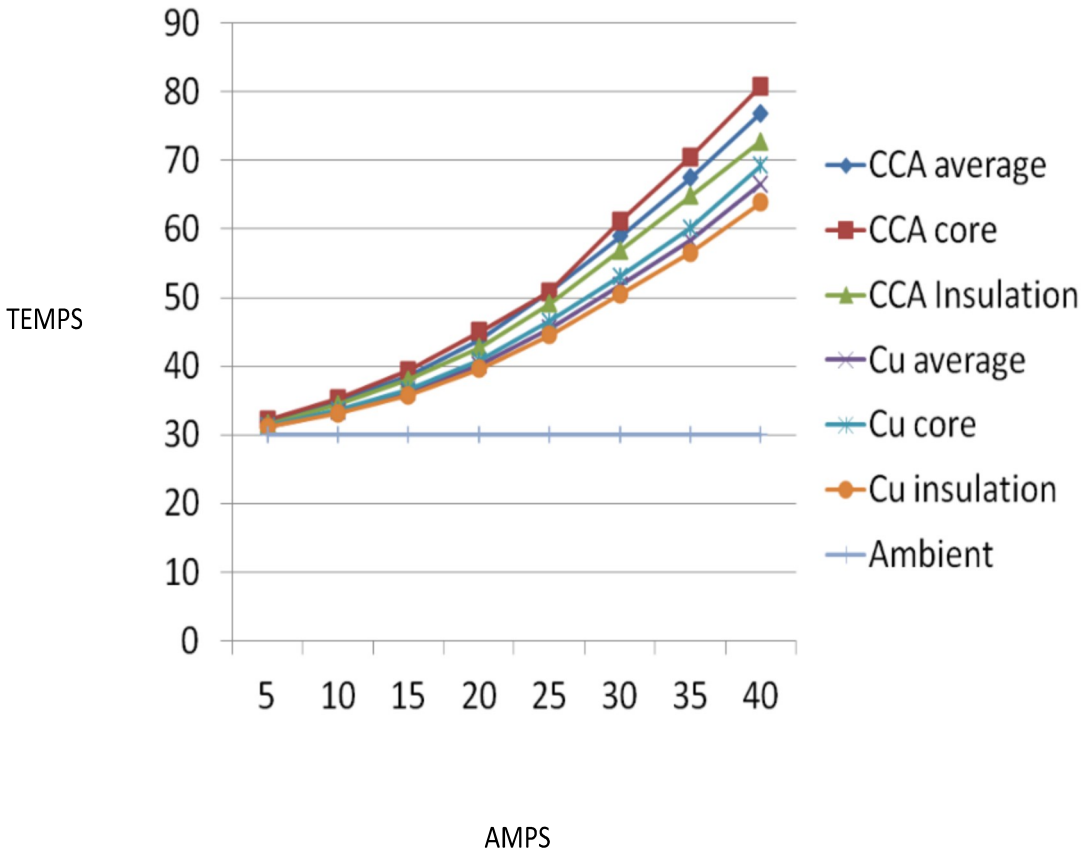
	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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12 AWG CCA Cu single conductor open air



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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 1 of 3)

Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)

(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 3of 3)

116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

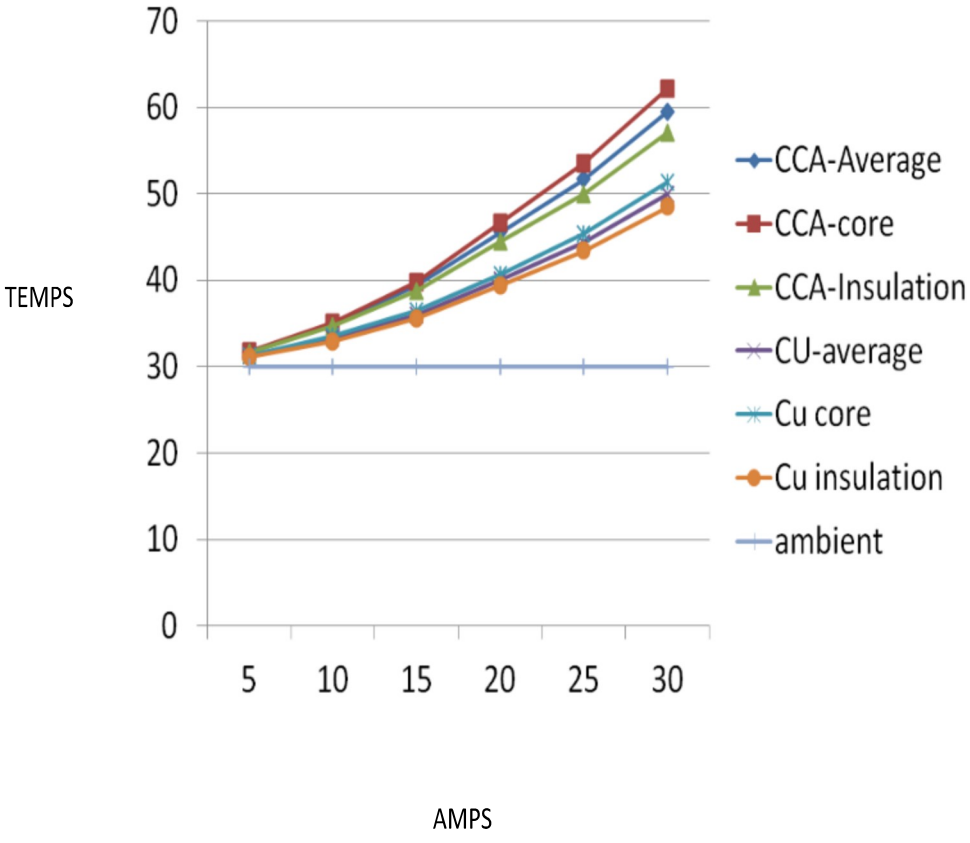
305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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12 AWG CCA-Cu NM Cable (2C)open air



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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
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315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

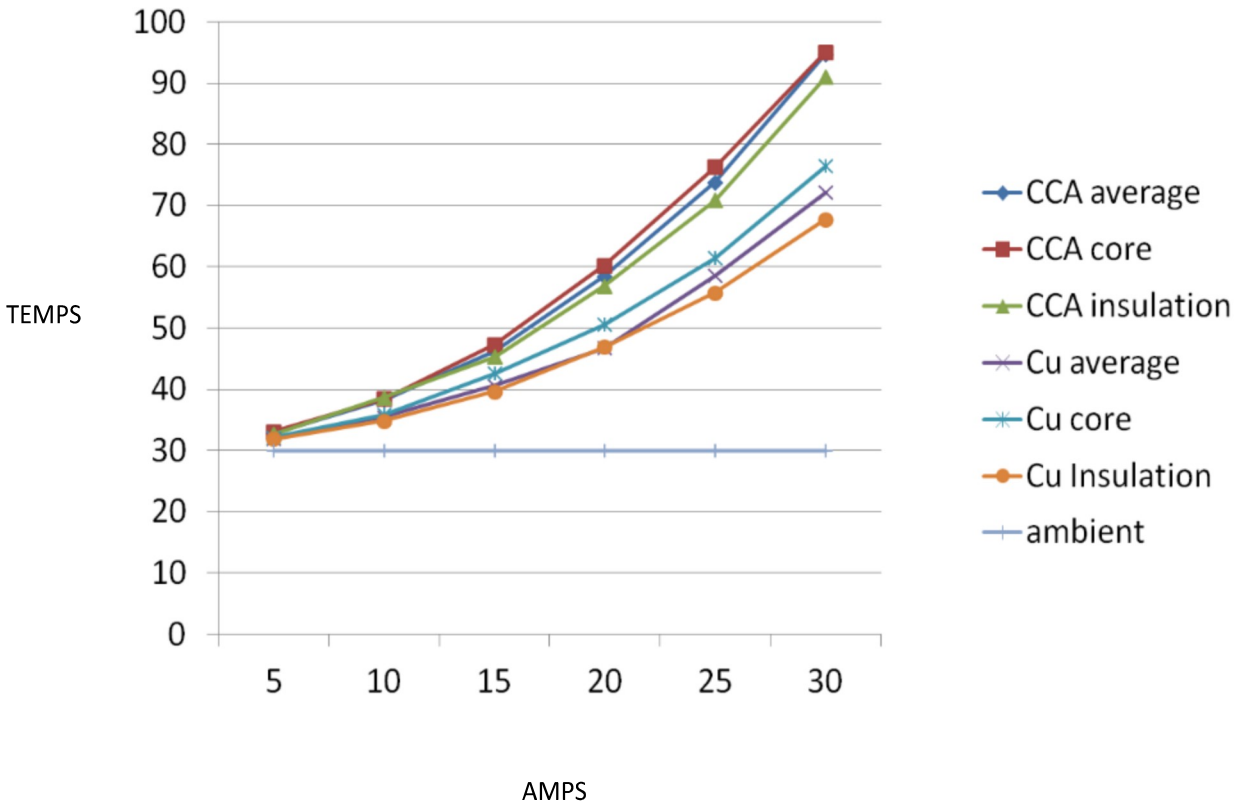
304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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12 AWG CCA-Cu in Conduit



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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
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Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
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113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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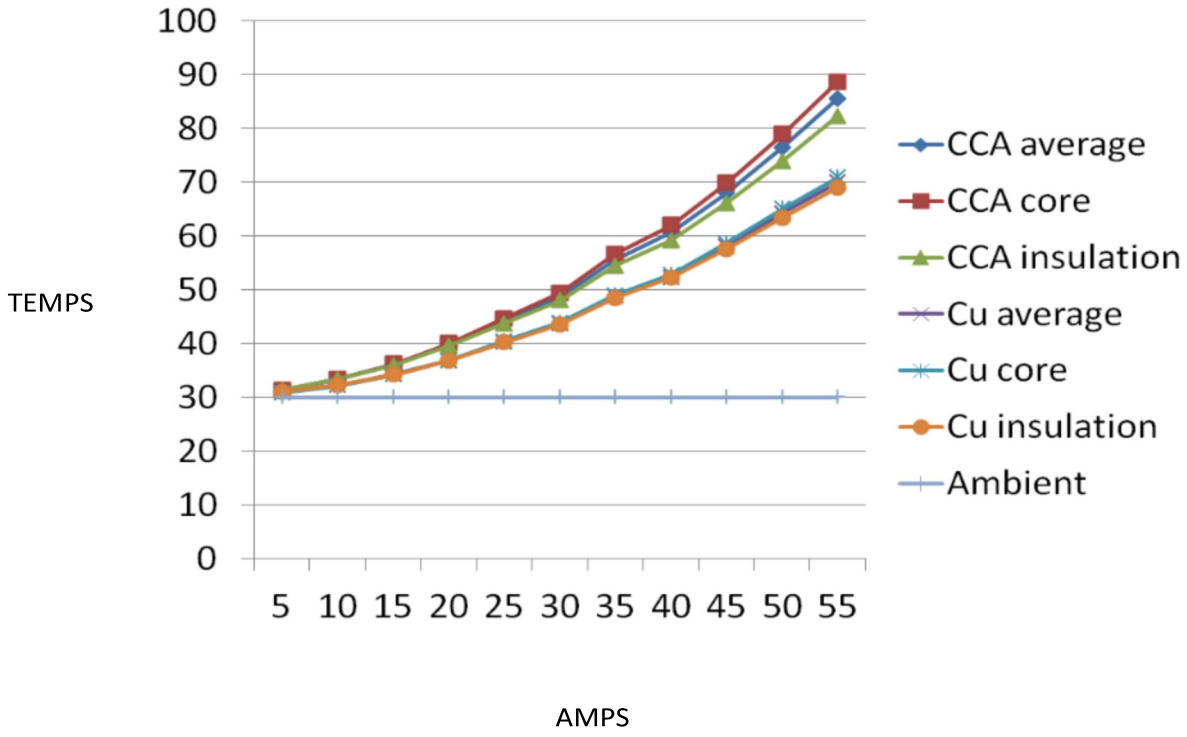
31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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10 AWG CCA CU Single Conductor open air



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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

Page 1 of 3

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

(Page 3 of 3)

114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

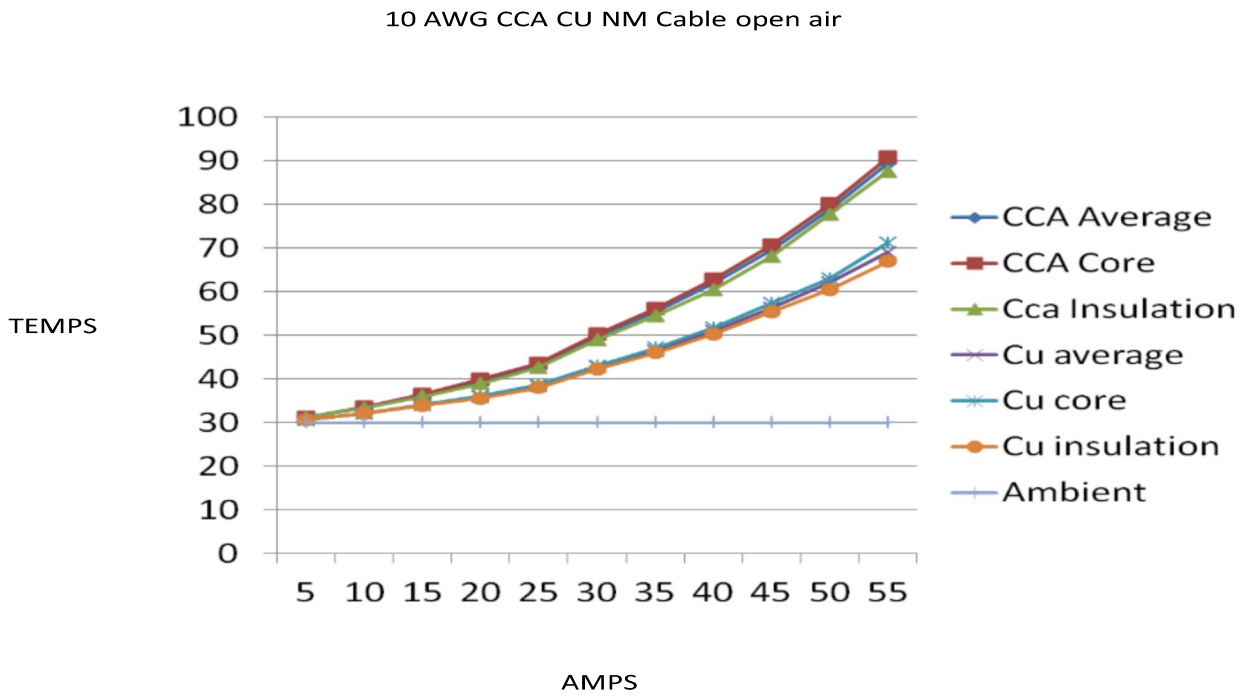
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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

(Page 1 of 3)

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)

(Page 2 of 3)

211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
(Page 3 of 3)

107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

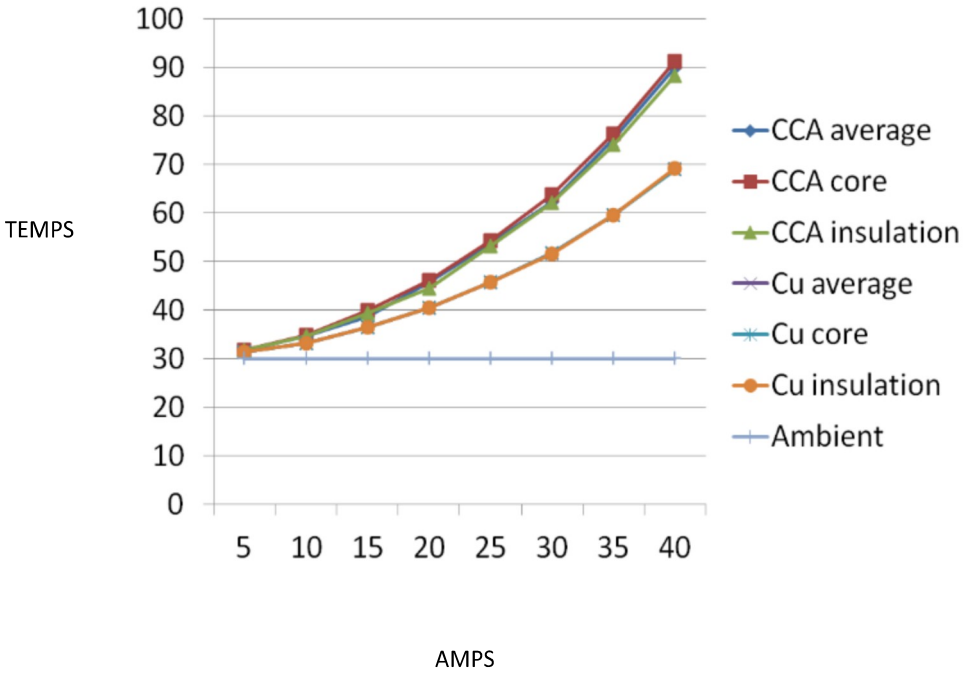
304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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10 AWG CCA Cu In conduit



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Summary

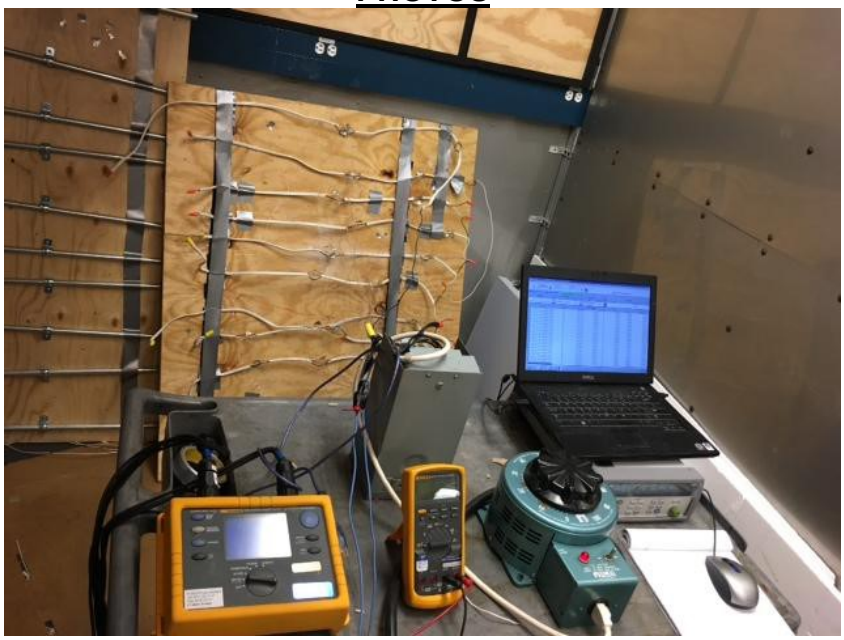
14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

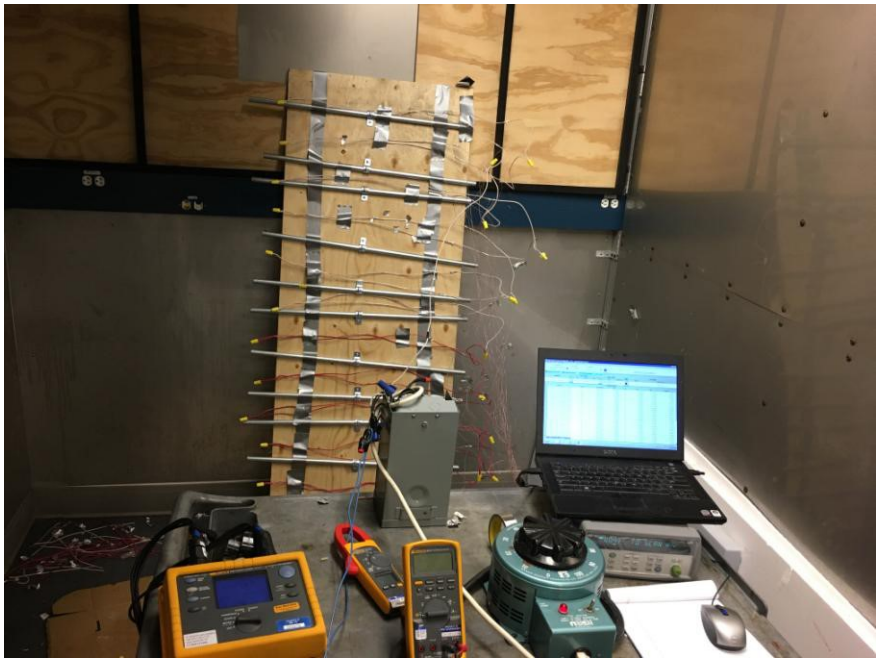
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APPENDIX A
PHOTOS

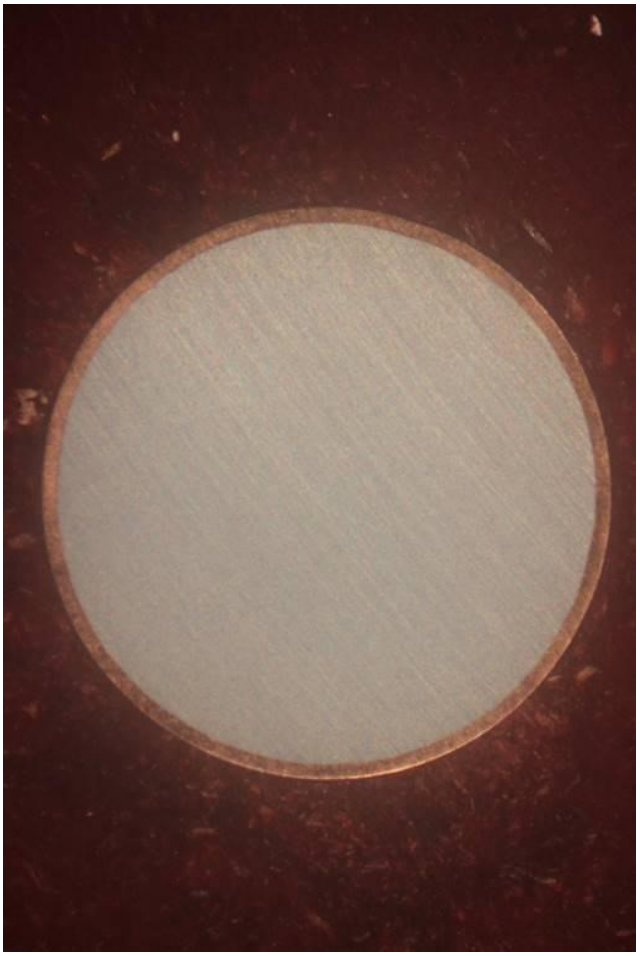




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Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: 3869120002 e W

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road
	Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: 3765740001 e W

17025 Accredited Certificate of Calibration

ACCREDITED
Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road
	Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 deg. F
Humidity:	20.00 %
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: 3869120002 e W

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road
	Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S0606032588B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced other than in full, without the specific written approval of Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Documen: 111.0 Revision 118 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 9/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found: Calibration data collected before the unit is adjusted and / or repaired.
- As - Left: Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left: Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µV/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by 'f'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017

S/N S0606032588B6

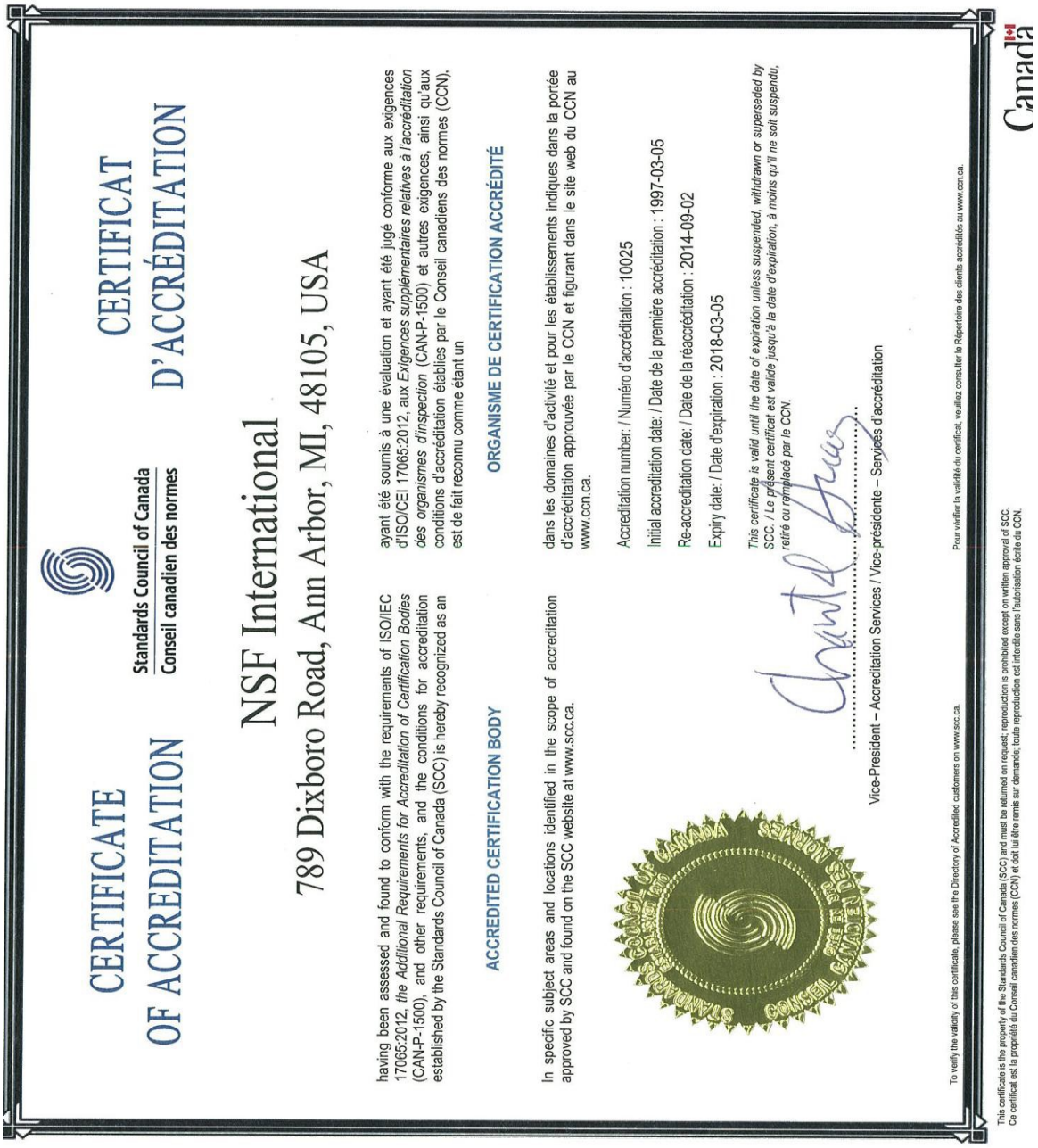
www.fluke.com

Cert # 322693
Date 28/2/2017

Calibration Technician

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APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

CERTIFICAT D'ACCRÉDITATION

Standards Council of Canada
Conseil canadien des normes

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ACCREDITED CERTIFICATION BODY

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ORGANISME DE CERTIFICATION ACCRÉDITÉ

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Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

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ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

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July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

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Terminal and Conductor Temperature Testing of 14 AWG Copper-Clad Aluminum and 14 AWG Copper Conductors

Part I – Static Heating and Flexing Tests

For

Bimetallics Task Group

Conducted at

Eaton Laboratories
Menomonee Falls, Wisconsin

Report by

Chuck Mello
on behalf of Bimetallics Task Group

Report Date

August 28, 2020

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1.0 Introduction and Purpose

At the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23, a Bimetallics Task Group of balanced interest was appointed. The scope was to review the proposed changes to the 2020 edition of the *NEC*® that relate to copper-clad aluminum conductors and recommend changes through tentative interim amendment(s) and/or to provide public inputs for the next revision cycle.

As the task group conducted the work, it was determined that testing data had been provided substantiating the ampacity of 14 AWG copper-clad aluminum but a number of related questions about 14 AWG copper-clad aluminum applications arose regarding terminal temperatures when applied to circuit breakers, wire splicing devices and device terminals. A testing plan was developed, reviewed over several task group meetings, and accepted by the task group to address the terminal temperature questions. This testing was completed at the Eaton Corporation laboratory facilities in Menomonee Falls, Wisconsin. The helpful assistance of Mr. Tom Domitrovich, Mr. Kevin Arnold, Mr. James Parrett, and Mr. Steve Averbeck with Eaton Corporation is greatly appreciated in arranging for and executing the testing.

This test report provides the testing arrangement, testing procedures and results for the static heating and the flexing tests. The Part I testing detailed in this report commenced July 30, 2020 and completed on August 26, 2020. Thermocycling testing is presently being conducted and those test results will be provided in a separate report. The separation of the reports is necessary to meet the NFPA deadline of September 10, 2020 to submit public inputs and any supporting data.

The purpose of this testing is to provide data, as requested by the Bimetallics Task Group, to understand certain installation and operating conditions when considering the application of 14 AWG copper-clad aluminum conductors at the proposed ampacity for branch circuits. The testing being completed also includes 14 AWG copper conductors at its *NEC*® ampacity for comparison and performance. The basis for comparison is at the 60ºC ampacity rating for copper (15 amps) and the proposed 60ºC ampacity rating for copper-clad aluminum (10 amps). This testing is designed to represent a typical installation to determine the following:

1) The temperature (temperature rise) on the terminals and conductor immediately adjacent to a 10 Amp and 15 Amp molded case circuit breaker, under normal and identified abnormal conditions
2) The temperature (temperature rise) on wire-splicing devices (e.g., Ideal Wire Nuts® or similar), and conductor immediately adjacent, commonly used for splicing in junction or device boxes or attaching leads from utilization equipment, under normal and abnormal conditions
3) The temperature (temperature rise) on wiring devices (single receptacle as representative) and conductor immediately adjacent under normal and abnormal conditions
4) Conductor retention on wiring devices after abnormal thermal-cycling
5) The flexing durability of 14 AWG copper-clad aluminum when installed and removed from a single-gang device box

Since the various product standards do not presently have requirements, procedures or parameters for 14 AWG copper-clad aluminum, the testing being conducted is based on the 10-ampere branch circuit rating at 60°C and percentage multipliers taken from the applicable standards. Where the standard does not provide a percentage value, then the current for the testing was interpolated from the values for relative copper and/or aluminum conductors from the standard. The values for testing of 14 AWG copper are taken from the applicable product safety standards with an ampacity basis of 15 Amps at 60°C

It is to be understood this testing is only being conducted to provide specific performance data and information as requested by the task group. The testing does not provide performance or data for certification of any of the components used for the testing. If 14 AWG copper-clad aluminum is accepted into the 2023 *NEC*®, then numerous UL standards will need to be revised and testing completed under the requirements established in those standards. This testing for certification could be more extensive and take much more time to complete than what is provided here. The goal again is to provide information for a typical installation specific to terminal temperatures. The changes to UL standards will not begin to occur until 14 AWG copper-clad aluminum is recognized for installation in the *NEC*®.

To provide a basis to consider the test results for 14 AWG copper-clad aluminum, duplicate test set ups were constructed using 14 AWG copper conductors. The only difference in the setup for 14 AWG copper is the circuit breaker was rated 15 Amps and the testing values were based on the 15 Amp ampacity. This additional testing data provides a direct comparison in the same environment at the 60ºC ampacity values for these two conductor types and assemblies.

2.0 Testing Arrangement and Setup

The test was conducted in a suitable facility with environmental controls and documented monitoring. The facility was free from extraneous changes in ambient temperature and from having random air flow (drafts) through the testing area. Ambient temperature was maintained between 20ºC and 25°C and recorded with thermocouples positioned in the testing area while temperature testing was completed.

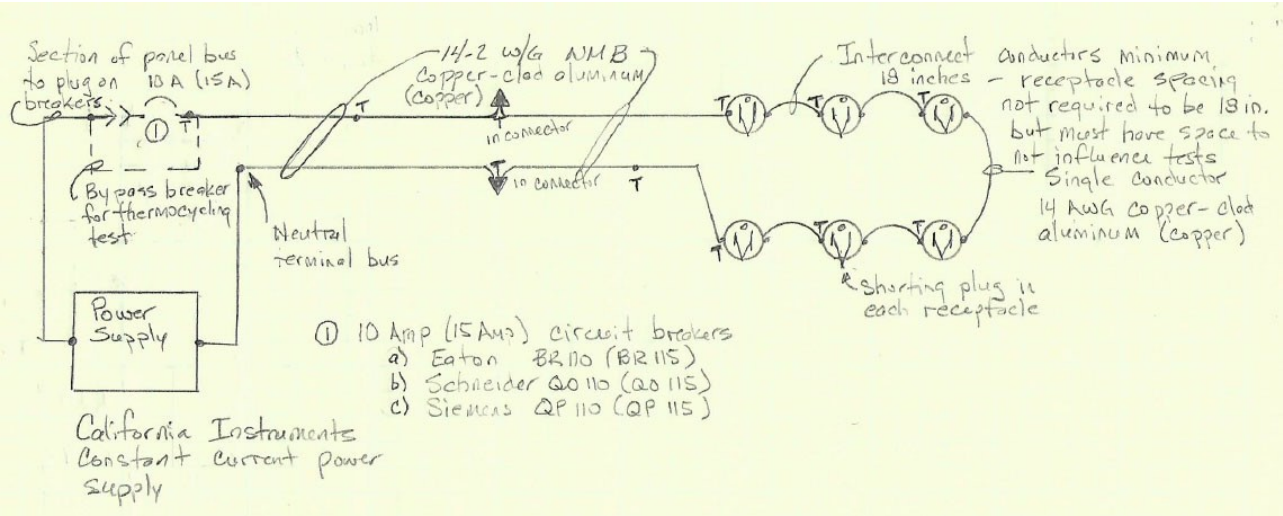


Figure 1 – Typical Test Circuit Diagram

The Eaton facility, being a division within a manufacturing company of wiring devices and circuit breakers, has laboratory technicians that are very familiar with testing of circuit components and equipment to UL standards.

The test circuit diagram shown in figure 1 above provides the basic layout of one (1) testing circuit consisting of one (1) circuit breaker, the conductor (14 AWG copper-clad aluminum or copper NM-B cable) two wire-splicing devices, and six (6) single receptacles. To complete tests 1 through 4 as described below, three (3) of these test circuits were assembled at a time. Photos 1 through 3 in Appendix A show the general test setup for completing the static heating testing. Each of the three (3) circuits have one of the manufacturer's (mfg. 1, mfg. 2, and mfg. 3) circuit breaker, the wire splicing devices on the black and white wire as described below, and three (3) each of receptacles from two of the manufacturers. Photos 4 through 7 show each of the setups with a sign indicating the circuit breaker, conductor material, wire splicing devices, and receptacles in that circuit.

For example, a setup had three (3) circuits with:

- Three different 10-amp circuit breakers (one each mfg. 1, mfg. 2, and mfg. 3)
- 14 AWG copper-clad aluminum NM-B conductors
- Mfg. 4 and mfg.5 wire splicing devices respectively, on the black and white conductors
- Three each of the mfg. 8 and mfg. 9 receptacles, and
- 14 AWG THHN copper-clad aluminum conductors for interconnection of the receptacles

These components were connected together to form a complete circuit. The second setup for 14 AWG copper-clad aluminum were same circuit breakers but with mfg.6 and mfg.7 wire spicing devices and with mfg. 10 and mfg.11 receptacles. The third and fourth setups were the same as 1 and 2 except using 15-amp circuit breakers and 14 AWG copper conductors.

Due to testing of several different circuit breakers, receptacles, and wire-splicing devices, the test arrangement was different than what may be used for certification testing of a single type of device. The test purpose was to approximate an actual installation under laboratory type conditions and not to establish certification type testing for any one device.

For tests 1 through 4 the three power supplies used were programmable constant current power supply sources. Each power supply was connected to one of the circuits and provided the current level specified for the tests being conducted.

For each of the four setups the following description is provided, see circuit diagram in figure 1 and Appendix A photos 1 through 7:

1) The three (3) circuits were mounted on an insulating sheet approximately 4 feet high and 8 feet wide. The partition had suitable framing to provide structural support for the partition to be in a vertical orientation to the floor.

2) During all testing, suitable barrier tape, safety cones, barriers, or other means was in place in accordance with the laboratory safety procedures to keep unauthorized persons out of the area and away from exposed live parts.

3) The individual conductors and devices were arranged horizontally with approximately 12 inches of vertical spacing between each horizontal assembly. Staples, or other fastening devices, such as cable ties, were used to keep the NM-B cable aligned with the respective test assembly.

4) For the circuit breaker testing the following was assembled:

   a) For the copper-clad aluminum conductors, three (3) 10-amp plug-on type panelboard circuit breakers were installed on sections of panelboard bus that are mounted onto the insulating board partition.

   b) For the copper conductors, three (3) 15-amp plug-on type panelboard circuit breakers were installed on sections of panelboard bus that are mounted onto the insulating board partition. The panelboard bus had a terminal for connection of one conductor from the power supply.

5) From the circuit breaker approximately 4 feet of 14-2 NM-B cable was installed and supported as provided above. From this center junction another 2 feet of 14-2 NM-B cable (copper-clad aluminum or copper as applicable) was installed. The junction in the middle had approximately 6 inches of exposed conductor and a splice completed with yellow wire-splicing devices as provided for the black, white and equipment grounding conductors. The following was applied to the two setups for the copper-clad aluminum conductors respectfully and repeated for the copper conductor setups.

   a) The black wire for the first circuit set of three used a mfg. 4 yellow wire-splicing devices

   b) The white wire for the first circuit set of three used an mfg. 5 yellow Wire Nuts®

   c) The black wire of the second circuit set of three used a mfg. 6 yellow wire-splicing devices

   d) The white wire of the second circuit set of three used a mfg. 7 yellow wire-splicing devices

   The manufacturer and location of the wire-splicing devices used was recorded for each test setup.

6) Six (6) receptacles were installed at the end of each horizontal assembly.

   a) The first set of circuits of copper-clad aluminum or of copper had three (3) mfg. 11 receptacles and then three (3) receptacles from mfg. 8 all connected in series.

   b) The second circuit of copper-clad aluminum or of copper had three (3) receptacles from mfg. 10 and then three (3) receptacles from mfg. 9 all connected in series.

   The receptacles were spaced a minimum of six (6) inches apart horizontally and/or vertically and were interconnected with a minimum of eighteen (18) inches of 14 AWG solid THHN copper-clad aluminum or copper conductors respectfully.

   The receptacles were mounted to the wall surface with screws, so that the face of the receptacle was approximately 1 1/2 inches from the insulating board partition surface.

   For each manufacturer the receptacles were connected to terminals as follows:

   a) One receptacle had the conductors installed at each wire binding screw and the conductors were wrapped counter-clockwise around the screw shank under the screw head, for 2/3 to 3/4 of wire binding screw circumference.

b) The second receptacle had the conductors installed into one side back terminal (entry hole) of the pressure plate terminal.

c) The third receptacle had two conductors installed into each back-side pressure plate terminal as follows: one conductor of the test circuit into each side (hot and neutral) of the pressure plate terminal and one additional short conductor of equal diameter and material into the other side (entry hole) of the same pressure plate terminal. The second conductor was to fill the slot only and is not required for any other purpose than to balance the mechanical clamping forces applied.

Each receptacle had a shorting plug installed as follows:

a) The ungrounded (BLACK) and grounded (WHITE) contacts of each receptacle being tested were connected together by a mated attachment plug having rigidly-attached solid blades.

b) The terminals of each attachment plug were short-circuited by the shortest feasible length of 14 AWG stranded copper conductor from type SJ flexible cord.

c) The flexible cord shorting conductor was mechanically terminated into the pressure plate terminals and the connection torqued to the manufacturer's specification.

7) The conductor from the neutral terminal of the last receptacle in the series was routed back using the white wire in the NM-B cable, through the wire-splicing devices and terminated at a terminal bar mounted to the support board for connection back to the power supply.

8) All connections were tightened as follows. Torquing tools were calibrated and calibration documented:

a) The circuit breaker terminals were torqued as specified on the circuit breaker nameplate.

b) The wire-splicing devices were torqued to the manufacturer's specification in the instructions. If there was no specification, then the 14 AWG copper-clad aluminum conductors were torqued to 2.47 lbf-in and the 14 AWG coper conductors were torqued to 4.11 lbf-in [Specification from UL 486C – 9.1.9.4]

c) The terminals of the receptacles and of the attachment plugs were torqued to the manufacturer's specification in the installation instructions. If there was no torque specification provided, then the terminals were torqued to 9 lbf-in.

9) Thermocouples were connected as shown in the diagram, figure 1 and as shown in Appendix A photos 8 and 11 through 14.

a) Thermocouples were installed on device terminals so that it did not interfere with the terminal.

For the wire-splicing devices, the thermocouples were attached into the wire bundle within the wire-splicing devices.

b) The thermocouples that measured center wire temperatures had a flap of the NM-B jacket and the conductor insulation peeled back to expose the conductor. The thermocouple was attached with thermo-cement to the conductor and the conductor insulation and jacket flap folded back to the original position with two wraps of black electrical tape wrapped to hold the flap in place.

c) A thermocouple was positioned midway in elevation to the test setup for each circuit and recorded the ambient temperature as testing was completed.

10) The power supply was a programable constant current power supply. The current was monitored and recorded by the data logger along with the temperature recordings. The power supply was connected to the lug on the panelboard bus serving the circuit breaker and to the neutral terminal bar where the return white conductor from the NM-B cable was terminated.

3.0 Materials for Testing

The generous support with the supplying of materials by Copperweld, Eaton, Hubbell, Legrand, Leviton, and Siemens are acknowledged and appreciated. The following materials were used to complete the setups as described above.

1) The circuit breakers for the copper-clad aluminum testing were single pole 10 Amp 120/240 Volt, 10,000 interrupting rating with five (5) each of the following (two (2) breakers to be used and the others as backup):
   a) Eaton BR110,
   b) Schneider QO110, and
   c) Siemens QP110.
2) The circuit breakers for the copper testing were single pole 15 Amp 120/240 Volt, 10,000 interrupting rating with five (5) each of the following (two (2) breakers to be used and the others as backup):
   a) Eaton BR115,
   b) Schneider QO115, and
   c) Siemens QP115.
3) The yellow wire-splicing devices were as follows:
   a) Gardner-Bender Ultra WingGard
   b) Ideal Wing-Twist
   c) 3M Performance Plus Red/Yellow+
   d) Commercial Electric WT4

4) The receptacles for both the copper-clad aluminum and copper testing were:
    a) Eaton (Cooper) model TR6250W, 5-15R single receptacle with wire binding screw and pressure plate terminals (back and side wired)
    b) Hubbell model HBL 5261, 5-15R single receptacle with both wire binding screw and pressure plate terminals (back and side wired)
    c) Legrand (Pass & Seymour) model TR 5251, 5-15R single receptacle with both wire binding screw and pressure plate terminals (back and side wired)
    d) Leviton model T 5015, 5-15R single receptacle with both wire binding screw and pressure plate terminals (back and side wired)
5) Thermocouples, UL calibrated, model UL 3055, with sufficient length to connect and route to datalogger recording device.
6) Datalogger recording device and laptop or another required device for the datalogger.
7) Programable power supplies from Eaton laboratory. Maximum current for the copper was 30 Amps and for the copper-clad aluminum was 20 amps.
8) Approximately 50 feet each of 14-2 w/ground copper-clad aluminum NM-B cable and of 14-2 w/ground copper NM-B cable.
9) Approximately 50 feet each of 14 AWG solid THHN copper-clad aluminum and 14 AWG solid THHN copper single conductors.

4.0 Test Procedures

4.1 Conductor Material Testing

A sample of each the 14-2 NM-B and 14 AWG THHN copper-clad aluminum conductors used for the testing was returned to the Copperweld factory laboratory for analysis. The testing was performed to confirm the conductors that were used for the testing at Eaton were in fact 14 AWG and met the requirements for copper-clad aluminum as specified in UL 83 Annex E and ASTM B566. The packaging was photo documented from the Eaton laboratory and the opening of the package at the Copperweld laboratory photo documented.

The Copperweld laboratory technician, who routinely performs the full ASTM B566 battery of testing, completed all the testing and documented it on a Copperweld laboratory test data sheet.

Standard materials testing was completed by Copperweld laboratory technicians including:

- DC resistance
- Copper thickness
- Copper Volume
- Tensile strength
- Elongation
- Adhesion
- Cohesion

The following tests, as completed by the Copperweld laboratory technician, were witnessed and documented by the UL Field Representative that normally completes follow-up inspections of copper-clad aluminum conductors as part of the recognized component program, under category DVVU2:

- DC resistance
- Copper thickness
- Tensile strength
- Elongation

4.2 Terminal Temperature Testing

The following test procedures, except the flexing test, used references from parts of UL 486(A)(B); UL 486(C); UL 489; UL 20; and UL 498.

As stated, the tests 1 through 4 were completed with all three (3) manufacturer's circuit breakers in three circuits at one time. These tests are identified with the test number from below with an "a", "b" or "c' representing the representative circuit breaker used:

a. mfg. 1 circuit breaker

b. mfg. 2 circuit breaker

c. mfg. 3 circuit breaker

This same nomenclature is used in the data sheets found in Appendix C. To minimize test setups, and the number of times terminations are completed or taken apart, all four (4) static heating tests were completed for the "a", "b", and "c" circuit setups. After these tests were completed, then the next setup was assembled by changing the wire splicing devices and receptacles or changing the conductors from copper-clad aluminum to copper as applicable.

All static heating tests, tests 1 through 4 commenced with all components at ambient temperature.

For all testing temperature equilibrium is three consecutive readings taken at no less than 5-minute intervals indicating no further rise in temperature above the ambient temperature. For tests where the circuit breaker trips, which may be before temperature equilibrium was attained, the last three recorded temperatures were recorded onto the data sheets.

Test #1 – Rated Current Temperature

Each circuit was operated at 100% of the branch circuit rating (CCA - 10 Amps or Cu - 15 Amps) until temperature equilibrium was achieved. The final temperatures were recorded. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at one-minute intervals.

Test #2 – Circuit Breaker Overload Temperature

Each circuit was operated at 135% of the branch circuit rating (CCA - 13.5 Amps or CU - 20.25 Amps) until temperature equilibrium was achieved or the circuit breaker tripped whichever came first. The circuit breaker elapsed trip time was recorded. Table 1, in section 4.3 below, provides the expected circuit breaker trip times from the manufacturer's time current curves. If the circuit breaker tripped, the last three recorded temperatures of the conductor, wire-splicing devices and wiring device were recorded on the datasheet. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at 20-second intervals.

Test #3 – Wiring Device Overload Temperature

Each circuit was operated at 150% of the branch circuit rating (CCA - 15 Amps, or CU - 22.5 Amps) until temperature equilibrium was achieved or the circuit breaker tripped whichever came first. The circuit breaker elapsed trip time was recorded. Expected circuit breaker trip times are in a table 1 below in section 4.3 of procedure. If the circuit breaker tripped, the last three recorded temperatures of the conductor, wire-splicing devices and wiring device were recorded on the datasheet. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at 10 second intervals.

Test #4 – Circuit Breaker Overload Temperature

Each circuit was operated at 200% of the branch circuit rating (CCA - 20 Amps, or CU 30 Amps) until temperature equilibrium was achieved or the circuit breaker trip tripped whichever came first. The circuit breaker elapsed trip time was recorded. Expected circuit breaker trip times are in a table 1 below in section 4.3 of procedure. If the circuit breaker tripped, the last three recorded temperatures of the conductor, wire-splicing devices and wiring device were recorded on the datasheet. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at 7 second intervals.

Test #5 – Wiring Device Thermal Cycling

The thermocycling testing is underway at the time this report is being written. In order to meet NFPA public input deadlines, this report is for all testing completed at this time. A subsequent report will be written for the thermocycling testing.

Test # 6 – Conductor Flexing Test

a) A standard 2 x 3 device box was mounted to a wood stud fixed to a table for support. See Appendix A photo 15. The device box was mounted with screws through the back of the box.

b) A length of 14-2 AWG copper-clad aluminum NM-B cable was installed into the device box using NM cable clamps. The NM-B had a minimum of 1/4 inch of cable jacket projecting into the box past the clamping device.

c) The outside end of the NM-B cable was connected to a digital multimeter to indicate continuity of the circuit through the receptacle, see Appendix A photo 16.

d) The NM-B cable jacket was stripped and cut to length so that 6 inches of conductor projected beyond the cable entry to the box and 3 inches beyond the front edge of the device box. A receptacle was terminated to the NM-B cable conductors and the conductors shaped to fit back in the box so the receptacle yoke mated with the box front edge.

e) For the first test, the NM-B conductors were installed using the wire binding screw with the conductors wrapped counter-clockwise around the screw shank under the screw head, for 2/3 to 3/4 of wire binding screw circumference.

f) A shorting plug was installed into the receptacle.

g) The 6-32 screws were removed and approximately 4-inch-long 10-32 screws were fixed to the device box ears and through the yoke of the receptacle providing a guideway for repeated insertion and removal. The 10-32 screws had nuts installed in the inside and outside of the device box ears to make rigid to the box, see Appendix A photo 15.

h) With the assembly complete, the receptacle was pushed into and retracted from the box for 10 cycles and the continuity monitored on the digital multimeter, see Appendix A photos 17 through 19.

i) Steps ‘b’ through ‘h’ were repeated two more times with new lengths of 14-2 NM-B copper-clad aluminum cable.

- For the second test the receptacle was assembled with the back-wiring pressure plate terminal and a single conductor.
- For the third test the receptacle was assembled with the back-wiring pressure plate terminal and two conductors for mechanical balance on the wiring terminal.

4.3 Bimetallics Testing Circuit Breaker Trip Times

The below table provides the expected trip times based on the manufacturers time current curves at 40°C. The testing for this project was completed at about 22°C, based on the ambient temperatures recorded. Therefore, the trip times recorded from this testing may be somewhat higher but should not exceed the limits set in the UL Standard.

The UL standard specifies that calibration testing be competed at an ambient temperature of 25°C. The UL standard calibration testing at 25°C specifies that at:

- 135% of rating the maximum trip time for a 0 - 50-amp circuit breaker is 1 hour
- 200% of rating the maximum trip time for a breaker 0 – 30 amps is 2 minutes.

Table 1

Manufacturer	Catalog No.	Trip Time Range in Seconds @ 40°C			
		100% rated current	135% rated current	150% rated current	200% rated current
Eaton	BR110	No trip	35 - 3600	20 - 500	12 - 40
	BR115	No trip	35 - 3600	20 - 500	12 - 40
Schneider	QO110	No trip	40 - 500	26 - 240	10 - 60
	QO115	No trip	30 - 210	21 - 100	8 - 28
Siemens	QP110	No trip	60 -800	40 - 450	19 - 150
	QP115	No trip	30 - 250	20 - 100	9 - 38

5.0 Test Results

5.1 Copper-Clad Aluminum Conductor Material Testing

After the static heating testing was completed, Eaton laboratory technicians packed and shipped samples of the copper-clad aluminum conductor, NM-B cable and THHN single conductor, that had been used for the testing to Copperweld's laboratory for verification testing. Appendix A photos 22 to 24 show the samples the Eaton laboratory technicians packaged into the bag and shipped to the Copperweld laboratory. Note the date on these photos as August 24, 2020. Appendix B pages B1 and B2 show photos of the received package and opening of that package with these samples for the testing.

The samples of the 14 AWG copper-clad aluminum NM-B cable and the 14 AWG copper-clad aluminum THHN single conductors were tested in the Copperweld factory laboratory on August 27, 2020. The Copperweld laboratory testing data is provided in Appendix B page B3 and the calibration of the test equipment on pages B4 through B6.

The UL field engineer that routinely completes the quarterly follow-up inspections for the copper-clad aluminum conductor witnessed the testing required under the UL standard follow-up program that was completed on August 27, 2020. As shown in Appendix B, page B7, the UL field engineer confirmed that "*the 14 Awg from the NMB and THHN samples passed the UL tests for DVVUs, including Tensile, Elongation, copper thickness and DC resistance*"

The test results for the copper-clad aluminum confirm that the conductors used for this testing were 14 AWG and that the material tested met the requirements in ASTM B566.

5.2 Test Setup and Torquing

The test setups were as described in Section 2.0 of this report and shown with photographs in Appendix A. The terminations were tightened to the applicable torque value with a calibrated torque wrench. For the static heating testing the following tables show the torque values applied for each setup and device terminal.

Copper-Clad Aluminum conductors with mfg. 11 and mfg. 8 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 4 wire splicing device	2.47	no	yes
mfg. 5 wire splicing device	2.47	no	yes
mfg. 11 receptacles	9	no	yes
mfg. 8 receptacles	12	yes	no

Copper-Clad Aluminum conductors with mfg. 10 and mfg. 9 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 6wire splicing device	2.47	no	yes
mfg. 7 wire splicing device	2.47	no	yes
mfg. 10 receptacles	9	no	yes
mfg. 9 receptacles	9	no	yes

Copper conductors with mfg. 11 and mfg. 8 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 4 wire splicing device	4.11	no	yes
mfg. 5 wire splicing device	4.11	no	yes
mfg. 11 receptacle	9	no	yes
mfg. 8 receptacle	12	yes	no

Copper conductors with mfg. 10 and mfg. 9 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 6wire splicing device	4.11	no	yes
mfg. 7 wire splicing device	4.11	no	yes
mfg. 10 receptacle	9	no	yes
mfg. 9 receptacle	9	no	yes

5.3 Static Heating Test

The following are the results of the static heating testing, tests 1 through 4 with references to the applicable appendix pages. For all the testing data, the final three recorded temperature values are shown at either temperature equilibrium or the final three temperatures recorded before a circuit breaker tripped. All testing commenced with all test measurement points at ambient temperature. Also shown in the tables in the appendix are:

- The elapsed time from the start of the test,
- The ambient temperature recorded at the time of the recorded values, and
- The current at the time of the recorded values.

Since the UL standards reference temperature rise for most of the devices, those calculated values are shown immediately adjacent to the recorded values. The temperature rise was calculated by taking the recorded temperature and subtracting the ambient temperature recorded for that time.

Since the method of termination on each the three receptacles from one manufacturer was different (wire binding screw, back wired with pressure plate with one conductor and back wired with pressure plate with two conductors) exact data comparison of terminal temperature needs to be done line by line. For example, from appendix page C1 – 1, the line 1a for copper-clad aluminum, top table, needs to compare with line 1a for copper, bottom table.

Otherwise, data in general for terminal temperatures of specific devices, circuit breakers, wire splicing devices and receptacles as well as the conductor, can be compared in general. To facilitate ease of comparison, the pages in appendices C1 though C4 have been arranged so that each page has the copper-clad aluminum data in the top table and the related copper data in the bottom table.

5.3.1 Static Heating at 100% Rated Current

The data for the static heating testing at 100 percent of rated current are shown in Appendix C1. The recorded values are all after the temperatures being recorded had achieved temperature equilibrium. As can be seen in line by line or with general comparisons, the terminal and conductor temperatures for the copper-clad aluminum were less than those recorded for copper when operating at rated current. All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.2 Static Heating at 135% Rated Current

The data for the static heating testing at 135 percent of rated current are shown in Appendix C2. The 135 percent current level is a calibration point for circuit breakers, rated up to 50 amps, where they are required to trip within 1 hour. The recorded values are the last three recorded temperatures before the circuit breaker tripped.

In doing analysis consideration must be given to the fact the temperatures recorded were still rising when the circuit breaker tripped. Therefore, when doing line by line or general comparisons, the circuit breaker trip time must be considered. It is noted the mfg. 1 10-amp circuit breaker tripped approximately twice as fast as the 15-amp circuit breaker, 8 vs. 19 seconds, and this resulted in higher recorded temperatures for copper. The test results with the mfg. 2 circuit breakers was reversed with the 15-amp breaker tripping in approximately half the time of the 10-amp circuit breaker, 3.5 vs. 5.5 seconds. Even with this time disparity the copper-clad aluminum with the longer time recorded lower temperatures than the copper. The trip times for the mfg. 3 circuit breakers had the 10-amp breaker tripping 3 times longer than the 15-amp breaker, but the copper-clad aluminum terminal temperatures still were less than or near to the copper terminal temperatures.

All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.3 Static Heating at 150% Rated Current

The data for the static heating testing at 150 percent of rated current are shown in Appendix C3. The 150 percent current level is a static heating test current for wiring devices. The recorded values are the last three recorded temperatures before the circuit breaker tripped.

In doing analysis consideration must be given to the fact the temperatures recorded were still rising when the circuit breaker tripped. Therefore, when doing line by line or general comparisons, the circuit breaker trip time must be considered. The test data results shown in appendix C3 generally follow that same pattern as occurred with the 135 percent testing.

All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.4 Static Heating at 200% Rated Current

The data for the static heating testing at 200 percent of rated current are shown in Appendix C4. The 200 percent current level is a calibration point for circuit breakers, rated up to 30 amps, where they are required to trip within 2 minutes. The recorded values are the last three recorded temperatures before the circuit breaker tripped.

In doing analysis consideration must be given to the fact the temperatures recorded were still rising when the circuit breaker tripped. Therefore, when doing line by line or general comparisons, the circuit breaker trip time must be considered. The test data results shown in appendix C4 generally follows the same pattern as occurred with the 135 percent and 150 percent testing.

All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.5 Static Heating at 135% Rated Current – Circuit Breaker Did Not Trip

The first attempt at the 135 percent testing found the mfg. 2 10-amp circuit breaker not to trip within the required 1-hour time. The data for this static heating test at 100 percent and at 135 percent of rated current are shown in Appendix C5. The top table on this appendix page is the 100 percent test data and the bottom table is the 135 percent test data. As stated before, the 135 percent current level is a calibration point for circuit breakers, rated up to 50 amps, where they are required to trip within 1 hour.

Since the circuit breaker failed to trip the test was stopped shortly after the 1-hour time had elapsed. Analysis of the 135 percent data recorded found that after 1-hour at this current level, above the proposed rated current, none of the terminal or conductor temperatures had risen above UL standards allowances.

5.3.6 Flexing Tests

The data for the flexing testing is shown in Appendix D. There is no UL or other known industry standard for this specific test and the test process used was established and agreed to by the task group to represent an installation condition. Three tests were conducted, one with the receptacle terminated with the 14 AWG copper-clad aluminum wrapped around the wiring binding screw, the second with a single conductor back wired into the pressure plate and the third with two conductors back wired into the pressure plate.

The test results found that after 10 cycles of fully inserting and removing the receptacle to the full extended position, the copper-clad aluminum

conductors for the back wired assemblies did not break and therefore passed this test.

For the wire binding screw termination, the first test found the flexing for the 10 cycles passed where the conductors did not break. But when the conductors were being removed both the black and white conductors broke off near the end of the insulation, see Appendix A photo 20. A second test was conducted and the black conductor was found to break off near the end of the insulation on the eighth cycle. A third test was completed, using a 14 AWG NM-B sample from another coil, and this assembly passed the 10 cycles and removal of conductors with no breaking or signs of weakening in the stripped portion of the conductor, see Appendix A photo 21.

As stated, there is no industry standard for completing this flexing test and the test was conducted due to specific questions asked by members of the task group. The results demonstrate that there may be limits to the amount of flexing these conductors can withstand, but it should be noted that in normal installations the insertion and removal of a wiring device occurs far less than the eight to ten times as conducted in this test.

6.0 Conclusions

The results from the temperature testing conducted in this project found the 14 AWG copper-clad aluminum to have terminal and conductor temperatures generally less than copper when tested at the 60°C ampacity values. In all cases, the temperature and temperature rise recorded were below those provided in the referenced UL standards. The flexing testing found that there may be some limitations to the number of flexing operations a 14 AWG copper-clad aluminum conductor can withstand, but the number of flexing operations to breakage is above those normally encountered in any installation.

As stated in the introduction, this testing project was to answer specific questions raised by the Bimetallics Task Group regarding temperature performance of 14 AWG copper-clad aluminum compared with 14 AWG copper in typical applications. **While testing conducted followed parts of several UL standards, it is to be understood the testing was only conducted to provide specific performance data and information as requested by the task group. The testing does not provide performance or data for certification of any of the components used for the testing.**

7.0 Test Equipment and Calibration

The following test and measurement equipment was used for the testing. The certificates of calibration for each of the above items is provided in Appendix E.

Description	manufacturer	Eaton Asset #	Cal Date	Cal Due
Thermocouples	Pacific Test and Measurement	N/A	7/10/2020	N/A
DACQ datalogger	Agilent (HP)	EM7054	7/16/2020	7/16/2021
DVM	Fluke	EM4437	7/16/2020	7/16/2021
DVM	Fluke	EM7014	7/16/2020	7/16/2021
DVM	Fluke	EM7024	7/16/2020	7/16/2021
CT	AEMC	EM6996	7/16/2020	7/16/2021
CT	AEMC	EM6997	7/16/2020	7/16/2021
CT	AEMC	EM8032	7/16/2020	7/16/2021
Torque wrench	CDI	EM8363	7/14/2020	7/14/2021
Tape measure	Stanley	EM6927	7/16/2020	7/16/2021

Appendix A - Photos



Photo 1 – Laboratory View



Photo 2 – Test Board and Test Equipment Arrangement

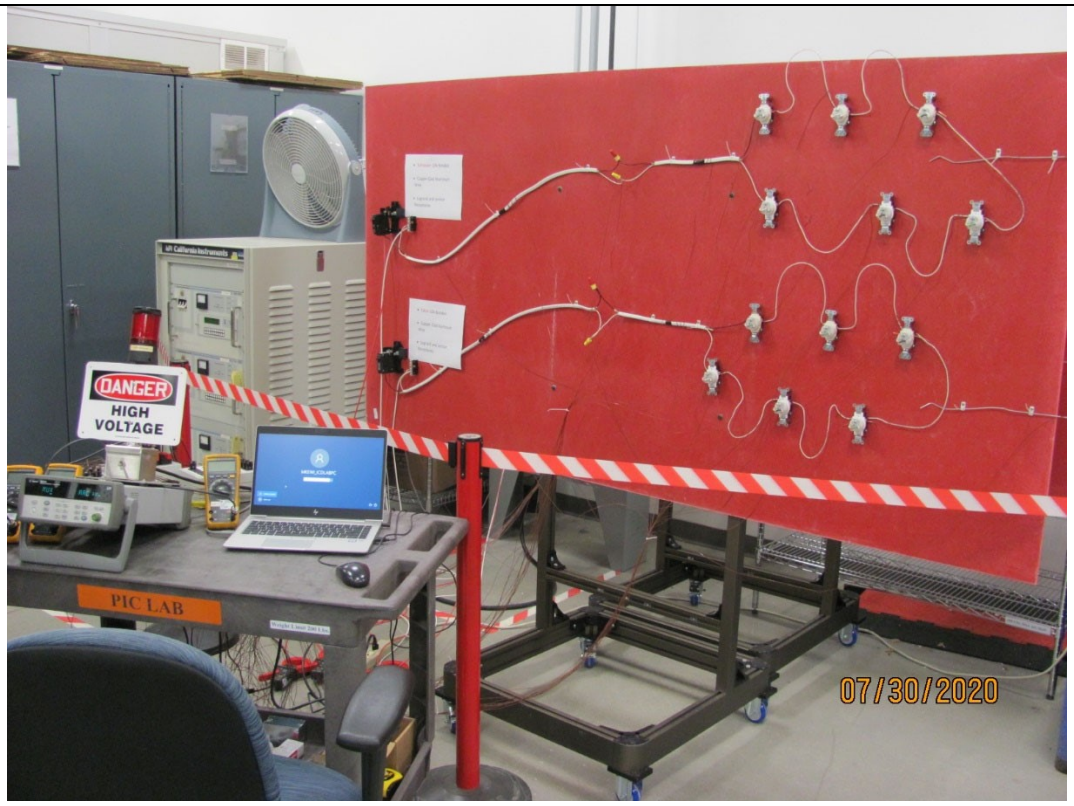


Photo 3 – Test Board and Test Equipment Arrangement



Photo 4 – Copper-Clad Aluminum with Eaton and Hubbell Receptacles

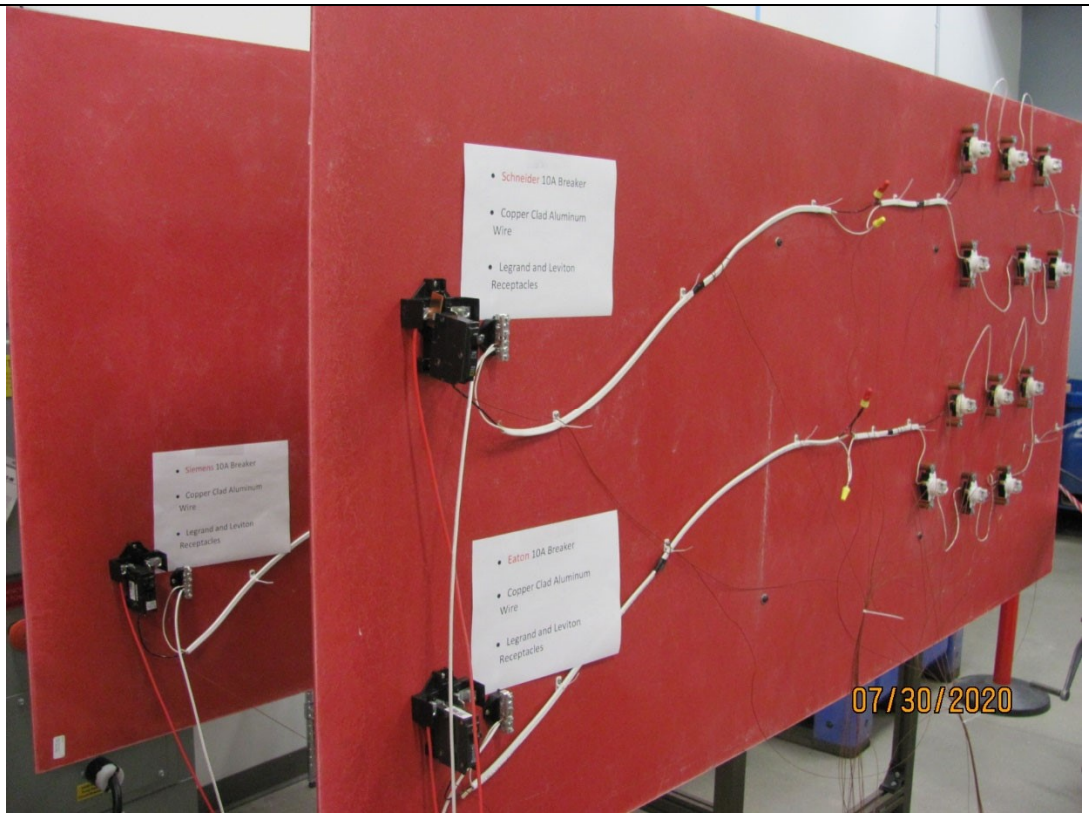


Photo 5 – Copper-Clad Aluminum with Legrand and Leviton Receptacles



Photo 6 – Copper with Eaton and Hubbell Receptacles

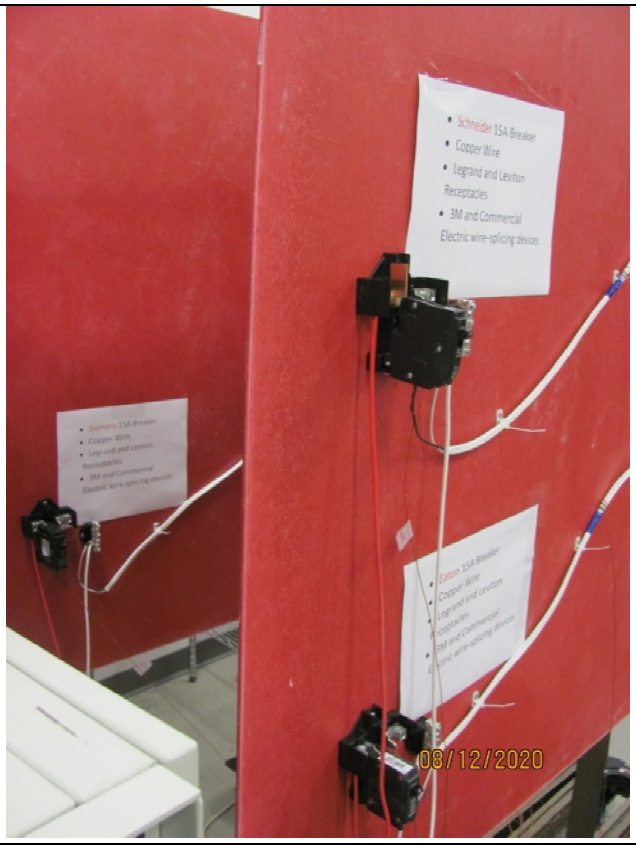


Photo 7 – Copper with Legrand and Leviton Receptacles

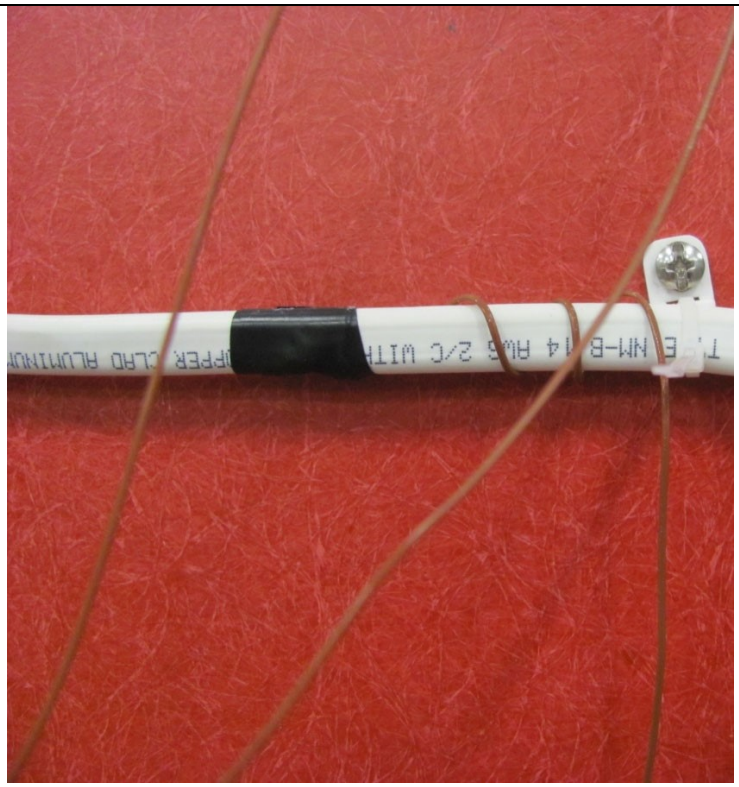


Photo 8 – Copper-Clad Aluminum NM-B Cable

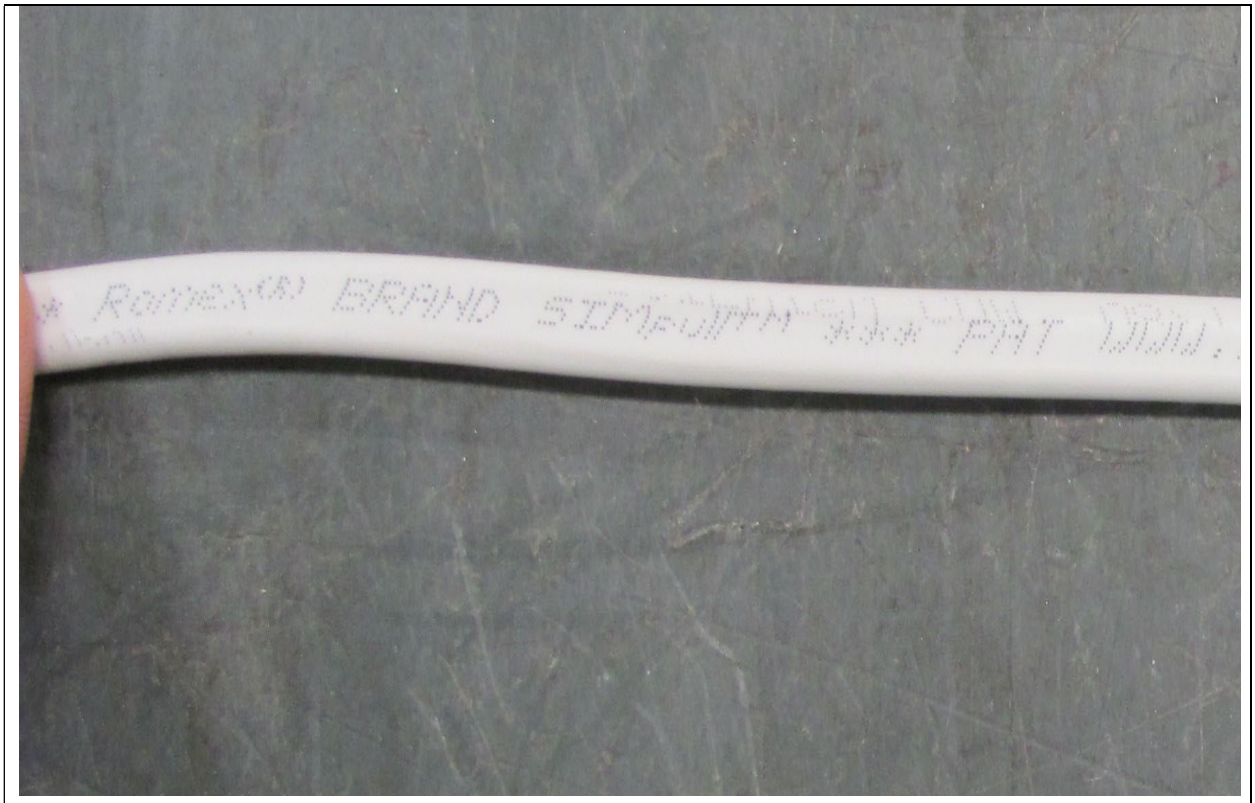


Photo 9 – Copper NM-B Cable



Photo 10 – Copper NM-B Cable Packaging

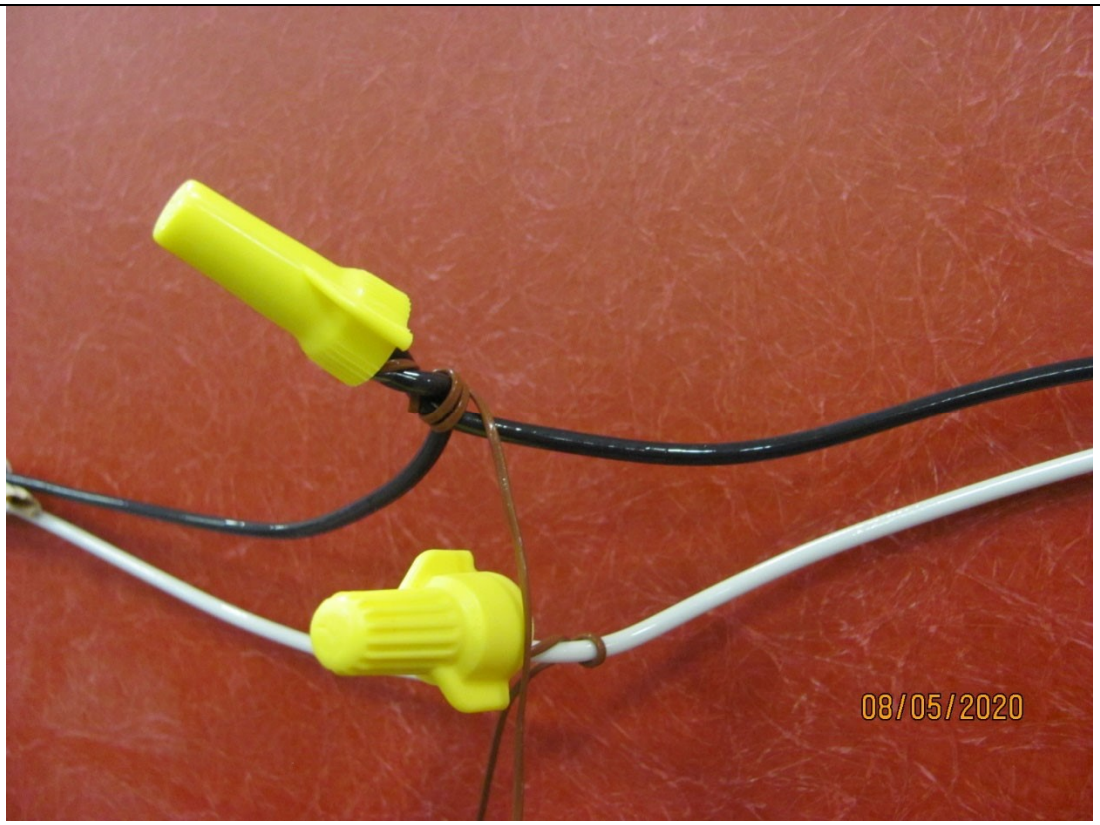


Photo 11 – Typical Installation of Wire Splicing Devices with Thermocouple



Photo 12 – Typical Installation of Receptacle using Wire Binding Screw

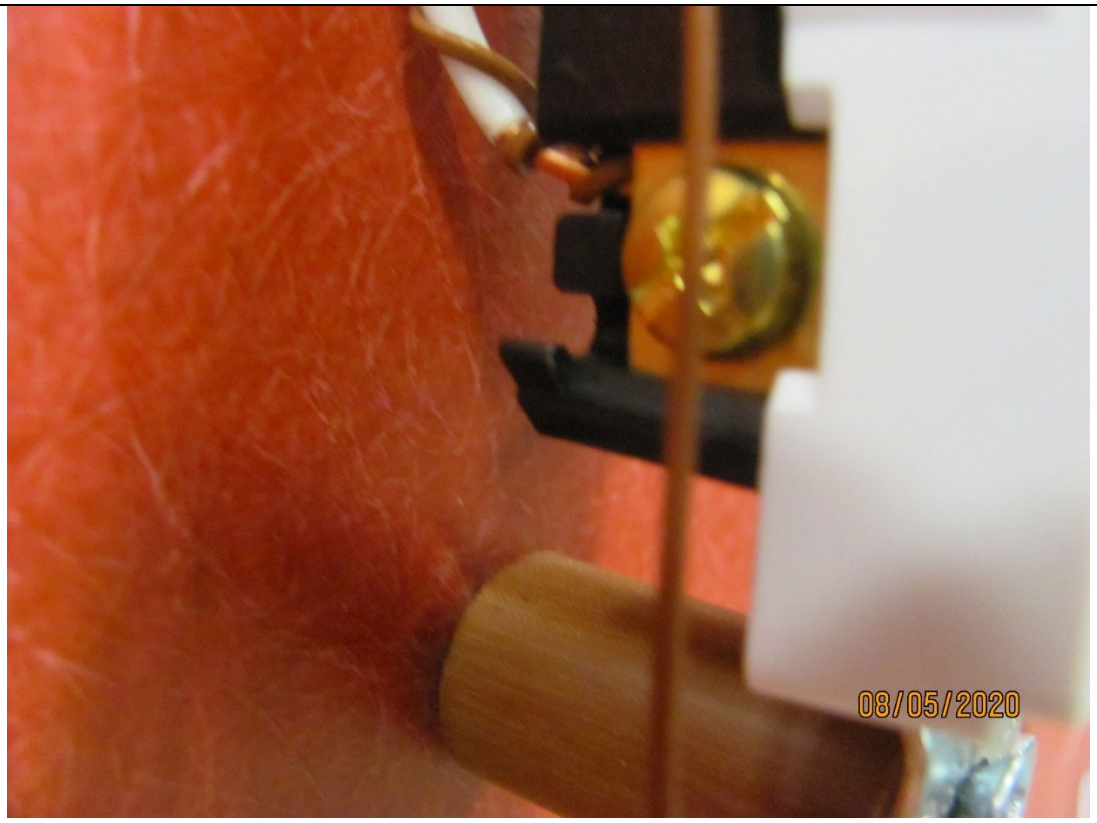


Photo 13 – Typical Installation of Receptacle Since Conductor Back Wired



Photo 14 – Typical Installation of Receptacle Two Conductors Back Wired

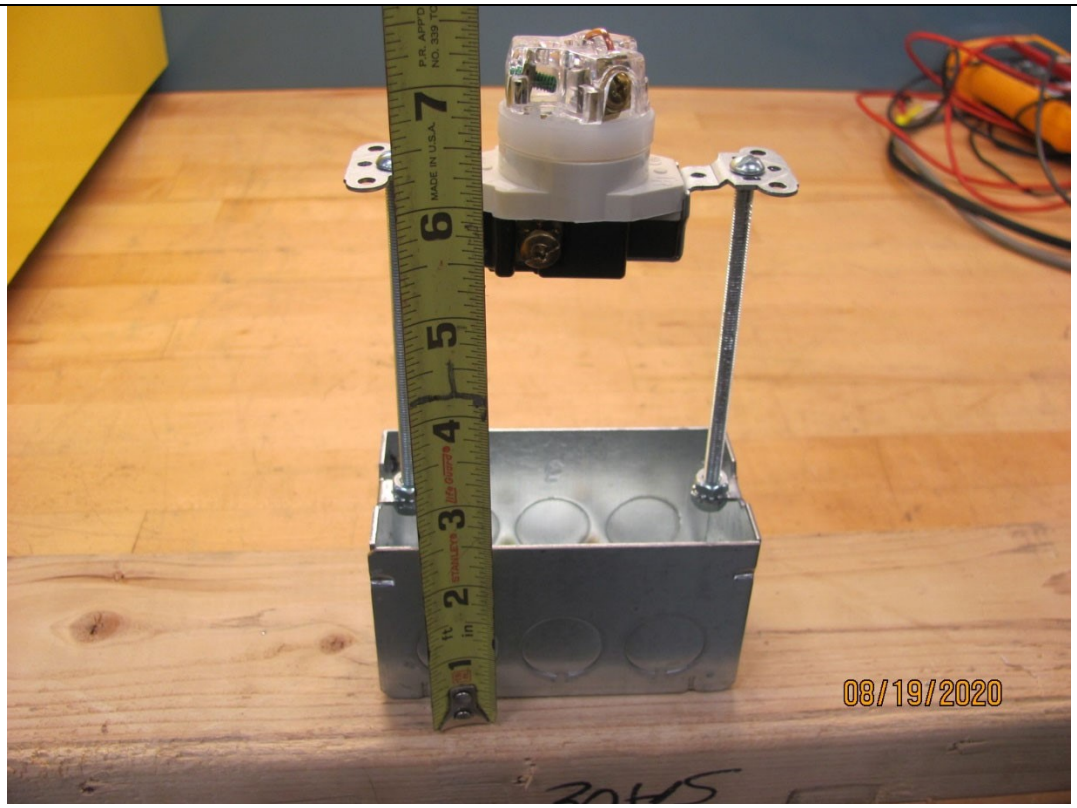


Photo 15 – Flexing Test Setup

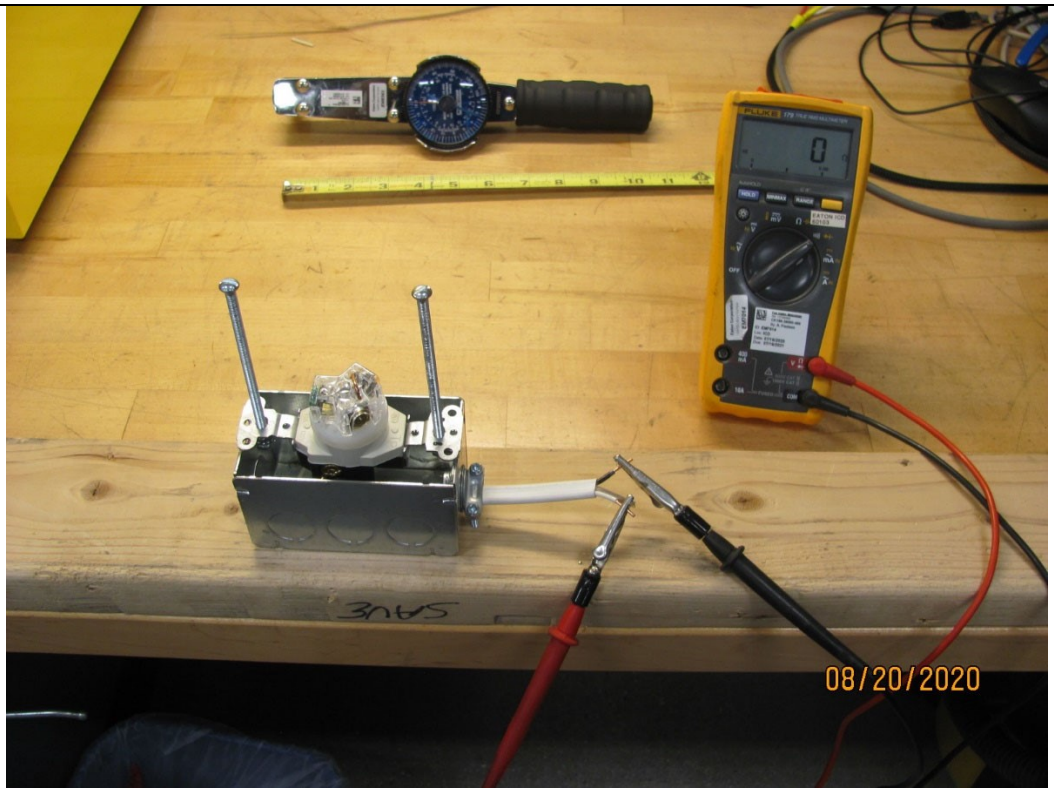


Photo 16 – Flexing Test Setup

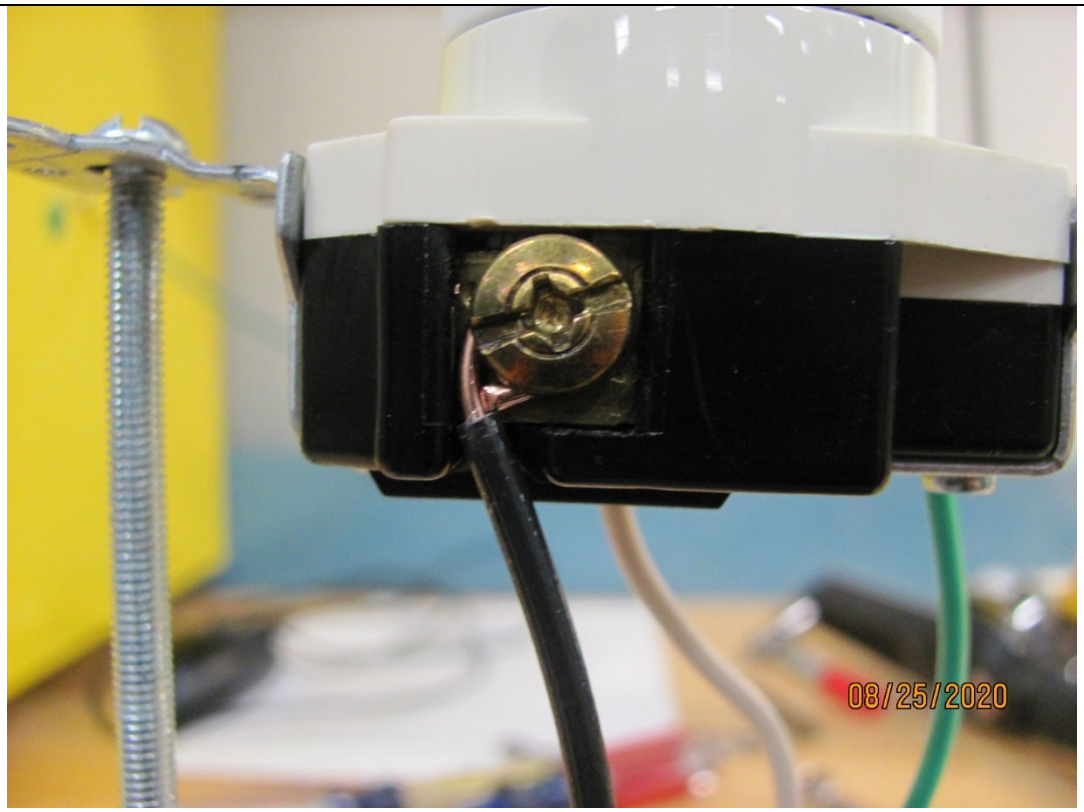


Photo 17 – Flexing Test Fully Extended

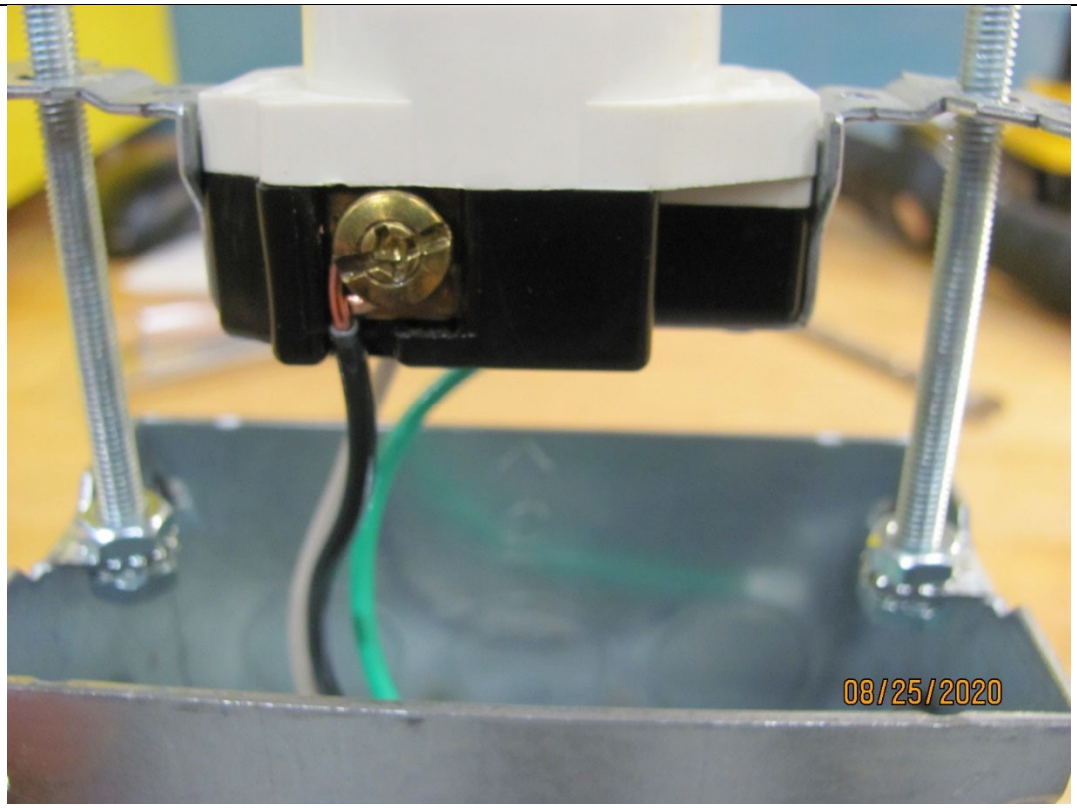


Photo 18 – Flexing Test Partial Insertion

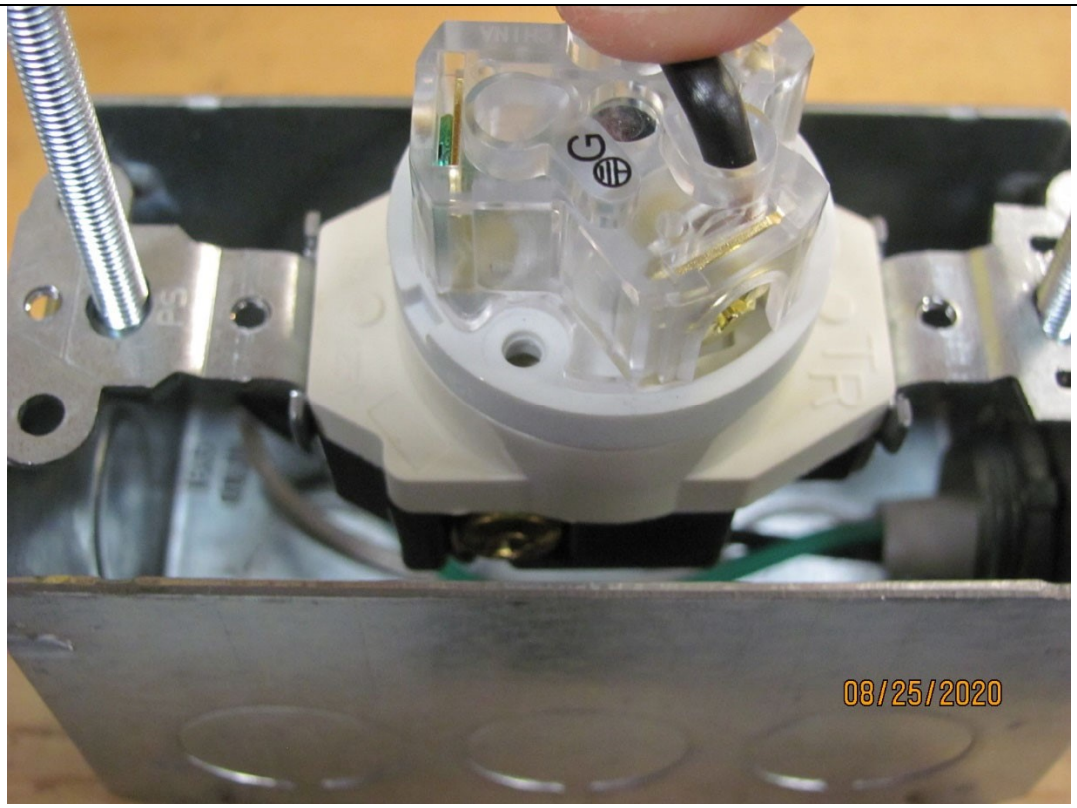


Photo 19 – Flexing Test Fully Inserted



Photo 20 – Flexing Test Broken Conductors When Removing

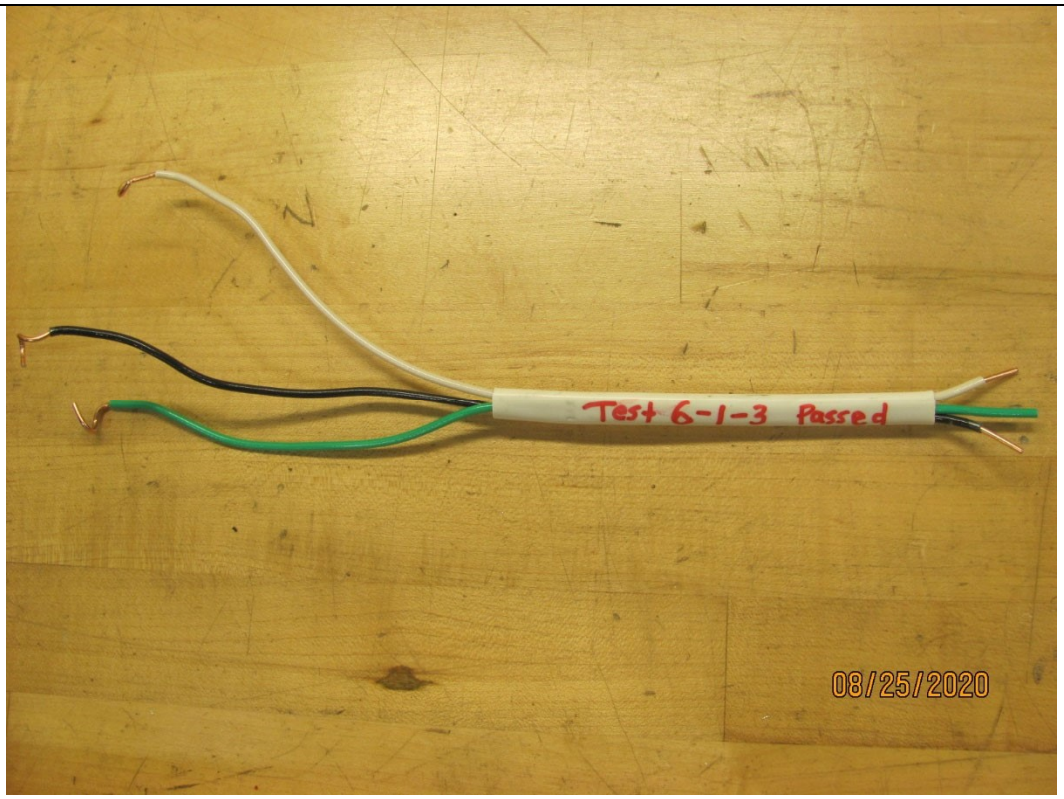


Photo 21 – Flexing Test Repeat No Conductor Breakage

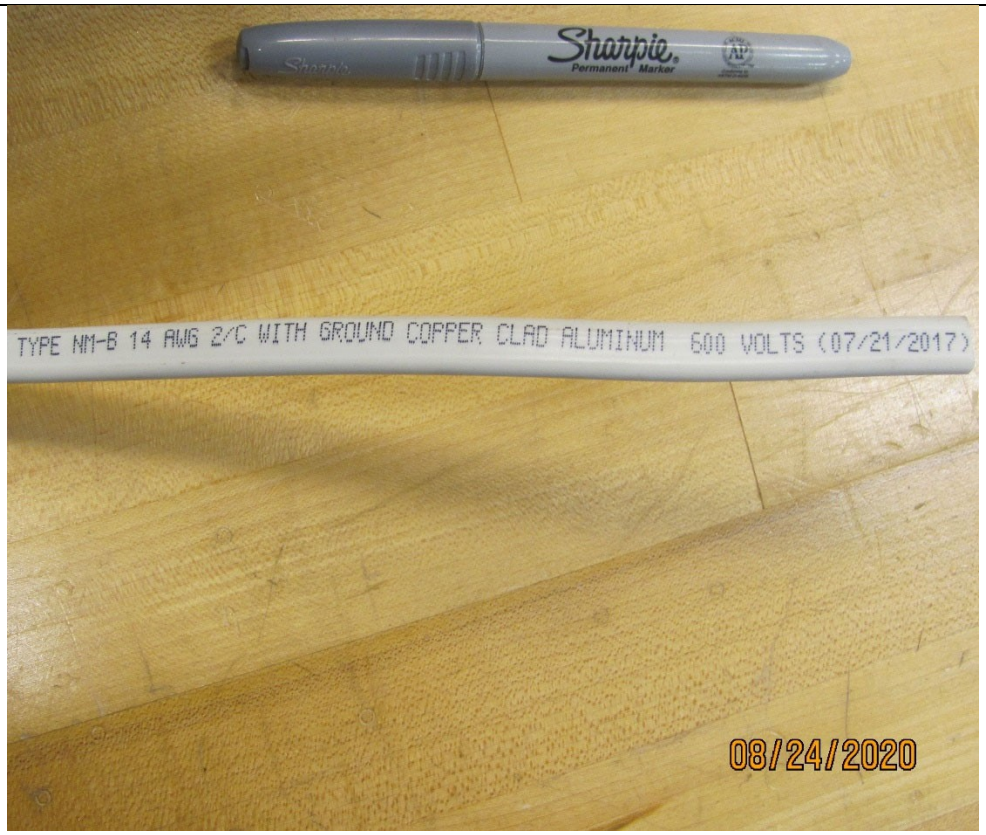


Photo 22 – Copper-Clad Aluminum NM-B Sample Packaging at Eaton

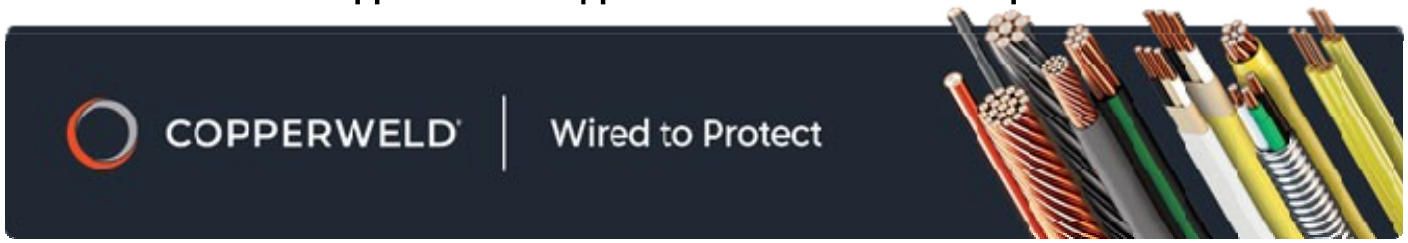


Photo 23 – Copper-Clad Aluminum THHN Sample Packaging at Eaton



Photo 24 – Copper-Clad Aluminum Sample Packaging at Eaton

Appendix B - Copper-Clad Aluminum Lab Report



The power of two

Metallurgical Laboratory Report

Customer:	**NEC Bimetallics Task Group**		
Subject:	**14 AWG Building Wire—NMB and THHN**		
Date:	**8-27-2020**	**Report No:**	**456**

Analysis By:	**Sammy Hampton --Metallographer**
Authored By:	**Sammy Hampton –Metallographer**
Approved By:	**Bill Lewey– QA Manager**

Tested to ASTM Designation: B 566-- 04a

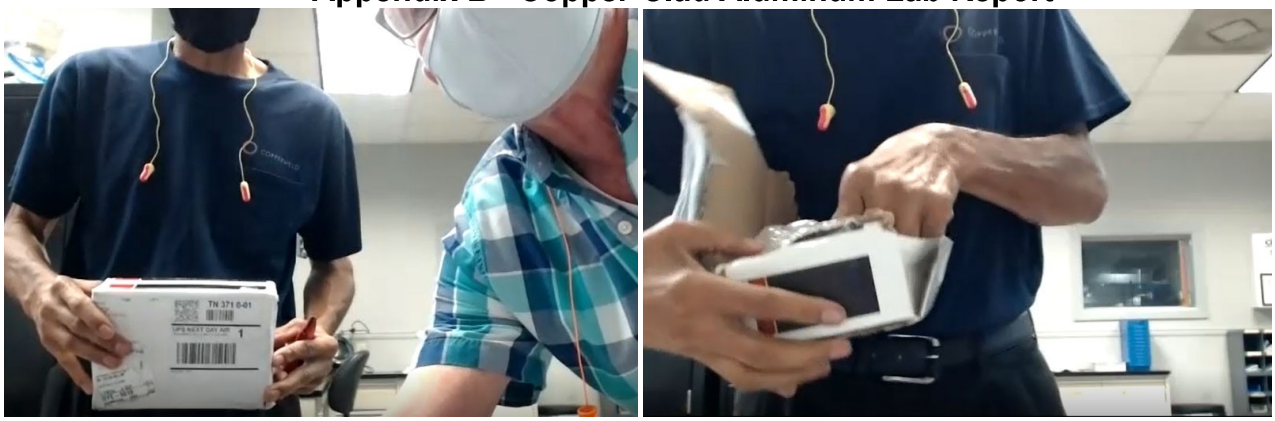
The NM and THHN class samples in this report were sent to Copperweld via a sealed package by Eaton Menomonee Falls test lab. The chain of custody was not broken. The testing was witnessed by a third party as part of routine auditing service. The witnessing session was recorded. The copper clad aluminum conductor material from these samples that was tested on August 27, 2020 by the Copperweld Metallurgical Lab was manufactured by Copperweld Bimetallics to ASTM B566 standards.





Package as received from Eaton

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Opening the Package



Package Contents

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Appendix B - Copper-Clad Aluminum Lab Report

The wire consists of a core of aluminum with a continuous outer cladding of copper metallurgically bonded to the core throughout and meets the requirements of this specification (5.1).

Test required	Test result	ASTM B 566 requirement	Result
Diameter	**0.0641”**	**± 0.0001 0.0640” minimum 0.0642” maximum**	**Pass**
Break load (lbs.)	55 pounds	64.4 pounds maximum	**Pass**
Tensile strength (psi)	17195 psi	20000 (psi) maximum	**Pass**
% elongation	22.78%	15.0% minimum	**Pass**
Copper thickness (minimum)	0.00148” = 4.6% of wire radius	minimum copper thickness= 3.5% of wire radius	**Pass**
Copper volume	10.05%	8% minimum 12% maximum	**Pass**
Adhesion test	No separation (see attached image 1)	The wire shall be repeatedly reverse bent to fracture by any convenient means. The copper clad aluminum wire shall be free from cladding delamination.	**Pass**
Cohesion test	No seams or splits (see attached images 2 and 3)	The copper clad aluminum wire shall be free from seams or splits	**Pass**

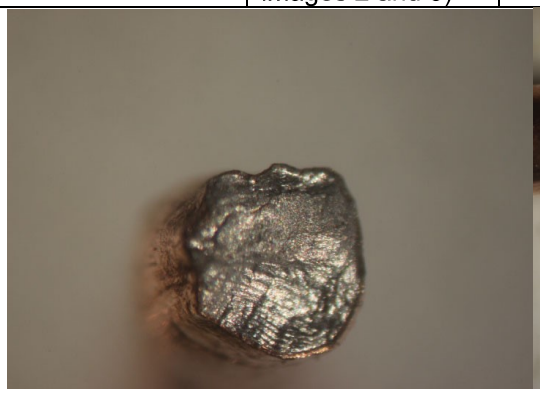


Image 1: adhesion test

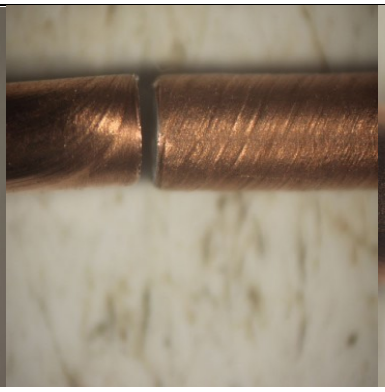


Image 2: cohesion test (torsion)

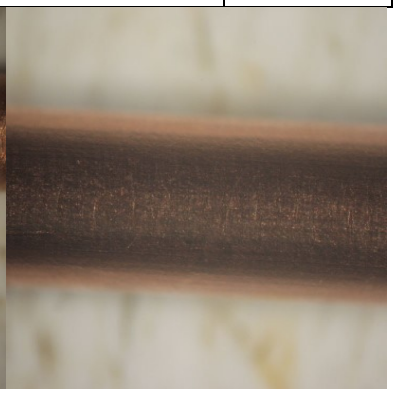


image 3: cohesion test (reverse torsion)

Test and measurement equipment

Equipment	Gauge ID	In calibration	Next due calibration
Micrometer	**CP-01**	**Yes**	**April 2021**
Tensile tester	**1755-2000**	**Yes**	**January 2022**
Ohmmeter	**62-1625**	**Yes**	**December 2020**
Calibration Certificates Attached below			

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PRECISION CALIBRATION SYSTEMS
107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID CP-01
Description Micrometer
Calibrated 8/3/2020
Performed At Customer Location

Manufacturer Mitutoyo
Model Number 293-344-30
Serial Number 66936496
Cal Procedure QS0003JB2010
Location Main
Building 254 Cotton Mill Rd. Fayetteville, TN 37334
Department Quality
Status In Service
Frequency Semi-Annual
Certificate # CO080320JM-03
Temp 73°F
Humidity 59%

Calibration Specifications

Group # 1
Group Name OD

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	End As	Left As	In Tol
0.25000 / 0.25000	Inch	Plus / Minus	0.000000	±0.00010	0.25000	Inch	0.25000	0.25000	Yes
0.50000 / 0.50000	Inch	Plus / Minus	0.000000	±0.00010	0.50000	Inch	0.50000	0.50000	Yes
1.00000 / 1.00000	Inch	Plus / Minus	0.000000	±0.00010	1.00000	Inch	1.00000	1.00000	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-GA-010 GAGE BLCK SET STD SHOP	Gage Block 81pc Set Standard	China	Rectangular Steel	E1599	4/8/2016	4/30/2021

Notes about this calibration

Uncertainty = ± (64.9+5.2L) µin (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By James Meadows
Date Finalized 8/3/2020 9:19:05AM

Total expanded measurement uncertainties expressed are based on a confidence level of 95%, coverage factor of (k=2). Decision Rule: The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. This is considered "shared responsibility." This calibration was conducted using standards traceable to the SI through NIST. The results on this certificate of accuracy apply only to the item described above. Accredited to ISO/IEC 17025: 2017.

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Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

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PCS PRECISION CALIBRATION SYSTEMS
107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID 1755-2000
Description Tensile Tester (2 Load cells)
Calibrated 8/4/2020
Performed At Customer Location

Manufacturer Thwing-Albert Instruments
Model Number EJA
Serial Number 1755-2000
Cal Procedure QS0033BG2013
Location Main
Building 254 Cotton Mill Rd. Fayetteville, TN 37334
Department Quality
Status In Service
Frequency Semi-Annual
Certificate # CO080420JM-13
Temp 70°F
Humidity 57%

Calibration Specifications

Group # 1
Group Name 0-11lb Load Cell 627022

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
1 / 1	lbf	Pct of Range	0.500000	0.00	1.00	lbf	1.01	1.01	Yes
2 / 2	lbf	Pct of Range	0.500000	0.00	2.00	lbf	2.01	2.01	Yes
3 / 3	lbf	Pct of Range	0.500000	0.00	3.00	lbf	3.01	3.01	Yes
5 / 5	lbf	Pct of Range	0.500000	0.00	5.00	lbf	5.02	5.02	Yes
7 / 7	lbf	Pct of Range	0.500000	0.00	7.00	lbf	7.03	7.03	Yes
10 / 10	lbf	Pct of Range	0.500000	0.00	10.00	lbf	10.04	10.04	Yes

Group # 2
Group Name 0-225 lb Load cell 608236

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
5 / 5	lbf	Pct of Range	0.500000	0.00	5.00	lbf	5.00	5.00	Yes
20.446 / 20.446	lbf	Pct of Range	0.500000	0.00	20.45	lbf	20.48	20.48	Yes
50.414 / 50.414	lbf	Pct of Range	0.500000	0.00	50.41	lbf	50.48	50.48	Yes
88.532 / 88.532	lbf	Pct of Range	0.500000	0.00	88.53	lbf	88.64	88.64	Yes
99.044 / 99.044	lbf	Pct of Range	0.500000	0.00	99.04	lbf	99.15	99.15	Yes
117.60 / 117.60	lbf	Pct of Range	0.500000	0.00	117.60	lbf	117.73	117.73	Yes
131.71 / 131.71	lbf	Pct of Range	0.500000	0.00	131.71	lbf	131.83	131.83	Yes
151.04 / 151.04	lbf	Pct of Range	0.500000	0.00	151.04	lbf	151.22	151.22	Yes
161.19 / 161.19	lbf	Pct of Range	0.500000	0.00	161.19	lbf	161.38	161.38	Yes
207.76 / 207.76	lbf	Pct of Range	0.500000	0.00	207.76	lbf	207.99	207.99	Yes

PCS PRECISION CALIBRATION SYSTEMS
107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID 1755-2000
Description Tensile Tester (2 Load cells)
Calibrated 8/4/2020
Performed At Customer Location

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-LO-005 5K LOAD CELL	Load Cell, 5000lb, Tension & Compression	Futek	LSB453	575093	1/7/2020	1/31/2022
Z-WE-003 HANGING WEIGHTS	Weight Set, 1-20lbs, Cast Iron	Rice Lake	ASTM Class 6	D7-D10 (20), D1-D4 (10), D1-D2 (2), 8MD8 (1), 8MB4 (2),8MB5 (5)	3/26/2019	3/31/2021

Notes about this calibration
Uncertainty = ± 0.23% of Reading (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By James Meadows
Date Finalized 8/4/2020 1:12:08PM

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). Decision Rule: The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. This is considered "shared responsibility." This calibration was conducted using standards traceable to the SI through NIST. The results on this certificate of accuracy apply only to the item described above. Accredited to ISO/IEC 17025: 2017.

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PRECISION CALIBRATION SYSTEMS
107 N Porter St
Winchester, TN 37398
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Phone: 866-521-3823
Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID 62-1625
Description Micro Ohm Meter
Calibrated 8/4/2020
Performed At Customer Location

Manufacturer Valhalla Scientific
Model Number 4176
Serial Number 62-1625
Cal Procedure QS0011JB2010
Location Main
Building 254 Cotton Mill Rd. Fayetteville, TN 37334
Department Quality
Status In Service
Frequency Semi-Annual
Certificate # CO080420JM-03
Temp 70°F
Humidity 57%

Calibration Specifications

Group # 1
Group Name Ohm - Source

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
1.000 / 1.000	Ohm	Pct of Reading	0.040000	0.0000	1.0000	Ohm	0.9998	0.9998	Yes
10.000 / 10.000	Ohm	Pct of Reading	0.040000	0.000	10.000	Ohm	9.999	9.999	Yes
100.000 / 100.000	Ohm	Pct of Reading	0.040000	0.00	100.00	Ohm	99.99	99.99	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-EL-020 DECADE RESISTANCE BOX	General Radio Small Decade Resistance Box	General Radio	1433-U	2545	12/18/2018	12/31/2020

Notes about this calibration

Uncertainty = ± 2 mOhm (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By James Meadows
Date Finalized 8/4/2020 12:47:33PM

Total expanded measurement uncertainties expressed are based on a confidence level of 95%, coverage factor of (k=2). Decision Rule: The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. This is considered "shared responsibility." This calibration was conducted using standards traceable to the SI through NIST. The results on this certificate of accuracy apply only to the item described above. Accredited to ISO/IEC 17025: 2017.

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Revision Date:05/08/2020
Rev: 04

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Follow-up Service Inspection Report
E491185 1200827165202

INSPECTION DETAILS			
Date:	2020-08-27	File Number.:	E491185
Responsible Office:	Melville	Volume:	1
Inspection Center:	232	CCN:	DVVU2
Product Type:	CCA Conductor	UL Rep Name:	Gregory Cornett
Deliverable Type:	Recognized	UL Rep ID:	20708
Party Site Number:	1626131	Subscriber Factory No.:	
Manufacturer Name:	Copperweld Bimetallics LLC	Factory Rep Name	Mr. Sammy Hampton
Manufacturer Address:	254 Cotton Mill Rd Fayetteville, TN 37334	Factory Rep Phone:	931-433-0495
		Factory Rep Email:	shampton@copperweld.com
Nature of visit:	Regular Inspection	Sample Status:	Sample requirements fulfilled for sample period
UL Marks Used?	Yes	UL Marks Removed?	No
Variation Notice Issued?	No	Inspection Conducted Remotely?	Yes
Comments After Submission:			

PRODUCT DOCUMENTS/PRODUCTION READY VISIT			
Model	**Product**	**Section**	**Multiple Listed**
14 Awg Class 10A	Copper Clad Aluminum	1	No

SAMPLE DOCUMENTS			
If samples are required to be sent to UL, indicate below. If required samples are not sent, explain in the Comments area.			
No Samples			
Additional Comments	14 Awg conductors from the NMB and THHN samples passed the UL tests for DVVU2, including Tensile, Elongation, copper thickness and DC Resistance.		

In addition to the requirements specified in the applicable UL Services agreement and Follow-Up Service Procedure, UL further defines responsibilities, duties and requirements for both manufacturers and UL representatives in the document titled "UL Mark Surveillance Requirements" that can be located at www.ul.com/fus, and in accordance with the applicable terms and conditions of the document at www.ul.com/responsibilities. Manufacturers without Internet access may obtain the current versions of these documents from their local UL customer service representative or UL field representative.

UL LLC
333 Pfingsten Road, Northbrook, IL 60062-2096 USA
T: 847.272.8800 / F: 847.272.8129 / W: ul.com

Appendix C1 Static Heating Testing at 100% Rated Current

Test 1a - thru Mfg. 1 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		124	129	134			
time (HH:MM:SS) →		1:53:00	1:58:00	2:03:00			
1a	Mfg. 11 - 1	28.70	28.86	28.73	6.47	6.63	6.50
2a	Mfg. 11 - 2	28.89	29.01	28.84	6.66	6.78	6.61
3a	Mfg. 11 - 3	27.88	28.00	27.72	5.65	5.77	5.49
4a	Mfg. 8 - 1	29.18	29.27	29.25	6.95	7.04	7.02
5a	Mfg. 8 - 2	28.99	29.11	28.99	6.76	6.88	6.76
6a	Mfg. 8 - 3	29.00	29.15	28.92	6.77	6.92	6.69
7a	circuit breaker	32.68	32.65	32.75	10.45	10.42	10.52
8a	line wire	32.25	32.29	32.43	10.02	10.06	10.20
9a	line wire splicing device	29.84	29.65	29.07	7.61	7.42	6.84
10a	load wire	30.67	30.92	30.94	8.44	8.69	8.71
11a	load wire splicing device	30.11	29.88	29.27	7.88	7.65	7.04
12a	room ambient	22.39	22.44	21.87			
13a	current (amps)	10.03	10.03	10.03			

Test 1a - thru Mfg. 1 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		80	85	90			
time (HH:MM:SS) →		1:17:00	1:22:00	1:27:00			
1a	Mfg. 11 - 1	33.06	33.61	33.40	11.02	11.58	11.36
2a	Mfg. 11 - 2	33.64	33.95	33.94	11.60	11.91	11.90
3a	Mfg. 11 - 3	31.05	31.56	31.60	9.01	9.52	9.56
4a	Mfg. 8 - 1	34.10	34.15	34.23	12.06	12.11	12.19
5a	Mfg. 8 - 2	33.60	34.20	33.86	11.56	12.16	11.82
6a	Mfg. 8 - 3	32.94	33.68	33.29	10.91	11.64	11.25
7a	circuit breaker	40.86	40.44	40.64	18.82	18.41	18.60
8a	line wire	33.93	34.21	33.87	11.89	12.17	11.83
9a	line wire splicing device	36.89	37.11	36.82	14.85	15.07	14.78
10a	load wire	32.70	33.48	32.99	10.66	11.44	10.95
11a	load wire splicing device	32.72	33.49	32.70	10.68	11.45	10.66
12a	room ambient	21.84	22.27	22.01			
13a	current (amps)	15.02	15.01	15.02			

Test 1b - thru Mfg. 2 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		124	129	134			
time (HH:MM:SS) →		1:53:00	1:58:00	2:03:00			
1b	Mfg. 11 - 1	28.57	28.60	28.36	6.49	6.52	6.27
2b	Mfg. 11 - 2	28.65	28.68	28.48	6.57	6.60	6.40
3b	Mfg. 11 - 3	27.37	27.39	27.10	5.28	5.31	5.02
4b	Mfg. 8 - 1	29.14	29.23	29.15	7.05	7.15	7.07
5b	Mfg. 8 - 2	30.65	30.75	30.48	8.57	8.66	8.40
6b	Mfg. 8 - 3	28.04	28.10	27.73	5.96	6.02	5.64
7b	circuit breaker	36.63	36.79	37.20	14.55	14.70	15.12
8b	line wire	30.98	31.03	30.93	8.90	8.95	8.85
9b	line wire splicing device	28.97	28.69	28.06	6.89	6.61	5.98
10b	load wire	28.60	28.55	28.00	6.52	6.47	5.92
11b	load wire splicing device	28.64	28.49	27.92	6.56	6.41	5.84
12b	room ambient	22.35	22.28	21.62			
13b	current (amps)	10.00	10.00	10.00			

Test 1b - thru Mfg. 2 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		80	85	90			
time (HH:MM:SS) →		1:17:00	1:22:00	1:27:00			
1b	Mfg. 11 - 1	33.38	33.85	33.55	11.43	11.89	11.59
2b	Mfg. 11 - 2	33.29	33.49	33.67	11.34	11.54	11.72
3b	Mfg. 11 - 3	30.94	31.47	31.45	8.99	9.52	9.49
4b	Mfg. 8 - 1	34.03	34.28	34.44	12.07	12.32	12.48
5b	Mfg. 8 - 2	33.61	34.03	33.75	11.66	12.08	11.80
6b	Mfg. 8 - 3	33.00	33.71	33.25	11.05	11.75	11.29
7b	circuit breaker	44.97	44.86	45.02	23.02	22.91	23.06
8b	line wire	33.21	33.70	33.32	11.25	11.74	11.37
9b	line wire splicing device	30.81	31.77	30.80	8.86	9.82	8.85
10b	load wire	32.53	33.49	32.83	10.58	11.54	10.88
11b	load wire splicing device	31.51	32.52	31.43	9.56	10.56	9.47
12b	room ambient	21.76	22.22	21.88			
13b	current (amps)	15.01	15.01	15.01			

Test 1c - thru Mfg. 3 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		124	129	134			
time (HH:MM:SS) →		1:53:00	1:58:00	2:03:00			
1c	Mfg. 11 - 1	29.46	29.56	29.18	7.40	7.50	7.12
2c	Mfg. 11 - 2	28.97	29.12	28.68	6.91	7.06	6.62
3c	Mfg. 11 - 3	27.82	28.02	27.47	5.76	5.96	5.41
4c	Mfg. 8 - 1	29.30	29.40	29.33	7.24	7.34	7.27
5c	Mfg. 8 - 2	28.68	28.72	28.43	6.62	6.66	6.37
6c	Mfg. 8 - 3	28.19	28.27	27.81	6.13	6.21	5.75
7c	circuit breaker	35.04	35.28	35.13	12.98	13.22	13.07
8c	line wire	31.23	31.27	30.87	9.17	9.21	8.81
9c	line wire splicing device	28.59	28.61	27.53	6.53	6.55	5.47
10c	load wire	30.74	30.84	30.26	8.68	8.78	8.20
11c	load wire splicing device	29.74	29.67	28.50	7.68	7.61	6.44
12c	room ambient	22.29	22.23	21.67			
13c	current (amps)	10.01	10.01	10.01			

Test 1c - thru Mfg. 3 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		80	85	90			
time (HH:MM:SS) →		1:17:00	1:22:00	1:27:00			
1c	Mfg. 11 - 1	32.95	33.38	33.25	11.06	11.48	11.36
2c	Mfg. 11 - 2	33.50	33.89	33.73	11.61	12.00	11.84
3c	Mfg. 11 - 3	32.27	32.60	32.50	10.38	10.71	10.61
4c	Mfg. 8 - 1	33.33	33.66	33.62	11.44	11.77	11.72
5c	Mfg. 8 - 2	33.87	34.28	34.11	11.98	12.39	12.21
6c	Mfg. 8 - 3	32.50	32.88	32.80	10.61	10.99	10.91
7c	circuit breaker	42.51	42.65	42.50	20.62	20.75	20.60
8c	line wire	31.74	32.44	32.16	9.84	10.54	10.27
9c	line wire splicing device	32.46	33.55	32.53	10.57	11.66	10.64
10c	load wire	32.23	33.29	32.70	10.34	11.40	10.81
11c	load wire splicing device	29.96	31.50	30.18	8.07	9.61	8.29
12c	room ambient	21.65	22.13	21.90			
13c	current (amps)	15.02	15.02	15.02			

Test 1a - thru Mfg. 1 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		67	72	77			
time (HH:MM:SS) →		1:04:00	1:09:00	1:14:00			
1a	Mfg. 10 - 1	33.35	33.09	33.35	11.17	10.90	11.17
2a	Mfg. 10 - 2	29.93	29.88	29.88	7.75	7.70	7.70
3a	Mfg. 10 - 3	28.83	28.80	28.74	6.65	6.62	6.56
4a	Mfg. 9 - 1	28.96	28.89	28.94	6.78	6.71	6.76
5a	Mfg. 9 - 2	29.33	29.07	29.09	7.15	6.89	6.91
6a	Mfg. 9 - 3	28.20	28.02	27.93	6.01	5.84	5.75
7a	circuit breaker	32.75	32.55	32.65	10.57	10.37	10.47
8a	line wire	32.76	32.27	32.44	10.58	10.09	10.26
9a	line wire splicing device	29.85	29.45	29.15	7.67	7.27	6.97
10a	load wire	31.09	30.73	31.01	8.91	8.55	8.83
11a	load wire splicing device	30.90	30.16	30.15	8.72	7.98	7.97
12a	room ambient	22.53	22.20	21.82			
13a	current (amps)	10.02	10.02	10.02			

Test 1a - thru Mfg. 1 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		122	127	132			
time (HH:MM:SS) →		2:00:00	2:05:00	2:10:00			
1a	Mfg. 10 - 1	38.41	38.10	38.31	17.09	16.78	16.99
2a	Mfg. 10 - 2	39.48	39.23	39.28	18.16	17.91	17.96
3a	Mfg. 10 - 3	34.47	34.18	34.12	13.15	12.87	12.80
4a	Mfg. 9 - 1	37.47	37.35	37.38	16.16	16.03	16.06
5a	Mfg. 9 - 2	38.46	38.17	38.12	17.14	16.85	16.80
6a	Mfg. 9 - 3	31.54	31.29	31.18	10.22	9.97	9.86
7a	circuit breaker	40.70	40.66	40.65	19.38	19.34	19.33
8a	line wire	34.07	34.00	34.12	12.75	12.69	12.80
9a	line wire splicing device	35.66	35.31	35.13	14.34	13.99	13.81
10a	load wire	32.81	32.43	32.75	11.49	11.11	11.43
11a	load wire splicing device	33.16	32.96	32.94	11.84	11.64	11.62
12a	room ambient	21.37	21.31	21.27			
13a	current (amps)	15.02	15.02	15.02			

Test 1b - thru Mfg. 2 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		129	134	139			
time (HH:MM:SS) →		2:06:07	2:11:06	2:16:07			
1b	Mfg. 10 - 1	31.13	31.54	31.37	9.64	10.05	9.88
2b	Mfg. 10 - 2	30.12	30.39	30.44	8.63	8.90	8.95
3b	Mfg. 10 - 3	28.95	29.13	29.19	7.46	7.64	7.70
4b	Mfg. 9 - 1	28.47	28.67	28.85	6.98	7.18	7.36
5b	Mfg. 9 - 2	28.62	29.01	28.85	7.13	7.52	7.36
6b	Mfg. 9 - 3	29.94	30.21	30.11	8.45	8.72	8.62
7b	circuit breaker	41.81	41.46	41.80	20.32	19.97	20.31
8b	line wire	31.66	31.83	32.15	10.17	10.34	10.66
9b	line wire splicing device	29.57	30.02	30.13	8.08	8.53	8.64
10b	load wire	28.92	29.64	29.57	7.43	8.15	8.08
11b	load wire splicing device	30.62	31.06	31.03	9.13	9.57	9.54
12b	room ambient	21.30	21.89	21.28			
13b	current (amps)	10.01	10.01	10.01			

Test 1b - thru Mfg. 2 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		122	127	132			
time (HH:MM:SS) →		2:00:00	2:05:00	2:10:00			
1b	Mfg. 10 - 1	39.02	38.87	38.81	17.86	17.72	17.65
2b	Mfg. 10 - 2	38.54	38.42	38.37	17.38	17.26	17.22
3b	Mfg. 10 - 3	35.00	34.94	34.56	13.84	13.78	13.40
4b	Mfg. 9 - 1	34.32	34.17	34.19	13.16	13.01	13.03
5b	Mfg. 9 - 2	33.68	33.52	33.44	12.52	12.36	12.29
6b	Mfg. 9 - 3	32.62	32.41	32.27	11.46	11.25	11.11
7b	circuit breaker	44.60	44.48	44.38	23.44	23.32	23.22
8b	line wire	33.27	33.12	33.14	12.11	11.96	11.98
9b	line wire splicing device	31.50	31.19	31.26	10.34	10.03	10.10
10b	load wire	31.96	31.65	31.72	10.81	10.49	10.56
11b	load wire splicing device	30.27	29.89	29.93	9.12	8.73	8.78
12b	room ambient	21.26	21.14	21.08			
13b	current (amps)	15.01	15.01	15.01			

Test 1c - thru Mfg. 3 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		67	72	77			
time (HH:MM:SS) →		1:04:00	1:09:00	1:14:00			
1c	Mfg. 10 - 1	31.05	30.92	30.45	9.04	8.91	8.44
2c	Mfg. 10 - 2	32.97	32.85	32.26	10.96	10.84	10.25
3c	Mfg. 10 - 3	29.07	28.94	28.28	7.06	6.93	6.27
4c	Mfg. 9 - 1	29.52	29.28	29.21	7.51	7.27	7.20
5c	Mfg. 9 - 2	30.06	29.90	29.40	8.05	7.89	7.39
6c	Mfg. 9 - 3	28.41	28.41	27.55	6.40	6.40	5.54
7c	circuit breaker	34.97	34.66	34.67	12.96	12.65	12.66
8c	line wire	31.77	31.18	30.88	9.76	9.17	8.87
9c	line wire splicing device	28.89	28.20	27.63	6.88	6.19	5.62
10c	load wire	31.27	30.69	30.26	9.26	8.68	8.25
11c	load wire splicing device	31.39	30.47	29.53	9.38	8.46	7.52
12c	room ambient	22.35	21.99	21.69			
13c	current (amps)	10.01	10.01	10.01			

Test 1c - thru Mfg. 3 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		122	127	132			
time (HH:MM:SS) →		2:00:00	2:05:00	2:10:00			
1c	Mfg. 10 - 1	36.19	35.94	35.85	15.02	14.77	14.68
2c	Mfg. 10 - 2	39.95	39.76	39.70	18.78	18.59	18.53
3c	Mfg. 10 - 3	39.01	39.15	38.69	17.85	17.98	17.52
4c	Mfg. 9 - 1	33.32	33.13	33.09	12.15	11.96	11.92
5c	Mfg. 9 - 2	34.01	33.90	33.74	12.84	12.74	12.57
6c	Mfg. 9 - 3	32.95	32.95	32.64	11.78	11.78	11.47
7c	circuit breaker	41.75	41.55	41.58	20.59	20.38	20.41
8c	line wire	30.73	30.68	30.61	9.56	9.51	9.44
9c	line wire splicing device	32.20	31.82	31.87	11.04	10.65	10.70
10c	load wire	31.34	31.12	31.14	10.17	9.95	9.97
11c	load wire splicing device	29.64	29.52	29.42	8.47	8.35	8.25
12c	room ambient	21.29	21.13	21.09			
13c	current (amps)	15.01	15.01	15.01			

Test 2a - thru Mfg. 1 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →							
time (MM:SS) →		7:20	7:40	8:00			
	Breaker trip time	8:20					
1a	Mfg. 11 - 1	30.60	30.69	30.76	8.65	8.73	8.80
2a	Mfg. 11 - 2	30.73	30.83	30.87	8.78	8.88	8.92
3a	Mfg. 11 - 3	29.72	29.82	29.85	7.76	7.87	7.89
4a	Mfg. 8 - 1	30.66	30.77	30.88	8.70	8.81	8.93
5a	Mfg. 8 - 2	30.87	30.96	31.05	8.91	9.01	9.09
6a	Mfg. 8 - 3	30.39	30.50	30.55	8.43	8.54	8.59
7a	circuit breaker	34.21	34.43	34.65	12.26	12.47	12.70
8a	line wire	38.55	38.70	38.80	16.59	16.74	16.85
9a	line wire splicing device	34.64	34.68	34.50	12.68	12.72	12.55
10a	load wire	36.44	36.44	36.36	14.49	14.48	14.40
11a	load wire splicing device	35.04	35.05	34.84	13.09	13.09	12.88
12a	room ambient	22.00	21.97	21.91			
13a	current (amps)	13.52	13.52	13.52			

Test 2a - thru Mfg. 1 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		60	61	62			
time (MM:SS) →		18:20	18:40	19:00			
	Breaker trip time	19:20					
1a	Mfg. 11 - 1	39.87	39.91	39.90	18.05	18.09	18.08
2a	Mfg. 11 - 2	40.66	40.69	40.70	18.84	18.87	18.88
3a	Mfg. 11 - 3	36.77	36.77	36.76	14.95	14.95	14.94
4a	Mfg. 8 - 1	40.83	40.88	40.89	19.01	19.06	19.07
5a	Mfg. 8 - 2	40.41	40.45	40.47	18.59	18.63	18.65
6a	Mfg. 8 - 3	39.06	39.09	39.15	17.24	17.27	17.33
7a	circuit breaker	51.78	51.96	52.02	29.96	30.14	30.20
8a	line wire	43.47	43.51	43.49	21.65	21.69	21.67
9a	line wire splicing device	48.83	48.80	48.22	27.02	26.99	26.40
10a	load wire	41.01	41.02	41.12	19.19	19.20	19.30
11a	load wire splicing device	42.69	42.60	42.48	20.87	20.78	20.66
12a	room ambient	21.84	21.84	21.78			
13a	current (amps)	19.97	19.97	20.24			

Test 2b - thru Mfg. 2 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		4:20	4:40	5:00			
	Breaker trip time	5:20					
1b	Mfg. 11 - 1	29.25	29.41	29.55	6.91	7.07	7.21
2b	Mfg. 11 - 2	28.86	29.03	29.22	6.52	6.69	6.88
3b	Mfg. 11 - 3	28.34	28.44	28.54	6.00	6.10	6.20
4b	Mfg. 8 - 1	29.37	29.59	29.79	7.03	7.25	7.45
5b	Mfg. 8 - 2	30.27	30.43	30.67	7.93	8.09	8.33
6b	Mfg. 8 - 3	28.84	28.97	29.10	6.50	6.63	6.76
7b	circuit breaker	34.99	35.63	36.29	12.65	13.29	13.95
8b	line wire	34.20	34.58	34.92	11.86	12.24	12.58
9b	line wire splicing device	33.21	33.11	33.12	10.87	10.77	10.78
10b	load wire	30.95	31.14	31.38	8.61	8.80	9.04
11b	load wire splicing device	32.76	32.73	32.78	10.42	10.39	10.44
12b	room ambient	22.40	22.34	22.29			
13b	current (amps)	13.51	13.51	13.51			

Test 2b - thru Mfg. 2 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		13	14	15			
time (MM:SS) →		2:20	2:40	3:00			
	Breaker trip time	3:20					
1b	Mfg. 11 - 1	31.85	32.56	33.17	9.91	10.62	11.23
2b	Mfg. 11 - 2	31.27	32.00	32.64	9.33	10.05	10.70
3b	Mfg. 11 - 3	30.01	30.61	31.08	8.07	8.67	9.14
4b	Mfg. 8 - 1	31.78	32.43	33.07	9.84	10.49	11.13
5b	Mfg. 8 - 2	32.35	32.97	33.48	10.41	11.03	11.54
6b	Mfg. 8 - 3	31.74	32.37	32.83	9.80	10.42	10.89
7b	circuit breaker	36.50	38.10	39.50	14.56	16.16	17.56
8b	line wire	32.89	33.90	34.83	10.95	11.96	12.89
9b	line wire splicing device	34.98	35.61	36.11	13.04	13.67	14.17
10b	load wire	33.90	34.76	35.58	11.96	12.82	13.64
11b	load wire splicing device	35.84	36.48	37.04	13.90	14.54	15.10
12b	room ambient	21.94	21.93	21.96			
13b	current (amps)	20.28	20.27	20.27			

Test 2c - thru Mfg. 3 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		59	60	61			
time (MM:SS) →		18:40	19:00	19:20			
	Breaker trip time	19:40					
1c	Mfg. 11 - 1	34.08	34.15	34.18	11.70	11.78	11.81
2c	Mfg. 11 - 2	33.23	33.27	33.31	10.85	10.89	10.93
3c	Mfg. 11 - 3	31.22	31.25	31.28	8.85	8.87	8.90
4c	Mfg. 8 - 1	33.48	33.50	33.56	11.10	11.13	11.19
5c	Mfg. 8 - 2	32.68	32.75	32.80	10.31	10.37	10.42
6c	Mfg. 8 - 3	31.96	32.03	32.09	9.58	9.66	9.71
7c	circuit breaker	43.05	43.08	43.19	20.67	20.71	20.81
8c	line wire	38.04	38.09	38.14	15.67	15.72	15.76
9c	line wire splicing device	33.55	33.75	33.89	11.17	11.38	11.51
10c	load wire	37.55	37.62	37.70	15.17	15.24	15.33
11c	load wire splicing device	35.83	36.09	36.28	13.46	13.71	13.91
12c	room ambient	22.51	22.28	22.34			
13c	current (amps)	13.51	13.51	13.51			

Test 2c - thru Mfg. 3 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		20	21	22			
time (MM:SS) →		5:00	5:20	5:40			
	Breaker trip time	6:00					
1c	Mfg. 11 - 1	34.62	34.96	35.21	12.63	12.97	13.22
2c	Mfg. 11 - 2	35.65	35.96	36.17	13.65	13.97	14.18
3c	Mfg. 11 - 3	33.85	34.05	34.25	11.85	12.05	12.25
4c	Mfg. 8 - 1	34.94	35.23	35.47	12.95	13.24	13.48
5c	Mfg. 8 - 2	35.87	36.13	36.37	13.87	14.13	14.38
6c	Mfg. 8 - 3	34.38	34.60	34.74	12.38	12.61	12.75
7c	circuit breaker	42.69	43.47	44.15	20.69	21.47	22.16
8c	line wire	36.07	36.49	36.77	14.08	14.50	14.78
9c	line wire splicing device	38.93	39.23	39.49	16.94	17.24	17.49
10c	load wire	37.64	37.92	38.15	15.64	15.92	16.16
11c	load wire splicing device	35.65	35.84	35.95	13.66	13.85	13.96
12c	room ambient	21.95	22.09	21.93			
13c	current (amps)	20.19	20.19	20.17			

Test 2a - thru Mfg. 1 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		26	27	28			
time (MM:SS) →		7:40	8:00	8:20			
	Breaker trip time	8:40					
1a	Mfg. 10 - 1	33.38	33.55	33.72	11.54	11.72	11.89
2a	Mfg. 10 - 2	32.41	32.50	32.60	10.58	10.67	10.77
3a	Mfg. 10 - 3	30.50	30.58	30.68	8.66	8.75	8.85
4a	Mfg. 9 - 1	30.51	30.62	30.74	8.67	8.79	8.91
5a	Mfg. 9 - 2	30.63	30.73	30.86	8.80	8.89	9.02
6a	Mfg. 9 - 3	29.45	29.52	29.63	7.62	7.69	7.79
7a	circuit breaker	34.35	34.60	34.84	12.51	12.77	13.00
8a	line wire	38.69	38.85	39.02	16.85	17.01	17.18
9a	line wire splicing device	34.03	34.11	34.24	12.19	12.27	12.40
10a	load wire	36.42	36.48	36.58	14.59	14.65	14.74
11a	load wire splicing device	36.28	36.41	36.59	14.45	14.58	14.76
12a	room ambient	21.84	21.90	21.76			
13a	current (amps)	13.52	13.52	13.52			

Test 2a - thru Mfg. 1 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		65	66	67			
time (MM:SS) →		20:00	20:20	20:40			
	Breaker trip time	21:00					
1a	Mfg. 10 - 1	47.14	47.05	47.05	26.19	26.10	26.09
2a	Mfg. 10 - 2	49.33	49.35	49.30	28.38	28.39	28.35
3a	Mfg. 10 - 3	43.32	43.29	43.14	22.36	22.34	22.19
4a	Mfg. 9 - 1	45.67	45.67	45.73	24.72	24.71	24.78
5a	Mfg. 9 - 2	46.98	46.95	46.85	26.03	25.99	25.90
6a	Mfg. 9 - 3	38.91	38.80	38.65	17.95	17.84	17.69
7a	circuit breaker	52.18	52.30	52.40	31.23	31.34	31.45
8a	line wire	43.36	43.34	43.31	22.40	22.39	22.35
9a	line wire splicing device	46.95	46.94	46.87	26.00	25.99	25.91
10a	load wire	41.51	41.36	41.20	20.56	20.41	20.25
11a	load wire splicing device	42.93	42.85	42.57	21.97	21.89	21.62
12a	room ambient	20.94	20.94	20.98			
13a	current (amps)	20.29	20.28	20.28			

Test 2b - thru Mfg. 2 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		21	22	23			
time (MM:SS) →		5:40	6:00	6:20			
	Breaker trip time	6:40					
1b	Mfg. 10 - 1	31.86	32.13	32.38	9.94	10.21	10.46
2b	Mfg. 10 - 2	32.09	32.28	32.45	10.17	10.36	10.53
3b	Mfg. 10 - 3	30.06	30.24	30.38	8.14	8.32	8.46
4b	Mfg. 9 - 1	29.45	29.60	29.73	7.53	7.68	7.81
5b	Mfg. 9 - 2	30.16	30.32	30.49	8.23	8.40	8.57
6b	Mfg. 9 - 3	29.34	29.52	29.64	7.42	7.60	7.72
7b	circuit breaker	37.11	37.68	38.17	15.19	15.76	16.25
8b	line wire	35.37	35.59	35.81	13.44	13.67	13.88
9b	line wire splicing device	32.21	32.37	32.46	10.28	10.45	10.54
10b	load wire	31.36	31.58	31.73	9.44	9.66	9.80
11b	load wire splicing device	35.28	35.40	35.49	13.36	13.47	13.56
12b	room ambient	21.93	21.95	21.88			
13b	current (amps)	13.50	13.50	13.50			

Test 2b - thru Mfg. 2 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		13	14	15			
time (MM:SS) →		2:40	3:00	3:20			
	Breaker trip time	3:40					
1b	Mfg. 10 - 1	34.43	35.44	36.33	13.42	14.43	15.32
2b	Mfg. 10 - 2	35.56	36.51	37.33	14.56	15.51	16.33
3b	Mfg. 10 - 3	33.00	33.73	34.31	12.00	12.73	13.30
4b	Mfg. 9 - 1	32.70	33.42	34.00	11.69	12.41	13.00
5b	Mfg. 9 - 2	32.65	33.31	33.89	11.64	12.30	12.89
6b	Mfg. 9 - 3	30.85	31.44	31.99	9.85	10.43	10.98
7b	circuit breaker	36.44	37.96	39.35	15.44	16.96	18.34
8b	line wire	32.46	33.42	34.28	11.45	12.41	13.28
9b	line wire splicing device	35.23	35.84	36.40	14.22	14.84	15.39
10b	load wire	33.42	34.26	35.03	12.42	13.26	14.02
11b	load wire splicing device	33.28	33.92	34.50	12.27	12.91	13.49
12b	room ambient	20.93	21.01	21.08			
13b	current (amps)	20.28	20.28	20.28			

Test 2c - thru Mfg. 3 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		53	54	55			
time (MM:SS) →		16:20	16:40	17:00			
	Breaker trip time	17:20					
1c	Mfg. 10 - 1	35.58	35.62	35.62	13.37	13.41	13.41
2c	Mfg. 10 - 2	36.59	36.62	36.62	14.38	14.41	14.41
3c	Mfg. 10 - 3	32.94	32.95	32.98	10.73	10.74	10.77
4c	Mfg. 9 - 1	33.08	33.07	33.07	10.87	10.86	10.86
5c	Mfg. 9 - 2	33.95	33.93	33.90	11.73	11.72	11.69
6c	Mfg. 9 - 3	31.62	31.62	31.58	9.40	9.41	9.37
7c	circuit breaker	41.72	41.81	41.92	19.51	19.60	19.71
8c	line wire	38.68	38.60	38.52	16.47	16.39	16.31
9c	line wire splicing device	33.41	33.23	33.04	11.19	11.02	10.83
10c	load wire	37.53	37.41	37.27	15.31	15.20	15.06
11c	load wire splicing device	38.23	37.83	37.38	16.01	15.62	15.17
12c	room ambient	22.28	22.22	22.14			
13c	current (amps)	13.50	13.50	13.50			

Test 2c - thru Mfg. 3 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		22	23	24			
time (MM:SS) →		5:40	6:00	6:20			
	Breaker trip time	6:40					
1c	Mfg. 10 - 1	37.66	38.19	38.64	16.09	16.61	17.07
2c	Mfg. 10 - 2	44.95	45.50	45.96	23.38	23.93	24.39
3c	Mfg. 10 - 3	44.95	45.37	45.69	23.38	23.80	24.12
4c	Mfg. 9 - 1	35.48	35.83	36.20	13.90	14.26	14.63
5c	Mfg. 9 - 2	38.33	38.69	39.10	16.75	17.12	17.52
6c	Mfg. 9 - 3	36.86	37.22	37.59	15.28	15.65	16.02
7c	circuit breaker	42.83	43.50	44.14	21.26	21.93	22.56
8c	line wire	35.89	36.21	36.61	14.32	14.64	15.04
9c	line wire splicing device	40.91	41.17	41.52	19.33	19.60	19.95
10c	load wire	37.99	38.35	38.72	16.42	16.78	17.15
11c	load wire splicing device	39.30	39.51	39.86	17.72	17.93	18.29
12c	room ambient	21.55	21.59	21.59			
13c	current (amps)	20.30	20.26	20.27			

Appendix C3 Static Heating Tests at 150% Rated Current

Test 3a - thru Mfg. 1 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		19	20	21			
time (MM:SS) →		2:00	2:10	2:20			
	Breaker trip time	2:30					
1a	Mfg. 11 - 1	27.90	28.21	28.45	5.51	5.83	6.06
2a	Mfg. 11 - 2	27.85	28.17	28.44	5.46	5.79	6.06
3a	Mfg. 11 - 3	27.44	27.71	27.97	5.05	5.32	5.58
4a	Mfg. 8 - 1	28.03	28.30	28.55	5.64	5.91	6.17
5a	Mfg. 8 - 2	28.67	28.93	29.21	6.28	6.55	6.83
6a	Mfg. 8 - 3	28.12	28.37	28.63	5.73	5.98	6.24
7a	circuit breaker	29.23	29.65	30.04	6.84	7.27	7.65
8a	line wire	33.45	33.99	34.55	11.06	11.60	12.16
9a	line wire splicing device	33.38	33.88	34.38	10.99	11.49	11.99
10a	load wire	32.35	32.80	33.28	9.96	10.41	10.89
11a	load wire splicing device	34.69	35.13	35.60	12.30	12.74	13.21
12a	room ambient	22.40	22.39	22.37			
13a	current (amps)	15.02	15.02	15.02			

Test 3a - thru Mfg. 1 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		31	32	33			
time (MM:SS) →		3:40	3:50	4:00			
	Breaker trip time	4:10					
1a	Mfg. 11 - 1	36.08	36.34	36.60	13.46	13.72	13.98
2a	Mfg. 11 - 2	36.41	36.67	36.97	13.79	14.05	14.35
3a	Mfg. 11 - 3	34.72	34.88	35.08	12.10	12.26	12.46
4a	Mfg. 8 - 1	36.33	36.58	36.86	13.71	13.96	14.24
5a	Mfg. 8 - 2	37.14	37.38	37.62	14.53	14.76	15.00
6a	Mfg. 8 - 3	36.40	36.56	36.84	13.78	13.94	14.22
7a	circuit breaker	40.83	41.35	41.83	18.21	18.73	19.21
8a	line wire	39.85	40.31	40.75	17.23	17.69	18.13
9a	line wire splicing device	49.53	49.93	50.18	26.91	27.31	27.56
10a	load wire	40.21	40.60	40.99	17.60	17.98	18.37
11a	load wire splicing device	45.48	45.83	46.22	22.86	23.21	23.60
12a	room ambient	22.65	22.62	22.58			
13a	current (amps)	22.56	22.53	22.53			

Test 3b - thru Mfg. 2 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		19	20	21			
time (MM:SS) →		2:00	2:10	2:20			
	Breaker trip time	2:30					
1b	Mfg. 11 - 1	28.11	28.40	28.72	5.67	5.96	6.28
2b	Mfg. 11 - 2	27.73	27.97	28.26	5.29	5.53	5.82
3b	Mfg. 11 - 3	27.57	27.80	28.05	5.12	5.36	5.60
4b	Mfg. 8 - 1	28.38	28.63	28.91	5.93	6.19	6.47
5b	Mfg. 8 - 2	29.23	29.50	29.82	6.79	7.06	7.37
6b	Mfg. 8 - 3	28.00	28.25	28.53	5.56	5.81	6.09
7b	circuit breaker	30.38	30.93	31.50	7.94	8.48	9.06
8b	line wire	31.30	31.79	32.30	8.85	9.34	9.86
9b	line wire splicing device	32.82	33.29	33.71	10.38	10.84	11.27
10b	load wire	28.66	29.10	29.50	6.21	6.66	7.06
11b	load wire splicing device	33.26	33.63	33.95	10.82	11.18	11.51
12b	room ambient	22.47	22.43	22.43			
13b	current (amps)	15.01	15.01	15.01			

Test 3b - thru Mfg. 2 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		13	14	15			
time (MM:SS) →		:40	:50	1:00			
	Breaker trip time	1:10					
1b	Mfg. 11 - 1	26.84	27.76	28.60	4.39	5.31	6.15
2b	Mfg. 11 - 2	26.26	27.11	27.94	3.81	4.66	5.49
3b	Mfg. 11 - 3	26.03	26.75	27.44	3.58	4.30	4.99
4b	Mfg. 8 - 1	26.61	27.54	28.41	4.16	5.09	5.96
5b	Mfg. 8 - 2	27.59	28.55	29.46	5.14	6.10	7.01
6b	Mfg. 8 - 3	27.23	28.09	28.93	4.78	5.64	6.48
7b	circuit breaker	27.33	28.59	29.90	4.88	6.14	7.45
8b	line wire	26.59	27.53	28.44	4.14	5.08	5.99
9b	line wire splicing device	29.28	30.58	31.77	6.83	8.13	9.32
10b	load wire	27.88	28.93	29.91	5.43	6.48	7.46
11b	load wire splicing device	29.84	31.22	32.45	7.39	8.77	10.00
12b	room ambient	22.46	22.43	22.45			
13b	current (amps)	22.51	22.49	22.49			

Test 3c - thru Mfg. 3 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		37	38	39			
time (MM:SS) →		5:00	5:10	5:20			
	Breaker trip time	5:30					
1c	Mfg. 11 - 1	32.34	32.46	32.62	9.83	9.96	10.12
2c	Mfg. 11 - 2	31.80	31.94	32.06	9.30	9.44	9.56
3c	Mfg. 11 - 3	29.96	30.07	30.17	7.46	7.56	7.67
4c	Mfg. 8 - 1	31.82	31.94	32.07	9.32	9.44	9.57
5c	Mfg. 8 - 2	31.64	31.77	31.86	9.13	9.26	9.36
6c	Mfg. 8 - 3	31.07	31.17	31.31	8.57	8.67	8.81
7c	circuit breaker	37.24	37.53	37.80	14.74	15.03	15.30
8c	line wire	38.50	38.75	39.00	16.00	16.25	16.50
9c	line wire splicing device	35.73	35.83	35.94	13.23	13.33	13.43
10c	load wire	37.84	38.06	38.26	15.33	15.56	15.75
11c	load wire splicing device	38.75	38.81	38.93	16.24	16.31	16.43
12c	room ambient	22.50	22.49	22.52			
13c	current (amps)	15.01	15.01	15.01			

Test 3c - thru Mfg. 3 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		23	24	25			
time (MM:SS) →		2:20	2:30	2:40			
	Breaker trip time	2:50					
1c	Mfg. 11 - 1	32.80	33.29	33.73	10.40	10.89	11.33
2c	Mfg. 11 - 2	34.13	34.67	35.12	11.73	12.27	12.72
3c	Mfg. 11 - 3	32.29	32.77	33.17	9.89	10.37	10.77
4c	Mfg. 8 - 1	33.21	33.67	34.07	10.81	11.27	11.67
5c	Mfg. 8 - 2	34.62	35.08	35.48	12.22	12.68	13.08
6c	Mfg. 8 - 3	32.76	33.21	33.64	10.36	10.81	11.24
7c	circuit breaker	37.29	38.07	38.83	14.89	15.67	16.43
8c	line wire	33.28	33.93	34.55	10.88	11.53	12.15
9c	line wire splicing device	40.01	40.55	41.07	17.61	18.15	18.67
10c	load wire	36.15	36.74	37.30	13.75	14.34	14.90
11c	load wire splicing device	37.79	38.32	38.82	15.39	15.92	16.42
12c	room ambient	22.38	22.41	22.41			
13c	current (amps)	22.43	22.44	22.42			

Test 3a - thru Mfg. 1 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		23	24	25			
time (MM:SS) →		2:20	2:30	2:40			
	Breaker trip time	2:50					
1a	Mfg. 10 - 1	29.81	30.21	30.55	7.56	7.96	8.30
2a	Mfg. 10 - 2	29.70	30.02	30.29	7.44	7.77	8.04
3a	Mfg. 10 - 3	28.37	28.62	28.85	6.12	6.37	6.60
4a	Mfg. 9 - 1	28.22	28.46	28.69	5.97	6.21	6.44
5a	Mfg. 9 - 2	28.46	28.71	28.94	6.21	6.46	6.69
6a	Mfg. 9 - 3	27.73	27.96	28.13	5.48	5.71	5.88
7a	circuit breaker	29.83	30.21	30.53	7.58	7.96	8.28
8a	line wire	34.40	34.90	35.38	12.15	12.65	13.13
9a	line wire splicing device	32.53	32.88	33.18	10.28	10.63	10.93
10a	load wire	33.43	33.88	34.25	11.17	11.63	12.00
11a	load wire splicing device	37.25	37.47	37.66	15.00	15.22	15.41
12a	room ambient	22.28	22.24	22.24			
13a	current (amps)	15.02	15.02	15.02			

Test 3a - thru Mfg. 1 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		38	39	40			
time (MM:SS) →		4:00	4:10	4:20			
	Breaker trip time	4:30					
1a	Mfg. 10 - 1	40.53	40.89	41.27	18.74	19.10	19.48
2a	Mfg. 10 - 2	42.28	42.67	43.05	20.49	20.88	21.26
3a	Mfg. 10 - 3	39.25	39.54	39.81	17.46	17.75	18.02
4a	Mfg. 9 - 1	39.03	39.37	39.68	17.24	17.58	17.89
5a	Mfg. 9 - 2	40.06	40.40	40.75	18.27	18.61	18.96
6a	Mfg. 9 - 3	35.92	36.14	36.35	14.14	14.35	14.56
7a	circuit breaker	41.66	42.13	42.62	19.87	20.34	20.83
8a	line wire	40.15	40.56	40.91	18.36	18.77	19.12
9a	line wire splicing device	47.60	47.94	48.23	25.81	26.16	26.44
10a	load wire	40.83	41.12	41.46	19.04	19.33	19.67
11a	load wire splicing device	46.50	46.62	46.74	24.72	24.83	24.95
12a	room ambient	21.81	21.79	21.76			
13a	current (amps)	22.35	22.35	22.35			

Test 3b - thru Mfg. 2 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		21	22	23			
time (MM:SS) →		2:00	2:10	2:20			
	Breaker trip time	2:30					
1b	Mfg. 10 - 1	28.72	29.12	29.50	6.58	6.98	7.36
2b	Mfg. 10 - 2	29.55	29.94	30.33	7.41	7.80	8.19
3b	Mfg. 10 - 3	28.01	28.30	28.56	5.87	6.16	6.42
4b	Mfg. 9 - 1	27.72	28.02	28.27	5.58	5.88	6.13
5b	Mfg. 9 - 2	27.97	28.28	28.55	5.83	6.14	6.41
6b	Mfg. 9 - 3	27.58	27.82	28.09	5.44	5.68	5.95
7b	circuit breaker	30.55	31.13	31.74	8.41	8.99	9.60
8b	line wire	31.18	31.69	32.20	9.04	9.55	10.06
9b	line wire splicing device	31.46	31.83	32.14	9.32	9.69	10.00
10b	load wire	28.42	28.81	29.21	6.28	6.67	7.07
11b	load wire splicing device	36.24	36.63	36.93	14.10	14.49	14.79
12b	room ambient	22.20	22.13	22.09			
13b	current (amps)	15.00	15.00	15.00			

Test 3b - thru Mfg. 2 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		18	19	20			
time (MM:SS) →		:40	:50	1:00			
	Breaker trip time	1:10					
1b	Mfg. 10 - 1	25.84	26.82	27.77	4.13	5.12	6.06
2b	Mfg. 10 - 2	29.58	31.10	32.54	7.88	9.40	10.83
3b	Mfg. 10 - 3	32.64	34.09	35.41	10.93	12.39	13.71
4b	Mfg. 9 - 1	25.84	26.77	27.65	4.14	5.07	5.94
5b	Mfg. 9 - 2	27.74	28.90	29.94	6.03	7.19	8.24
6b	Mfg. 9 - 3	27.36	28.35	29.32	5.65	6.65	7.62
7b	circuit breaker	26.69	27.90	29.05	4.98	6.20	7.35
8b	line wire	25.29	26.13	26.94	3.59	4.42	5.23
9b	line wire splicing device	28.85	30.25	31.50	7.14	8.54	9.80
10b	load wire	27.35	28.42	29.40	5.65	6.72	7.70
11b	load wire splicing device	29.03	30.42	31.68	7.33	8.71	9.98
12b	room ambient	21.68	21.70	21.73			
13b	current (amps)	22.56	22.55	22.52			

Test 3c - thru Mfg. 3 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		44	45	46			
time (MM:SS) →		5:50	6:00	6:10			
	Breaker trip time	6:20					
1c	Mfg. 10 - 1	33.95	34.06	34.18	12.26	12.38	12.49
2c	Mfg. 10 - 2	34.86	35.03	35.17	13.17	13.34	13.48
3c	Mfg. 10 - 3	32.06	32.16	32.23	10.37	10.47	10.55
4c	Mfg. 9 - 1	31.67	31.77	31.89	9.98	10.08	10.20
5c	Mfg. 9 - 2	31.89	31.99	32.07	10.20	10.30	10.39
6c	Mfg. 9 - 3	30.51	30.58	30.63	8.82	8.89	8.94
7c	circuit breaker	37.51	37.73	37.94	15.82	16.04	16.25
8c	line wire	38.17	38.32	38.46	16.48	16.63	16.77
9c	line wire splicing device	33.48	33.53	33.58	11.79	11.84	11.89
10c	load wire	37.25	37.38	37.51	15.57	15.70	15.82
11c	load wire splicing device	39.05	39.08	39.09	17.36	17.39	17.40
12c	room ambient	21.68	21.69	21.69			
13c	current (amps)	15.00	15.00	15.00			

Test 3c - thru Mfg. 3 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		28	29	30			
time (MM:SS) →		2:20	2:30	2:40			
	Breaker trip time	2:50					
1c	Mfg. 10 - 1	28.08	27.72	27.38	6.22	5.87	5.53
2c	Mfg. 10 - 2	27.85	27.43	27.08	5.99	5.58	5.23
3c	Mfg. 10 - 3	26.82	26.45	26.13	4.97	4.59	4.27
4c	Mfg. 9 - 1	26.62	26.30	26.02	4.76	4.45	4.17
5c	Mfg. 9 - 2	26.78	26.44	26.12	4.92	4.58	4.27
6c	Mfg. 9 - 3	26.00	25.71	25.47	4.15	3.86	3.62
7c	circuit breaker	30.09	29.81	29.54	8.23	7.95	7.68
8c	line wire	27.46	27.28	27.08	5.61	5.42	5.22
9c	line wire splicing device	27.03	26.55	26.12	5.18	4.69	4.26
10c	load wire	27.36	27.10	26.84	5.50	5.24	4.98
11c	load wire splicing device	27.70	27.09	26.53	5.84	5.23	4.67
12c	room ambient	21.89	21.86	21.82			
13c	current (amps)	22.40	22.39	22.39			

Test 4a - thru Mfg. 1 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		10	11	12			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1a	Mfg. 11 - 1	24.11	24.67	25.32	2.07	2.62	3.28
2a	Mfg. 11 - 2	24.06	24.59	25.25	2.02	2.55	3.20
3a	Mfg. 11 - 3	24.07	24.57	25.16	2.03	2.52	3.12
4a	Mfg. 8 - 1	24.08	24.69	25.40	2.03	2.64	3.35
5a	Mfg. 8 - 2	24.66	25.33	26.11	2.61	3.28	4.06
6a	Mfg. 8 - 3	24.22	24.83	25.55	2.17	2.79	3.50
7a	circuit breaker	24.11	24.82	25.62	2.07	2.77	3.57
8a	line wire	27.40	28.75	30.11	5.35	6.71	8.06
9a	line wire splicing device	25.44	26.76	28.29	3.40	4.72	6.24
10a	load wire	26.61	27.77	28.96	4.57	5.72	6.91
11a	load wire splicing device	26.63	28.24	30.08	4.59	6.20	8.04
12a	room ambient	22.05	22.06	22.03			
13a	current (amps)	19.99	20.01	20.01			

Test 4a - thru Mfg. 1 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		20	21	22			
time (MM:SS) →		:28	:35	:42			
	Breaker trip time	:49					
1a	Mfg. 11 - 1	27.71	28.87	30.04	5.22	6.37	7.55
2a	Mfg. 11 - 2	27.71	28.87	30.05	5.22	6.38	7.56
3a	Mfg. 11 - 3	27.95	28.97	30.04	5.46	6.47	7.54
4a	Mfg. 8 - 1	27.60	28.90	30.19	5.11	6.40	7.70
5a	Mfg. 8 - 2	28.56	29.91	31.25	6.06	7.42	8.76
6a	Mfg. 8 - 3	29.13	30.23	31.51	6.63	7.73	9.02
7a	circuit breaker	27.85	29.29	30.80	5.35	6.80	8.30
8a	line wire	29.17	30.44	31.74	6.68	7.95	9.24
9a	line wire splicing device	36.20	38.78	41.38	13.71	16.28	18.89
10a	load wire	29.69	31.07	32.48	7.20	8.58	9.98
11a	load wire splicing device	36.64	39.18	41.65	14.14	16.69	19.15
12a	room ambient	22.48	22.48	22.52			
13a	current (amps)	29.87	29.79	29.76			

Test 4b - thru Mfg. 2 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		10	11	12			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1b	Mfg. 11 - 1	23.92	24.53	25.23	2.00	2.60	3.30
2b	Mfg. 11 - 2	23.87	24.40	25.03	1.95	2.48	3.10
3b	Mfg. 11 - 3	24.04	24.56	25.19	2.11	2.64	3.27
4b	Mfg. 8 - 1	24.03	24.67	25.43	2.11	2.74	3.51
5b	Mfg. 8 - 2	24.81	25.54	26.38	2.89	3.62	4.46
6b	Mfg. 8 - 3	24.09	24.69	25.38	2.17	2.77	3.46
7b	circuit breaker	23.99	24.68	25.52	2.07	2.75	3.60
8b	line wire	25.64	26.65	27.71	3.72	4.73	5.78
9b	line wire splicing device	25.15	26.44	27.96	3.22	4.52	6.03
10b	load wire	23.65	24.33	25.10	1.73	2.41	3.18
11b	load wire splicing device	26.05	27.55	29.19	4.13	5.63	7.27
12b	room ambient	21.94	21.92	21.90			
13b	current (amps)	20.00	20.00	20.00			

Test 4b - thru Mfg. 2 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		:00	:09	:15			
	Breaker trip time	:21					
1b	Mfg. 11 - 1	22.78	24.58	25.64	0.28	2.08	3.14
2b	Mfg. 11 - 2	22.55	23.95	24.94	0.05	1.45	2.44
3b	Mfg. 11 - 3	22.78	24.32	25.15	0.28	1.82	2.65
4b	Mfg. 8 - 1	22.67	24.22	25.26	0.17	1.72	2.76
5b	Mfg. 8 - 2	23.01	25.35	26.56	0.52	2.85	4.06
6b	Mfg. 8 - 3	23.06	25.22	26.32	0.57	2.72	3.83
7b	circuit breaker	22.89	24.64	25.66	0.39	2.15	3.17
8b	line wire	22.78	24.14	25.26	0.28	1.64	2.76
9b	line wire splicing device	22.80	25.27	27.08	0.30	2.77	4.59
10b	load wire	22.73	25.29	26.72	0.23	2.79	4.22
11b	load wire splicing device	22.84	25.76	27.75	0.34	3.26	5.26
12b	room ambient	22.49	22.49	22.51			
13b	current (amps)	29.72	29.67	29.65			

Test 4c - thru Mfg. 3 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		:56	1:03	1:10			
	Breaker trip time	1:17					
1c	Mfg. 11 - 1	27.91	28.45	29.02	5.96	6.50	7.07
2c	Mfg. 11 - 2	27.83	28.34	28.85	5.88	6.39	6.90
3c	Mfg. 11 - 3	26.46	26.84	27.26	4.51	4.89	5.31
4c	Mfg. 8 - 1	28.33	28.89	29.46	6.38	6.94	7.51
5c	Mfg. 8 - 2	28.77	29.28	29.81	6.82	7.33	7.86
6c	Mfg. 8 - 3	27.76	28.25	28.71	5.81	6.30	6.76
7c	circuit breaker	30.95	31.72	32.52	8.99	9.77	10.56
8c	line wire	32.07	32.86	33.68	10.12	10.91	11.73
9c	line wire splicing device	31.50	32.36	33.19	9.54	10.41	11.24
10c	load wire	32.53	33.29	34.09	10.58	11.34	12.14
11c	load wire splicing device	36.35	37.44	38.34	14.40	15.49	16.39
12c	room ambient	22.03	21.91	21.92			
13c	current (amps)	20.00	20.00	20.00			

Test 4c - thru Mfg. 3 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		18	19	20			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1c	Mfg. 11 - 1	24.86	25.82	26.97	2.56	3.52	4.67
2c	Mfg. 11 - 2	25.87	27.00	28.27	3.57	4.70	5.97
3c	Mfg. 11 - 3	25.45	26.38	27.49	3.15	4.08	5.19
4c	Mfg. 8 - 1	25.11	26.19	27.48	2.81	3.89	5.18
5c	Mfg. 8 - 2	26.49	27.73	29.14	4.19	5.43	6.85
6c	Mfg. 8 - 3	25.08	26.08	27.24	2.78	3.78	4.94
7c	circuit breaker	25.44	26.60	28.04	3.14	4.30	5.74
8c	line wire	24.49	25.44	26.52	2.20	3.15	4.22
9c	line wire splicing device	27.39	29.24	31.37	5.09	6.95	9.07
10c	load wire	26.18	27.74	29.43	3.88	5.44	7.13
11c	load wire splicing device	26.21	27.89	29.79	3.91	5.59	7.49
12c	room ambient	22.31	22.30	22.29			
13c	current (amps)	29.59	29.78	29.83			

Test 4a - thru Mfg. 1 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		27	28	29			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1a	Mfg. 10 - 1	24.20	24.89	25.74	2.53	3.23	4.07
2a	Mfg. 10 - 2	24.11	24.81	25.65	2.45	3.14	3.99
3a	Mfg. 10 - 3	23.82	24.42	25.12	2.16	2.76	3.45
4a	Mfg. 9 - 1	23.70	24.28	24.96	2.04	2.62	3.29
5a	Mfg. 9 - 2	23.89	24.51	25.23	2.22	2.84	3.57
6a	Mfg. 9 - 3	23.66	24.22	24.90	1.99	2.55	3.23
7a	circuit breaker	23.81	24.47	25.29	2.14	2.80	3.63
8a	line wire	26.99	28.37	29.76	5.32	6.71	8.09
9a	line wire splicing device	24.05	25.15	26.46	2.39	3.48	4.79
10a	load wire	26.61	27.85	29.13	4.94	6.19	7.47
11a	load wire splicing device	28.24	30.24	32.42	6.58	8.58	10.75
12a	room ambient	21.68	21.67	21.66			
13a	current (amps)	20.02	20.03	20.03			

Test 4a - thru Mfg. 1 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		17	18	19			
time (MM:SS) →		:28	:35	:42			
	Breaker trip time	:49					
1a	Mfg. 10 - 1	27.27	28.75	30.17	5.77	7.24	8.67
2a	Mfg. 10 - 2	28.89	30.53	32.07	7.38	9.02	10.56
3a	Mfg. 10 - 3	27.89	29.33	30.74	6.38	7.82	9.24
4a	Mfg. 9 - 1	27.16	28.54	29.90	5.66	7.04	8.39
5a	Mfg. 9 - 2	28.09	29.55	30.97	6.58	8.05	9.46
6a	Mfg. 9 - 3	27.93	29.14	30.27	6.43	7.64	8.77
7a	circuit breaker	26.82	28.27	29.71	5.32	6.77	8.20
8a	line wire	28.15	29.45	30.67	6.65	7.95	9.17
9a	line wire splicing device	34.08	36.63	38.99	12.57	15.13	17.49
10a	load wire	28.54	29.95	31.29	7.03	8.45	9.79
11a	load wire splicing device	35.97	38.68	41.18	14.47	17.17	19.67
12a	room ambient	21.49	21.52	21.51			
13a	current (amps)	29.88	29.83	29.82			

Test 4b - thru Mfg. 2 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		27	28	29			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1b	Mfg. 10 - 1	23.68	24.31	25.08	2.15	2.79	3.55
2b	Mfg. 10 - 2	24.00	24.79	25.66	2.47	3.26	4.13
3b	Mfg. 10 - 3	23.96	24.59	25.27	2.43	3.06	3.74
4b	Mfg. 9 - 1	23.67	24.25	24.93	2.14	2.73	3.40
5b	Mfg. 9 - 2	23.75	24.36	25.10	2.22	2.84	3.58
6b	Mfg. 9 - 3	23.79	24.37	25.03	2.26	2.84	3.50
7b	circuit breaker	23.69	24.36	25.21	2.16	2.84	3.69
8b	line wire	25.34	26.37	27.40	3.81	4.84	5.88
9b	line wire splicing device	24.37	25.54	26.91	2.84	4.01	5.38
10b	load wire	23.38	24.06	24.84	1.86	2.54	3.32
11b	load wire splicing device	28.62	30.57	32.60	7.09	9.05	11.07
12b	room ambient	21.54	21.54	21.50			
13b	current (amps)	19.99	19.99	19.99			

Test 4b - thru Mfg. 2 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		13	14	15			
time (MM:SS) →		0:00	:09	:15			
	Breaker trip time	:21					
1b	Mfg. 10 - 1	21.91	23.26	24.56	0.52	1.87	3.16
2b	Mfg. 10 - 2	21.93	24.79	26.37	0.54	3.40	4.97
3b	Mfg. 10 - 3	21.91	23.93	25.26	0.52	2.54	3.87
4b	Mfg. 9 - 1	21.95	24.22	25.49	0.56	2.83	4.10
5b	Mfg. 9 - 2	21.93	24.57	25.87	0.54	3.18	4.48
6b	Mfg. 9 - 3	21.90	24.12	25.30	0.51	2.73	3.90
7b	circuit breaker	22.03	23.68	24.72	0.64	2.28	3.33
8b	line wire	22.07	23.08	24.22	0.68	1.69	2.83
9b	line wire splicing device	21.89	24.14	26.27	0.50	2.75	4.87
10b	load wire	21.93	24.17	25.69	0.54	2.78	4.30
11b	load wire splicing device	21.95	26.40	28.99	0.56	5.01	7.60
12b	room ambient	21.40	21.38	21.40			
13b	current (amps)	30.03	29.98	29.94			

Test 4c - thru Mfg. 3 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		33	34	35			
time (MM:SS) →		:56	1:03	1:10			
	Breaker trip time	1:17					
1c	Mfg. 10 - 1	28.89	29.56	30.22	7.33	8.01	8.67
2c	Mfg. 10 - 2	29.13	29.80	30.47	7.57	8.25	8.92
3c	Mfg. 10 - 3	28.24	28.82	29.43	6.69	7.27	7.87
4c	Mfg. 9 - 1	27.96	28.54	29.11	6.41	6.98	7.56
5c	Mfg. 9 - 2	27.95	28.55	29.13	6.40	6.99	7.58
6c	Mfg. 9 - 3	27.87	28.37	28.89	6.31	6.82	7.34
7c	circuit breaker	30.46	31.20	31.96	8.91	9.65	10.41
8c	line wire	31.76	32.54	33.32	10.20	10.99	11.77
9c	line wire splicing device	30.32	31.15	31.96	8.77	9.60	10.41
10c	load wire	32.17	32.94	33.69	10.62	11.39	12.14
11c	load wire splicing device	39.40	40.57	41.66	17.85	19.02	20.11
12c	room ambient	21.59	21.54	21.53			
13c	current (amps)	20.00	20.00	20.00			

Test 4c - thru Mfg. 3 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		:21	:28	:35			
	Breaker trip time	:42					
1c	Mfg. 10 - 1	24.57	25.84	27.05	3.19	4.45	5.67
2c	Mfg. 10 - 2	28.42	30.54	32.56	7.04	9.16	11.18
3c	Mfg. 10 - 3	33.47	35.78	37.86	12.09	14.40	16.48
4c	Mfg. 9 - 1	24.87	26.08	27.27	3.49	4.70	5.89
5c	Mfg. 9 - 2	27.04	28.63	30.11	5.66	7.25	8.73
6c	Mfg. 9 - 3	26.95	28.35	29.72	5.57	6.97	8.34
7c	circuit breaker	25.75	27.15	28.60	4.37	5.77	7.22
8c	line wire	24.57	25.65	26.68	3.19	4.27	5.30
9c	line wire splicing device	27.76	29.81	31.74	6.38	8.43	10.35
10c	load wire	26.52	28.22	29.72	5.14	6.84	8.34
11c	load wire splicing device	27.66	29.85	31.88	6.28	8.47	10.49
12c	room ambient	21.40	21.37	21.36			
13c	current (amps)	29.34	29.29	30.17			

Test 1b - thru Mfg. 2 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		67	72	77			
time (HH:MM:SS) →		1:04:00	1:09:00	1:14:00			
1b	Mfg. 10 - 1	33.66	33.62	33.48	12.17	12.13	11.99
2b	Mfg. 10 - 2	30.46	30.56	30.61	8.97	9.07	9.12
3b	Mfg. 10 - 3	28.97	29.03	28.87	7.48	7.54	7.38
4b	Mfg. 9 - 1	28.59	28.61	28.68	7.10	7.12	7.19
5b	Mfg. 9 - 2	29.99	29.94	29.81	8.50	8.45	8.32
6b	Mfg. 9 - 3	28.44	28.40	28.15	6.95	6.91	6.66
7b	circuit breaker	41.26	41.48	41.60	19.77	19.99	20.11
8b	line wire	31.15	30.97	30.89	9.66	9.48	9.40
9b	line wire splicing device	28.63	28.27	28.01	7.14	6.78	6.52
10b	load wire	28.45	28.20	28.09	6.96	6.71	6.60
11b	load wire splicing device	30.47	29.94	29.87	8.98	8.45	8.38
12b	room ambient	22.46	22.07	21.66			
13b	current (amps)	10.01	10.01	10.01			

Test 2b - thru Mfg. 2 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		202	203	204			
time (MM:SS) →		66:20	66:40	67:00			
	Breaker trip time	> 67 mins. (no trip)					
1b	Mfg. 10 - 1	40.89	40.89	40.88	18.96	18.97	18.96
2b	Mfg. 10 - 2	37.03	37.03	37.04	15.11	15.11	15.12
3b	Mfg. 10 - 3	34.24	34.26	34.21	12.31	12.34	12.29
4b	Mfg. 9 - 1	33.52	33.50	33.53	11.60	11.58	11.61
5b	Mfg. 9 - 2	35.79	35.78	35.75	13.87	13.86	13.83
6b	Mfg. 9 - 3	33.44	33.45	33.39	11.52	11.53	11.47
7b	circuit breaker	56.60	56.56	56.59	34.68	34.64	34.67
8b	line wire	38.73	38.68	38.65	16.81	16.76	16.72
9b	line wire splicing device	33.69	33.57	33.57	11.76	11.65	11.65
10b	load wire	33.57	33.50	33.50	11.65	11.57	11.58
11b	load wire splicing device	37.08	36.99	37.04	15.16	15.07	15.12
12b	room ambient	22.10	22.03	21.97			
13b	current (amps)	13.49	13.49	13.49			

Appendix D Flexing Tests

Conductor Flexing tests on 14-2 AWG copper-clad aluminum NMB cable:

test #	wire connection method	pass / fail (10x flexion)	comments
6-1	wrap around terminal screw	pass	ends of hot and neutral wires broke when removing them from their terminals after the test
6-2	single compression	pass	
6-3	double compression	pass	
6-1-1	wrap around terminal screw	failed	retest of 6-1; hot wire (black) broke on 8th flexion
6-1-2	wrap around terminal screw	pass	retest of 6-1 using copper wire
6-1-3	wrap around terminal screw	pass	retest of 6-1

NOTE: One Legrand receptacle was used for all 3 tests above and 9in/lbs was applied to all three terminal screws.

PACIFIC TEST AND MEASUREMENT

PO Box 2363, Clackamas, OR 97015
15648 114th Ave. Suite 109, Clackamas OR 97015
Phone: 503-406-4373 Fax: 503 905 0457
www.pacifictestandmeasurement.com

Certificate of Conformance

Issued to:	CDCMello Consulting LLC PO Box 872317 Vancouver, WA 98687
Customer PO:	Verbal Chuck Mello
Model:	UL3055
Lot Number:	952103-019
Report:	JK202006300-003
Description:	Type J, 30 Gauge FEP/FEP Teflon, Special Limits of Error Tolerance, 15 feet length, Thermocouple

Pacific Test and Measurement Inc certifies that the order of thermocouples meets all applicable instructions, specifications, and in accordance with DAP UL 00-OP-C0037 version 10.0. The preferred method of welding to produce a single point weld or bead using ThermX model 258B welder has been used to assemble the thermocouple junction which has been proven as reliable and repeatable through validation. The finish products were assembled from UL4047, a spool of described wire calibrated to accredited standards as described in the calibration report.

Certified by: _____ Date: ___7-10-2020_____
(Quality Department)

ACCREDITED
CERT #2496.01

Report of Calibration

Eustis Co.,Inc./Pyrocom Calibration lab
12407-B Mukilteo Speedway #200
Lynnwood, wa 98087

Model: UL4047 Serial: 952103-019 Description: TYPE J, 30AWG, FEP/FEP	Customer: . . CDCMello Consulting LLC PO Box 872317 Vancouver, WA 98687
Calibration Range: Limited Received Condition: New Current: N/A Procedure: ECP 339/341	

The unit under test (UUT) on this certificate has been calibrated by comparison method as covered by ASTM E220-13, and calibrated against standards traceable to the National Institute of Standards and Technology (NIST). Eustis Co., Inc./Pyrocom Calibration Lab meets the requirements of ANSI/NCSL Z540-1-1994 and ISO/IEC 17025 and is accredited by A2LA via Certificate Number 2496.01 for calibrations within the scope to which it applies. The uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2. All results contained within this certificate relate only to the item calibrated. Any number of factors may cause the calibrated item to drift out of calibration.

Nominal Value (Set-point) (C)	Actual Value (Reference) (C)	UUT (Test Sensor) (C)	Error (C)	Measurement Uncertainty (C)	Method of Realization
21.00	21.41	21.38	-0.03	+/- 0.31	COMP
40.00	40.08	40.02	-0.06	+/- 0.40	COMP
95.00	95.02	94.97	-0.05	+/- 0.40	COMP
150.00	150.02	150.10	0.08	+/- 0.50	COMP
200.00	200.01	200.23	0.22	+/- 0.50	COMP

Test Equipment

Manufacturer	Model	Description	Serial Number	Recall Date
Hart Scientific	1560	"Black Stack" Base Unit	96539	NCR
Hart Scientific	2560	SPRT Module	A25631	3/24/2021
Fluke	5628	4 Wire SPRT	4303	3/26/2021
Fluke	2566	Thermocouple Scanner	B7A380	3/24/2021
Fluke	9173	Metrology Well, 700 C	B47975	NCR
Fluke	7380	Bath, Ultra Low-Temperature	B2A527	NCR

Calibration Date: 6/18/2020
Temperature: 23.0 C
Humidity: 47%
Customer Order: 74523

Technician: Julia Kulin

Approved By: Walter Paulson
QA Manager

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Report of Calibration

Notes: The thermocouple wire meets or exceeds the criteria established for type "J" SPECIAL LIMITS OF ERROR per ASTM E230/E230M-17 table 1 & ISA-MC96.1-1982 Par. 2.5 Table 8 +/- 1.1°C OR +/- .4% whichever is greater. Lot calibration data supplied for your reference.
Calibrated item meets special limits of error for all results given according to the comparison of "error" reading to the specifications found in ASTM E230/E230M-17 table 1 & MC96.1-1982 table 8; acceptance determination is ultimately the responsibility of the customer, taking into account all uncertainties and other factors. The closer the results are to the specification limits, the greater the risk that the unit under test will be out of tolerance.

Report issue date: JUN 1 9 2020

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Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Certification Number CK198-33105-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Data Acquisition Unit
Make	Keysight
Model	34972A
Serial Number	MY49002695
Identification	EM7054
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 57.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-006 rev. 2

This certificate shall not be altered in any form or reproduced, except in full, without prior written approval from originating lab. These results relate only to the item(s) calibrated.
Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
Root Difference Square guardbanding method used.						
UUT IDENTIFICATION						
Serial Number: MY49002695 Firmware Level: 1.11-1.12-02-01						
INPUT MODULE CHARACTERISTICS						
Model: 34901A Firmware Level: 2.3						
SELF TEST				Pass	Pass	

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Oshkosh, WI 54902
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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
INTERNAL DMM VERIFICATION						
ZERO OFFSET VERIFICATION						
DC CURRENT						
10 mA Range						
0.00000 mA	0.00000	-0.00200	0.00200	0.00003	0.00003	0.000007
100 mA Range						
0.0000 mA	0.0000	-0.0050	0.0050	0.0000	0.0000	0.00006
1 A Range						
0.000000 A	0.000000	-0.000100	0.000100	0.000001	0.000001	0.0000006
DC VOLTS						
100 mV Range						
0.0000 mV	0.0000	-0.0040	0.0040	0.0004	0.0004	0.00007
1 V Range						
0.000000 V	0.000000	-0.000007	0.000007	0.000001	0.000001	0.0000007
10 V Range						
0.00000 V	0.00000	-0.00005	0.00005	0.00000	0.00000	0.000007
100 V Range						
0.0000 V	0.0000	-0.0006	0.0006	0.0000	0.0000	0.00006
300 V Range						
0.000 V	0.000	-0.009	0.009	0.000	0.000	0.0006
2 WIRE						
100 Range						
0.0000 Ohm	0.0000	-4.0040	4.0040	0.0626	0.0626	0.00007
1 k Range						
0.000000 kOhm	0.000000	-0.004010	0.004010	0.000065	0.000065	0.0000006
10 k Range						
0.00000 kOhm	0.00000	-0.00410	0.00410	0.00008	0.00008	0.000006
100 k Range						
0.0000 kOhm	0.0000	-0.0050	0.0050	0.0002	0.0002	0.00007
1 M Range						
0.000000 MOhm	0.000000	-0.000014	0.000014	0.000000	0.000000	0.0000007
10 M Range						

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
0.00000 MOhm	0.00000	-0.00010	0.00010	0.00000	0.00000	0.000007
100 M? Range						
0.0000 MOhm	0.0000	-0.0100	0.0100	0.0000	0.0000	0.00006
4 WIRE						
100 Range						
0.0000 Ohm	0.0000	-0.0040	0.0040	-0.0023	-0.0023	0.00006
1 k Range						
0.000000 kOhm	0.000000	-0.000010	0.000010	0.000000	0.000000	0.0000006
10 k Range						
0.00000 kOhm	0.00000	-0.00010	0.00010	0.00000	0.00000	0.000007
100 k Range						
0.0000 kOhm	0.0000	-0.0010	0.0010	0.0000	0.0000	0.00007
1 M Range						
0.000000 MOhm	0.000000	-0.000010	0.000010	0.000000	0.000000	0.0000006
10 M Range						
0.00000 MOhm	0.00000	-0.00010	0.00010	0.00000	0.00000	0.000006
100 M Range						
0.0000 MOhm	0.0000	-0.0100	0.0100	0.0000	0.0000	0.00007
GAIN VERIFICATION						
DC VOLTS						
100 mV Range						
100.0000 mV	100.0000	99.9910	100.0090	100.0000	100.0000	0.00006
-100.0000 mV	-100.0000	-100.0090	-99.9910	-99.9987	-99.9987	0.00007
1 V Range						
1.000000 V	1.000000	0.999953	1.000047	0.999993	0.999993	0.0000007
-1.000000 V	-1.000000	-1.000047	-0.999953	-0.999989	-0.999989	0.0000007
10 V Range						
10.00000 V	10.00000	9.99960	10.00040	9.99994	9.99994	0.000006
-10.00000 V	-10.00000	-10.00040	-9.99960	-9.99992	-9.99992	0.000006
100 V Range						
100.0000 V	100.0000	99.9949	100.0051	99.9996	99.9996	0.00007
-100.0000 V	-100.0000	-100.0051	-99.9949	-99.9993	-99.9993	0.00007
300 V Range						
300.000 V	300.000	299.978	300.022	299.998	299.998	0.0006

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
2 WIRE						
100 Range						
100.0000 Ohm	100.0000	95.9860	104.0140	100.0067	100.0067	0.00007
1 k Range						
1.000000 kOhm	1.000000	0.995890	1.004110	1.000032	1.000032	0.0000006
10 k Range						
10.00000 kOhm	10.00000	9.99490	10.00510	10.00035	10.00035	0.000007
100 k Range						
100.0000 kOhm	100.0000	99.9850	100.0150	100.0029	100.0029	0.00006
1 M Range						
1.000000 MOhm	1.000000	0.999886	1.000114	1.000016	1.000016	0.0000006
10 M Range						
10.00000 MOhm	10.00000	9.99590	10.00410	9.99768	9.99768	0.000006
100 M Range						
100.0000 MOhm	100.0000	99.1900	100.8100	100.3688	100.3688	0.00007
4 WIRE						
100 Range						
100.0000 Ohm	100.0000	99.9860	100.0140	100.0039	100.0039	0.00006
1 k Range						
1.000000 kOhm	1.000000	0.999890	1.000110	1.000030	1.000030	0.0000007
10 k Range						
10.00000 kOhm	10.00000	9.99890	10.00110	10.00032	10.00032	0.000006
100 k Range						
100.0000 kOhm	100.0000	99.9890	100.0110	100.0021	100.0021	0.00007
1 M Range						
1.000000 MOhm	1.000000	0.999890	1.000110	0.999970	0.999970	0.0000007
10 M Range						
10.00000 MOhm	10.00000	9.99590	10.00410	9.99595	9.99595	0.000006
100 M Range						
100.0000 MOhm	100.0000	99.1900	100.8100	99.8275	99.8275	0.00006
DC CURRENT						
10 mA Range						
10.00000 mA	10.00000	9.99300	10.00700	9.99898	9.99898	0.000007
-10.00000 mA	-10.00000	-10.00700	-9.99300	-9.99887	-9.99887	0.000007

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
100 mA Range						
100.0000 mA	100.0000	99.9450	100.0550	99.9882	99.9882	0.00006
-100.0000 mA	-100.0000	-100.0550	-99.9450	-99.9879	-99.9879	0.00006
1 A Range						
1.000000 A	1.000000	0.998900	1.001100	0.999534	0.999534	0.0000006
-1.000000 A	-1.000000	-1.001100	-0.998900	-0.999537	-0.999537	0.0000006
AC VOLTS						
100 mV Range						
10.0000 mV @ 1 kHz	10.0000	9.9540	10.0460	9.9997	9.9997	0.00006
100.0000 mV @ 1 kHz	100.0000	99.9000	100.1000	99.9912	99.9912	0.00006
100.0000 mV @ 50 kHz	100.0000	99.8300	100.1700	99.9383	99.9383	0.00006
1 V Range						
1.000000 V @ 20 Hz	1.000000	0.999000	1.001000	0.999803	0.999803	0.0000006
1.000000 V @ 1 kHz	1.000000	0.999000	1.001000	0.999950	0.999950	0.0000006
1.000000 V @ 20 kHz	1.000000	0.999000	1.001000	0.999888	0.999888	0.0000006
1.000000 V @ 50 kHz	1.000000	0.998300	1.001700	0.999504	0.999504	0.0000007
1.000000 V @ 100 kHz	1.000000	0.993200	1.006800	0.998811	0.998811	0.0000006
1.000000 V @ 200 kHz	1.000000	0.955000	1.045000	0.999068	0.999068	0.0000006
1.000000 V @ 250 kHz	1.000000	0.955000	1.045000	0.999202	0.999202	0.0000007
1.000000 V @ 300 kHz	1.000000	0.955000	1.045000	0.998797	0.998797	0.0000006
10 V Range						
0.10000 V @ 1 kHz	0.10000	0.08594	0.11406	0.10086	0.10086	0.000006
1.00000 V @ 1 kHz	1.00000	0.99540	1.00460	0.99992	0.99992	0.000006
10.00000 V @ 10 Hz	10.00000	9.99000	10.01000	9.99743	9.99743	0.000007
10.00000 V @ 1 kHz	10.00000	9.99000	10.01000	9.99855	9.99855	0.000006
10.00000 V @ 50 kHz	10.00000	9.98300	10.01700	9.99499	9.99499	0.000006
100 V Range						
100.0000 V @ 1 kHz	100.0000	99.9000	100.1000	99.9653	99.9653	0.00006
100.0000 V @ 50 kHz	100.0000	99.8300	100.1700	99.8943	99.8943	0.00006

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
300 V Range						
300.000 V @ 1 kHz	300.000	299.580	300.420	299.884	299.884	0.0006
200.000 V @ 50 kHz	200.000	199.400	200.600	199.750	199.750	0.0007
AC CURRENT						
10 mA Range						
10.00000 mA @ 1 kHz	10.00000	9.98600	10.01400	9.99766	9.99766	0.000007
100 mA Range						
100.0000 mA @ 1 kHz	100.0000	99.4000	100.6000	99.9484	99.9484	0.00007
1 A Range						
0.010000 A @ 1 kHz	0.010000	0.008590	0.011410	0.009960	0.009960	0.0000007
1.000000 A @ 1 kHz	1.000000	0.998600	1.001400	0.999502	0.999502	0.0000006
FREQUENCY						
100 Hz Range						
100.0000 Hz	100.0000	99.9000	100.1000	100.0056	100.0056	0.00007
100 kHz Range						
100.0000 kHz	100.0000	99.9900	100.0100	100.0001	100.0001	0.00007

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY

Certificate No. ACT-1272

Certification Number CK198-39504-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Multimeter Digital Multimeter
Make	Fluke
Model	179
Serial Number	77840008
Identification	EM4437
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	68.3°F, 20.2°C, 56.2%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-001 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in base units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
600 mV Range						
300.0 mV @ 45 Hz	300.0	296.7	303.3	299.2	299.2	0.07
6 V Range						
5.000 V @ 500 Hz	5.000	4.947	5.053	4.987	4.987	0.0007
5.000 V @ 1 kHz	5.000	4.897	5.103	4.949	4.949	0.0007
60 V Range						
50.00 V @ 45 Hz	50.00	49.47	50.53	49.98	49.98	0.007
50.00 V @ 1 kHz	50.00	48.97	51.03	50.02	50.02	0.007
600 V Range						
300.0 V @ 45 Hz	300.0	296.7	303.3	299.9	299.9	0.07
500.0 V @ 500 Hz	500.0	494.7	505.3	500.5	500.5	0.06
500.0 V @ 1 kHz	500.0	489.7	510.3	500.5	500.5	0.06
1000 V Range						
1000 V @ 45 Hz	1000	987	1013	1002	1002	0.7

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
FREQUENCY						
45.00 Hz @ 1 V	45.00	44.95	45.06	45.01	45.01	0.007
50.00 kHz @ 5 V	50.00	49.94	50.06	50.00	50.00	0.006
DC VOLTAGE						
6 V Range						
5.000 V	5.000	4.994	5.007	4.997	4.997	0.0006
600 V Range						
300.0 V	300.0	299.5	300.5	299.8	299.8	0.06
1000 V Range						
1000 V	1000	997	1004	999	999	0.6
-1000 V	-1000	-1004	-997	-1000	-1000	0.7
DC VOLTS						
FREQUENCY						
45.00 Hz @ 3 V	45.00	44.95	45.06	45.01	45.01	0.007
50.00 kHz @ 30 V	50.00	49.94	50.06	50.00	50.00	0.007
DC MILLIVOLTS						
30.0 mV	30.0	29.8	30.2	30.0	30.0	0.06
-300.0 mV	-300.0	-300.5	-299.5	-299.9	-299.9	0.06
600.0 mV	600.0	599.3	600.7	599.7	599.7	0.07
TEMPERATURE						
0.0 °C	0.0	-1.0	1.0	1.0	1.0	0.06
-40.0 °C	-40.0	-41.4	-38.6	-39.0	-39.0	0.07
400.0 °C	400.0	395.0	405.0	400.9	400.9	0.06
OHMS						
600 Ohm Range						
19.0 Ohm	19.0	18.6	19.4	19.3	19.3	0.07
50 MOhm Range						
19.00 MOhm	19.00	18.68	19.32	19.00	19.00	0.006
CAPACITANCE						
1000 nF Range						
900 nF	900	887	913	899	899	0.6
CONTINUITY						
0 Ohms: Beeper On				Pass	Pass	
190 Ohms: Beeper Off				Pass	Pass	
DIODE TEST						

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
2.000 V	2.000	1.978	2.022	2.000	2.000	0.0007
AC MILLIAMPS						
60 mA Range						
3.00 mA @ 45 Hz	3.00	2.92	3.08	3.00	3.00	0.007
50.00 mA @ 1 kHz	50.00	49.22	50.78	50.06	50.06	0.006
400 mA Range						
400.0 mA @ 1 kHz	400.0	393.7	406.3	400.4	400.4	0.07
AC AMPS						
6 A Range						
4.000 A @ 45 Hz	4.000	3.937	4.063	4.005	4.005	0.0007
10A Range						
9.00 A @ 1 kHz	9.00	8.84	9.16	9.04	9.04	0.007
DC MILLIAMPS						
60 mA Range						
3.00 mA	3.00	2.94	3.06	3.00	3.00	0.006
50.00 mA	50.00	49.47	50.53	49.92	49.92	0.007
400 mA Range						
-400.0 mA	-400.0	-404.3	-395.7	-399.8	-399.8	0.07
DC AMPS						
6 A Range						
4.000 A	4.000	3.957	4.043	3.999	3.999	0.0007
10 A Range						
-9.00 A	-9.00	-9.12	-8.88	-9.01	-9.01	0.006

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CERTIFICATE OF CALIBRATION

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Certificate No. ACT-1272

Certification Number CK198-38060-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Multimeter Digital Multimeter
Make	Fluke
Model	175
Serial Number	13700492
Identification	EM7014
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	68.2°F, 20.1°C, 56.6%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-001 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in base units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
600 mV Range						
300.0 mV @ 45 Hz	300.0	296.7	303.3	299.9	299.9	0.07
6 V Range						
5.000 V @ 500 Hz	5.000	4.947	5.053	4.994	4.994	0.0007
5.000 V @ 1 kHz	5.000	4.897	5.103	4.955	4.955	0.0006
60 V Range						
50.00 V @ 45 Hz	50.00	49.47	50.53	49.94	49.94	0.007
50.00 V @ 1 kHz	50.00	48.97	51.03	50.06	50.06	0.006
600 V Range						
300.0 V @ 45 Hz	300.0	296.7	303.3	299.8	299.8	0.07
500.0 V @ 500 Hz	500.0	494.7	505.3	500.4	500.4	0.07
500.0 V @ 1 kHz	500.0	489.7	510.3	500.4	500.4	0.06
1000 V Range						
1000 V @ 45 Hz	1000	987	1013	996	996	0.6

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
FREQUENCY						
45.00 Hz @ 1 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 5 V	50.00	49.94	50.06	50.00	50.00	0.007
DC VOLTAGE						
6 V Range						
5.000 V	5.000	4.990	5.010	5.000	5.000	0.0007
600 V Range						
300.0 V	300.0	299.4	300.6	300.0	300.0	0.06
1000 V Range						
1000 V	1000	997	1004	1000	1000	0.7
-1000 V	-1000	-1004	-997	-1000	-1000	0.7
DC VOLTS						
FREQUENCY						
45.00 Hz @ 3 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 30 V	50.00	49.94	50.06	50.00	50.00	0.007
DC MILLIVOLTS						
30.0 mV	30.0	29.8	30.2	30.0	30.0	0.07
-300.0 mV	-300.0	-300.6	-299.4	-299.9	-299.9	0.06
600.0 mV	600.0	598.9	601.1	599.9	599.9	0.06
OHMS						
600 Ohm Range						
19.0 Ohm	19.0	18.6	19.4	19.0	19.0	0.07
50 MOhm Range						
19.00 MOhm	19.00	18.68	19.32	18.99	18.99	0.006
CAPACITANCE						
1000 nF Range						
900 nF	900	887	913	900	900	0.7
CONTINUITY						
0 Ohms: Beeper On				Pass	Pass	
190 Ohms: Beeper Off				Pass	Pass	
DIODE TEST						
2.000 V	2.000	1.978	2.022	2.001	2.001	0.0006
AC MILLIAMPS						
60 mA Range						

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
3.00 mA @ 45 Hz	3.00	2.92	3.08	3.01	3.01	0.007
50.00 mA @ 1 kHz	50.00	49.22	50.78	49.96	49.96	0.007
400 mA Range						
400.0 mA @ 1 kHz	400.0	393.7	406.3	399.4	399.4	0.06
AC AMPS						
6 A Range						
4.000 A @ 45 Hz	4.000	3.937	4.063	3.997	3.997	0.0007
10A Range						
9.00 A @ 1 kHz	9.00	8.84	9.16	9.00	9.00	0.007
DC MILLIAMPS						
60 mA Range						
3.00 mA	3.00	2.94	3.06	3.02	3.02	0.006
50.00 mA	50.00	49.47	50.53	49.99	49.99	0.006
400 mA Range						
-400.0 mA	-400.0	-404.3	-395.7	-400.0	-400.0	0.07
DC AMPS						
6 A Range						
4.000 A	4.000	3.957	4.043	3.999	3.999	0.0007
10 A Range						
-9.00 A	-9.00	-9.12	-8.88	-9.00	-9.00	0.007

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CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK198-38779-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Multimeter Digital Multimeter
Make	Fluke
Model	179
Serial Number	14370601
Identification	EM7024
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	68.2°F, 20.1°C, 56.6%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-001 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
600 mV Range						
300.0 mV @ 45 Hz	300.0	296.7	303.3	300.0	300.0	0.06
6 V Range						
5.000 V @ 500 Hz	5.000	4.947	5.053	4.997	4.997	0.0006
5.000 V @ 1 kHz	5.000	4.897	5.103	4.961	4.961	0.0006
60 V Range						
50.00 V @ 45 Hz	50.00	49.47	50.53	49.97	49.97	0.006
50.00 V @ 1 kHz	50.00	48.97	51.03	50.10	50.10	0.007
600 V Range						
300.0 V @ 45 Hz	300.0	296.7	303.3	300.0	300.0	0.07
500.0 V @ 500 Hz	500.0	494.7	505.3	500.9	500.9	0.06
500.0 V @ 1 kHz	500.0	489.7	510.3	500.8	500.8	0.06
1000 V Range						
1000 V @ 45 Hz	1000	987	1013	997	997	0.7

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
FREQUENCY						
45.00 Hz @ 1 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 5 V	50.00	49.94	50.06	50.00	50.00	0.006
DC VOLTAGE						
6 V Range						
5.000 V	5.000	4.994	5.007	5.000	5.000	0.0006
600 V Range						
300.0 V	300.0	299.5	300.5	299.9	299.9	0.06
1000 V Range						
1000 V	1000	997	1004	1000	1000	0.7
-1000 V	-1000	-1004	-997	-1000	-1000	0.7
DC VOLTS						
FREQUENCY						
45.00 Hz @ 3 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 30 V	50.00	49.94	50.06	50.00	50.00	0.006
DC MILLIVOLTS						
30.0 mV	30.0	29.8	30.2	30.0	30.0	0.06
-300.0 mV	-300.0	-300.5	-299.5	-299.9	-299.9	0.06
600.0 mV	600.0	599.3	600.7	599.8	599.8	0.06
TEMPERATURE						
0.0 °C	0.0	-1.0	1.0	0.5	0.5	0.06
-40.0 °C	-40.0	-41.4	-38.6	-39.3	-39.3	0.06
400.0 °C	400.0	395.0	405.0	400.4	400.4	0.06
OHMS						
600 Ohm Range						
19.0 Ohm	19.0	18.6	19.4	19.0	19.0	0.06
50 MOhm Range						
19.00 MOhm	19.00	18.68	19.32	18.98	18.98	0.006
CAPACITANCE						
1000 nF Range						
900 nF	900	887	913	900	900	0.6
CONTINUITY						
0 Ohms: Beeper On				Pass	Pass	
190 Ohms: Beeper Off				Pass	Pass	
DIODE TEST						

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
2.000 V	2.000	1.978	2.022	2.001	2.001	0.0007
AC MILLIAMPS						
60 mA Range						
3.00 mA @ 45 Hz	3.00	2.92	3.08	3.02	3.02	0.006
50.00 mA @ 1 kHz	50.00	49.22	50.78	50.03	50.03	0.006
400 mA Range						
400.0 mA @ 1 kHz	400.0	393.7	406.3	399.9	399.9	0.06
AC AMPS						
6 A Range						
4.000 A @ 45 Hz	4.000	3.937	4.063	4.004	4.004	0.0006
10A Range						
9.00 A @ 1 kHz	9.00	8.84	9.16	9.01	9.01	0.007
DC MILLIAMPS						
60 mA Range						
3.00 mA	3.00	2.94	3.06	3.01	3.01	0.007
50.00 mA	50.00	49.47	50.53	49.99	49.99	0.007
400 mA Range						
-400.0 mA	-400.0	-404.3	-395.7	-399.9	-399.9	0.06
DC AMPS						
6 A Range						
4.000 A	4.000	3.957	4.043	3.998	3.998	0.0006
10 A Range						
-9.00 A	-9.00	-9.12	-8.88	-9.00	-9.00	0.007

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK198-41226-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Clamp Meter
Make	AEMC
Model	SR759
Serial Number	224137GKDV
Identification	EM6996
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 56.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-007 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-546	24560221	CK093-41519-573	04/30/2021
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
1A Range; 1000mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 mA	10.0	8.7	11.3	10.1	10.1	0.07
100 mA	100.0	96.0	104.0	101.3	101.3	0.06
500 mA	500.0	495.5	504.5	504.5	504.5	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
1 A	1.000	0.992	1.008	1.008	1.008	0.0006
10A Range; 100mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
100 mA	10.0	9.7	10.3	10.0	10.0	0.07
1 A	100.0	99.3	100.7	100.4	100.4	0.07
5 A	500.0	497.5	502.5	501.8	501.8	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
10 A	1.000	0.995	1.005	1.004	1.004	0.0007
100A Range; 10mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
1 A	10.0	9.7	10.3	10.0	10.0	0.07
10 A	100.0	99.3	100.7	100.1	100.1	0.06

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0 (V AC)	498.5 (V AC)	501.5 (V AC)	500.3 (V AC)	500.3 (V AC)	0.06 (V AC)
100 A	1.000	0.998	1.002	1.001	1.001	0.0006
1000A Range; 1mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 A	10.0	9.7	10.3	10.0	10.0	0.06
100 A	100.0	99.3	100.7	100.1	100.1	0.07
500 A	500.0	499.0	501.0	500.5	500.5	0.07
900 A	900.0	898.0	902.0	901.2	901.2	0.07

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY

Certificate No. ACT-1272

Certification Number CK198-40179-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Clamp Meter
Make	AEMC
Model	SR759
Serial Number	224139GKDV
Identification	EM6997
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 56.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-007 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-546	24560221	CK093-41519-573	04/30/2021
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
1A Range; 1000mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 mA	10.0	8.7	11.3	10.1	10.1	0.06
100 mA	100.0	96.0	104.0	101.1	101.1	0.06
500 mA	500.0	495.5	504.5	504.5	504.5	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
1 A	1.000	0.992	1.008	1.008	1.008	0.0006
10A Range; 100mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
100 mA	10.0	9.7	10.3	10.0	10.0	0.07
1 A	100.0	99.3	100.7	100.2	100.2	0.06
5 A	500.0	497.5	502.5	500.9	500.9	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
10 A	1.000	0.995	1.005	1.002	1.002	0.0006
100A Range; 10mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
1 A	10.0	9.7	10.3	10.0	10.0	0.06
10 A	100.0	99.3	100.7	100.1	100.1	0.07

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0 (V AC)	498.5 (V AC)	501.5 (V AC)	500.1 (V AC)	500.1 (V AC)	0.06 (V AC)
100 A	1.000	0.998	1.002	1.001	1.001	0.0006
1000A Range; 1mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 A	10.0	9.7	10.3	10.0	10.0	0.07
100 A	100.0	99.3	100.7	100.1	100.1	0.06
500 A	500.0	499.0	501.0	500.3	500.3	0.06
900 A	900.0	898.0	902.0	901.4	901.4	0.06

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK198-41583-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Clamp Meter
Make	AEMC
Model	SR759
Serial Number	239584HKDV
Identification	EM8032
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 56.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-007 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-546	24560221	CK093-41519-573	04/30/2021
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
1A Range; 1000mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 mA	10.0	8.7	11.3	10.2	10.2	0.07
100 mA	100.0	96.0	104.0	101.1	101.1	0.07
500 mA	500.0	495.5	504.5	504.3	504.3	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
1 A	1.000	0.992	1.008	1.007	1.007	0.0007
10A Range; 100mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
100 mA	10.0	9.7	10.3	10.0	10.0	0.07
1 A	100.0	99.3	100.7	100.2	100.2	0.07
5 A	500.0	497.5	502.5	500.7	500.7	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
10 A	1.000	0.995	1.005	1.002	1.002	0.0006
100A Range; 10mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
1 A	10.0	9.7	10.3	10.0	10.0	0.07
10 A	100.0	99.3	100.7	100.0	100.0	0.07

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0 (V AC)	498.5 (V AC)	501.5 (V AC)	500.0 (V AC)	500.0 (V AC)	0.07 (V AC)
100 A	1.000	0.998	1.002	1.000	1.000	0.0007
1000A Range; 1mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 A	10.0	9.7	10.3	10.0	10.0	0.07
100 A	100.0	99.3	100.7	100.0	100.0	0.06
500 A	500.0	499.0	501.0	500.3	500.3	0.07
900 A	900.0	898.0	902.0	900.6	900.6	0.07

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK196-72143-379

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Torque Wrench
Make	CDI
Model	1502LDIN (3%)
Serial Number	0312910937
Identification	EM8363
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Jim Peterson
Technical Review By	Kevin Dehne
Calibration Location	FVM
Calibration Conditions	69.0°F, 20.6°C, 54.2%RH
Calibration Date	07/14/2020
Recalibration Due	07/14/2021

Procedures Followed
FVE-014 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-093	03111	CK191-31886-628	10/31/2020
FVS-275A	RY11838	CJ191-70508-513	07/28/2020

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
Clockwise	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)
	30.00	29.10	30.90	29.89	29.89	0.091
	90.00	87.30	92.70	90.23	90.23	0.271
	150.00	145.50	154.50	152.00	152.00	0.450
Counter Clockwise	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)
	30.00	29.10	30.90	30.31	30.31	0.091
	90.00	87.30	92.70	89.53	89.53	0.271
	150.00	145.50	154.50	148.58	148.58	0.450

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK198-49542-348

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Tape Measure
Make	Stanley
Model	30-824
Serial Number	
Identification	EM6927
Customer Location	ICD
	Tony
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Matthew Roughen
Technical Review By	Laura Fuhrmann
Calibration Location	FVM
Calibration Conditions	69.5°F, 20.8°C, 34.8%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVM-042 rev. 1

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVM-044	C404R	CH121-20770-384	05/28/2022
FVM-079A	RY11924	CJ191-72229-513	07/28/2020

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
Length	(in)	(in)	(in)	(in)	(in)	
	12.000	11.969	12.031	11.995	11.995	0.0006
	24.000	23.938	24.062	23.995	23.995	0.0007
	48.000	47.938	48.062	47.995	47.995	0.0007
	72.000	71.938	72.062	71.995	71.995	0.0007
	144.000	143.938	144.062	143.995	143.995	0.0006
	216.000	215.938	216.062	215.995	215.995	0.0006
	312.000	311.938	312.062	311.995	311.995	0.0007
Length	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
	500.00	499.00	501.00	499.87	499.87	0.007
	1000.00	999.00	1001.00	999.87	999.87	0.006
	5000.00	4999.00	5001.00	4999.87	4999.87	0.008
	8000.00	7999.00	8001.00	7999.87	7999.87	0.012

Public Input No. 3974-NFPA 70-2020 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The ampacities shall be as specified in Table 310.21 where all of the following conditions apply:

(1) Wind velocity is 610 mm/sec (2 ft/sec).

(2) Conductors are 80°C (176°F) total conductor temperature.

(3) Wiring is installed in a 40°C (104°F) ambient temperature.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	—	—	18	—	—	—	—
14*	15	20	25	—	—	—	—
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800

900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

—

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14*	25	30	35	—	—	—	20** 25** 30** 14*
12*	30	35	40	25	30	35	12*
10*	40	50	55	35	40	45	10*
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2

1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250
300	375	445	500	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.17 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

**Applicable only to copper-clad aluminum conductors

Table 310.18 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway or Cable

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
2	160	171	191	124	2
1	186	197	215	145	1
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.18 shall be referenced for conditions of use.

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient

temperature is other than 40°C (104°F).

2. Section 310.19 shall be referenced for conditions of use.

Table 310.20 Ampacities of Conductors on a Messenger

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6
4	101	117	78	91	4
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.20 shall be referenced for conditions of use.

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors		AAC Aluminum Conductors	
Bare	Covered	Bare	Covered

AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
8	98	8	103	8	76	8	80
6	124	6	130	6	96	6	101
4	155	4	163	4	121	4	127
2	209	2	219	2	163	2	171
1/0	282	1/0	297	1/0	220	1/0	231
2/0	329	2/0	344	2/0	255	2/0	268
3/0	382	3/0	401	3/0	297	3/0	312
4/0	444	4/0	466	4/0	346	4/0	364
250	494	250	519	266.8	403	266.8	423
300	556	300	584	336.4	468	336.4	492
500	773	500	812	397.5	522	397.5	548
750	1000	750	1050	477.0	588	477.0	617
1000	1193	1000	1253	556.5	650	556.5	682
—	—	—	—	636.0	709	636.0	744
—	—	—	—	795.0	819	795.0	860
—	—	—	—	954.0	920	—	—
—	—	—	—	1033.5	968	1033.5	1017
—	—	—	—	1272	1103	1272	1201
—	—	—	—	1590	1267	1590	1381
—	—	—	—	2000	1454	2000	1527

Note: Section 310.21 shall be referenced for conditions of use.

Additional Proposed Changes

File Name	Description	Approved
Proposed_Table_310.17_Ampacity_2023_Draft_Fnl.docx	File provided for clarity of changes to Table 310.17 for ampacity of 14 AWG copper-clad aluminum and relate note. Attachment to show changes proposed in table and clear substantiation since Terra does not show changes to table correctly.	
NSF_Final_Report_J-00265162_Copperweld_FFR-_CCA-Cu_Revised_10-27-17.pdf	NSF Report showing testing data for 14 AWG copper-clad aluminum conductor temperatures at various current levels. Specific pages in report cited in substantiation.	

Terminal_and_Conductor_Temperature_Testing_Part_I_Fnl.pdf	Terminal temperature test report from testing conducted at request of the task group.

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Changes

The changes made in this public input were to Table 310.17 to add a set of ampacities for 14 AWG Copper-Clad Aluminum conductors. In addition, "14" was added to the conductor sizes in the far-right column. The ampacity values were added along with a double asterisk (**) to a new note at the bottom of the table to indicate that the ampacities at this AWG size apply to Copper-Clad Aluminum conductors only and do not apply to single-metal aluminum conductors. In the far-right hand column, a single asterisk (*) was added to the "14" reference the existing note that section 240.4(D) would need to be checked for applicable overcurrent protection device when 14 AWG Copper-Clad Aluminum is installed. For clarity a separate attachment is provided of the legislatively revised table.

Technical Substantiation

What is ampacity? The definition in Article 100 states that ampacity is:
"The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. (CMP-6)"

From 310.17 the conditions of use are:

310.17 Ampacities of Single-Insulated Conductors in Free Air. The ampacities shall be as specified in Table 310.17 where all of the following conditions apply:
(1) Conductors are rated 0 volts through 2000 volts.
(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C

The conclusion then is that ampacity is about temperature and, under the specified conditions of use, amount of current that can be carried without exceeding the identified insulation temperatures of 60, 75 and 90ºC.

What is "ampacity" from the tables vs. the actual current that can be applied as provided in the rest of

the Code? The wire ampacity is the current limit set for the conductor and its respective insulation based on the temperature class of the insulation at 60, 75 and 90ºC for most of the applications. Other parts of the Code then revise the “allowed current” to fit with the testing of equipment, equipment terminals, device terminals, and splicing connectors. When the overall testing is completed, the item with the lowest allowed temperature then sets at what current the conductor is allowed to carry.

For example, considering all of the Section 310.17 conditions of use are met, 10 AWG copper THHN wire has an ampacity from Table 310.17 of 45 Amps. A 30 Amp circuit breaker that this conductor could be terminated on is typically limited to 75ºC or possibly 60ºC. The wiring device, such as a conventional receptacle (that the other end of the conductor is connected to) of configurations having ampere ratings less than 100 Amps, typically is standardized at a temperature limit of 60ºC. Therefore, considering the aggregate of the circuit’s components, the overall current allowed on this conductor is 30 amps as set in 240.4(D)(7). In short, the receptacle is the limiting component in this case. But, at the conclusion of all this, the “ampacity” of this 10 AWG THHN conductor unto itself is still 45 Amps.

What testing was done to determine the ampacity of 14 AWG Copper-Clad Aluminum at 60, 75, 90ºC? Following the historical path, as discussed below, that determined ampacities for different sizes of conductors, laboratory temperature testing of multiple samples of 14 AWG THHN Copper-Clad Aluminum was completed. In summary, the samples were connected in series so that whatever test current was set was the same current applied to all conductors.

Calibrated thermocouples were attached to the core conductor material and to the insulation. The ambient temperature in the testing laboratory was also recorded along with the temperature on the test samples. All data was recorded using a data-logger, that was downloaded into a spreadsheet for analysis. The initial test current was set at 5 Amps and held until temperature equilibrium was attained, approximately 30 minutes for each current level. After temperature equilibrium was reached, the test current was raised in steps of 5 Amps and held again until temperature equilibrium was attained.

The raw data from the multiple samples at each test current level was temperature-corrected to the ambient of 30ºC based on the conditions of use in the Code ampacity tables. The resultant temperature values were then averaged to determine the average conductor core temperature and the average surface insulation temperature. The values proposed in the table are based on the core average temperature, which was found slightly higher than the insulation temperature and is a more conservative value. The selection was also based on which condition, cable or conduit had the higher temperature result. As seen below the conductors in conduit were found to have the greater temperature conditions.

The summary of 14 AWG Copper-Clad Aluminum ambient-temperature-corrected average core temperature and average insulation surface temperature for these conductors in free air is provided below.

Current (Amps)	Free Air	
	Average Core (Degrees C)	Average Insulation Surface (Degrees C)
5	32.40	32.20
10	36.52	36.22
15	42.16	41.20
20	51.77	49.71
25	61.51	58.50
30	75.91	71.02
35	92.67	86.68

[Ref. NSF Report pages: 7 - 9]

The following are the worst-case conductor core temperatures for conductors in free air at a 30ºC ambient.
The ampacity of 20 Amps for 60ºC insulations would have a core temperature of 50.79ºC
The ampacity of 25 Amps for 75ºC insulations would have a core temperature of 61.51ºC
The ampacity of 30 Amps for 90ºC insulations would have a core temperature of 75.91ºC

How does this compare to 14 AWG copper at 60, 75, and 90ºC? While the ampacity for a conductor

with a given insulation should stand alone, testing was completed simultaneously with 14 AWG copper THHN conductors using the same procedure as summarized above. The comparison results are:

Insulation Temperature Rating	14 AWG Copper Clad Aluminum		14 AWG Copper	
	Proposed Ampacity	Core Temperature at Proposed Ampacity (Degrees C)	Ampacity from Table	Core Temperature at Table Ampacity (Degrees C)
60ºC	20	51.77	25	49.98
75ºC	25	61.51	30	58.69
90ºC	30	75.91	35	67.91

[Ref. NSF Report pages: (CCA) 7 - 9 and (Cu) 14 - 15]

This testing demonstrates that for the proposed ampacities the Copper-Clad Aluminum conductor will operate at or just slightly above that of copper but well under the insulation temperature for each class. How were the existing ampacity values determined? The current carrying capacity of a conductor has appeared in every National Electrical Code® since 1897 edition, which replaced local electrical codes from the New York Board of Fire Underwriters, the Underwriters Association of the Middle Department, and others. Initial current carrying values were being determined by different groups as early as the 1880s with one of the first published tables in 1889. The first Code was also based on work from the National Underwriters Association which became Underwriters Laboratories in 1901.

In the late 1890s and early 1900s a consultant, Ira Henry, employed by National Underwriters Association developed requirements for rubber insulated wire which was replacing the various versions of cotton covered wire. These values remained stable for almost 30 years. In the late 1920s research was undertaken by several entities to update these current values because of improvements in rubber insulating material.

For one investigation, started in 1931, aging testing was done on multiple samples, using three wire sizes ranging from 14 AWG to 4/0 AWG of “code grade rubber insulation”, initially from nine different manufacturers. These aging tests were done at a set temperature in an oven over various periods of time, much as insulation aging testing is done today. After the first round showed excessive deterioration, a second set of tests (with of the same sizes and two additional manufacturers contributing samples) was completed at a lower oven temperature. These tests were to find out how much temperature over time caused the rubber to deteriorate as measured by tensile strength and elongation. The result was that the insulation could withstand 50ºC for the expected life. The second part of the investigation then completed temperature testing at different currents was conducted to see how much current could be carried by each size wire and stay under 50ºC. This resulted in an AIEE paper published in 1938 and updates to the National Electrical Code® allowable current (ampacity) tables.

Later when thermoplastic insulation was introduced the current values were again updated to reflect the superior performance of thermoplastic compounds and the different insulation temperature values of 60, 75 and 90ºC were introduced based on the performance of the different insulation compound formulas. Later still, thermo-set insulations were introduced and again temperature testing was completed for current values for these insulations. The testing completed was based on how much current a given size and material of conductor could carry before the insulation was impacted to deteriorate. To complete the tables, mathematical formulas were developed from the 1930s into the late 1990s to account for the different conductor sizes and different installation conditions. The most widely used formulas were from or based on the work of Neher-McGrath, which were mostly used to address underground installations. This is what we call today “ampacity” as reflected in the Article 310 tables.

From the first Code edition allowing aluminum until the 1956 NEC®, the permitted current for aluminum was fixed at 84% of the table values for copper. The 1956 Code created the first separate tables, Tables 1A and 1B in Chapter 10, where aluminum conductors had values set, but a note still limited aluminum conductors to 84% of copper. The 84% limit was dropped in later Codes. Copper-Clad Aluminum was introduced in the 1971 NEC® in the second stage of code-making activities. This introduction was to provide an alternative to the problems being seen with the use of the 1350 alloy aluminum conductors in branch circuits.

The 1975 NEC® cycle added 18 AWG and 16 AWG copper conductors with values of 25 and 27 amps respectfully to Table 310-17. The proposal was from the code panel itself. The panel’s substantiation

for these additions was that these values were taken from the 1971 edition of NFPA 79, the standard for industrial electric machinery. The 1981 Code changed these ampacity values to 18 and 24 Amps in Table 310-16. These ampacity values are only in the 90ºC column and there are no values provided for 60 or 75ºC through up to and including the 2020 NEC®.

The ampacity adjustment that happened in the 2011 NEC® cycle was from a coordinated effort to align the National Electrical Code® and the Canadian Electrical Code, Part I. This activity had been underway for over 10 years. The basis for these changes was for an application of a temperature adjustment formula using the ampacities of existing size conductors at 75ºC. This temperature value was selected since both the NEC® and CEC were in essential agreement on the ampacity at this temperature and the working binational task group agreed with this as the starting point to apply the adjustment formula.

Presently there are no UL standards or UL-published test procedures to determine ampacity. The UL standards for wire and cable are primarily evaluating the insulation and how it performs in normal and abnormal conditions, as stated in the UL standards' Scopes "in accordance with NFPA Standard 70, National Electrical Code (NEC)". For most testing completed, the "ampacity" of the conductor is taken directly from the Code. Present IEEE standards utilize extensive tables, IEEE 835 has over 3000 pages of ampacity tables, with formulas to determine a different ampacity based on specific installation conditions. These tables address conductors for voltages from 600 volts to 500,000 volts. There is no formula or process to establish an ampacity for a new size conductor.

Testing laboratory qualifications. The NSF laboratory that completed the main temperature testing is an OSHA recognized electrical testing laboratory with 36 electrical UL standards that require the capability to test temperature for equipment, equipment terminals and conductors. They are also accredited by the Standards Council of Canada and have ISO registration for quality controls. The NSF report provided complete details of their recognitions.

References:

National Electrical Code® – 1897 (replica), 1915, 1956, 1971, 1975, 1981, 2011, 2020 and related proposals, comments and panel statements as available.
Behind the Code – NEC® History by W. Creighton Schwan and David E. Shapiro, third edition
The National Electrical Code and Free Enterprise (A History), Merwin Brandon 1971 Published by the National Fire Protection Association
The Current-Carrying Capacity of Rubber-Insulated Conductors, S.J. Rosch, AIEE Transactions, Vol. 57, March 1938
J.H. Neher and M.H. McGrath, "The Calculation of the Temperature Rise and Load Capability of Cable Systems ", AIEE Transactions Part III - Power Apparatus and Systems, Vol. 76, October 1957, pp. 752-772.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	Branch circuit conductors added 14 AWG copper-clad aluminum
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	

Submitter Information Verification

Submitter Full Name: David Hittinger
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Submittal Date: Wed Sep 09 16:33:51 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8427-NFPA 70-2021

Statement: The minimum conductor sizes for copper and copper-clad aluminum are being reduced to 16 AWG copper and 14 AWG copper-clad aluminum. These revisions are based on testing submitted in support of the use of copper-clad aluminum conductors for 10 amp circuits, and the decades of successful use of 16 AWG copper conductors in fixture wire, motor wiring, control wiring, and other current-carrying applications as permitted in the NEC.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN	90°C (194°F) Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN	Size AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	-	-	18	-	-	-	-
16*	-	-	24	-	-	-	-
14*	25	30	35	- 20**	- 25**	- 30**	- 14*
12*	30	35	40	25	30	35	12*
10*	40	50	55	35	40	45	10*
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250
300	375	445	500	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:
1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).
2. Section 310.17 shall be referenced for conditions of use.

* Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the *Code*.

** Applicable only to copper-clad aluminum conductors

Substantiation

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Changes

The changes made in this public input were to Table 310.17 to add a set of ampacities for 14 AWG Copper-Clad Aluminum conductors. In addition, "14" was added to the conductor sizes in the far-right column. The ampacity values were added along with a double asterisk (**) to a new note at the bottom of the table to indicate that the ampacities at this AWG size apply to Copper-Clad Aluminum conductors only and do not apply to single-metal aluminum conductors. In the far-right hand column, a single asterisk (*) was added to the "14" reference the existing note that section 240.4(D) would need to be checked for applicable overcurrent protection device when 14 AWG Copper-Clad Aluminum is installed. For clarity a separate attachment is provided of the legislatively revised table.

Technical Substantiation

What is ampacity? The definition in Article 100 states that ampacity is:

> "The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. (CMP-6)"

From 310.17 the conditions of use are:

> **310.17 Ampacities of Single-Insulated Conductors in Free Air.** The ampacities shall be as specified in Table 310.17 where all of the following conditions apply:

(1) Conductors are rated 0 volts through 2000 volts.

(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C

The conclusion then is that ampacity is about temperature and, under the specified conditions of use, amount of current that can be carried without exceeding the identified insulation temperatures of 60, 75 and 90ºC.

What is "ampacity" from the tables vs. the actual current that can be applied as provided in the rest of the Code? The wire ampacity is the current limit set for the conductor and its respective insulation based on the temperature class of the insulation at 60, 75 and 90ºC for most of the applications. Other parts of the Code then revise the "allowed current" to fit with the testing of equipment, equipment terminals, device terminals, and splicing connectors. When the overall testing is completed, the item with the lowest allowed temperature then sets at what current the conductor is allowed to carry.

For example, considering all of the Section 310.17 conditions of use are met, 10 AWG copper THHN wire has an ampacity from Table 310.17 of 45 Amps. A 30 Amp circuit breaker that this conductor could be terminated on is typically limited to 75ºC or possibly 60ºC. The wiring device, such as a conventional receptacle (that the other end of the conductor is connected to) of configurations having ampere ratings less than 100 Amps, typically is standardized at a temperature limit of 60ºC. Therefore, considering the aggregate of the circuit's components, the overall current allowed on this conductor is 30 amps as set in 240.4(D)(7). In short, the receptacle is the limiting component in this case. But, at the conclusion of all this, the "ampacity" of this 10 AWG THHN conductor unto itself is still 45 Amps.

What testing was done to determine the ampacity of 14 AWG Copper-Clad Aluminum at 60, 75, 90ºC? Following the historical path, as discussed below, that determined ampacities for different sizes of conductors, laboratory temperature testing of multiple samples of 14 AWG THHN Copper-Clad Aluminum was completed. In summary, the samples were connected in series so that whatever test current was set was the same current applied to all conductors.

Calibrated thermocouples were attached to the core conductor material and to the insulation. The ambient temperature in the testing laboratory was also recorded along with the temperature on the test samples. All data was recorded using a data-logger, that was downloaded into a spreadsheet for analysis. The initial test current was set at 5 Amps and held until temperature equilibrium was attained, approximately 30 minutes for each current level. After temperature equilibrium was reached, the test current was raised in steps of 5 Amps and held again until temperature equilibrium was attained.

The raw data from the multiple samples at each test current level was temperature-corrected to the ambient of 30ºC based on the conditions of use in the Code ampacity tables. The resultant temperature values were then averaged to determine the average conductor core temperature and the average surface insulation temperature. The values proposed in the table are based on the core average temperature, which was found slightly higher than the insulation temperature and is a more conservative value. The selection was also based on which condition, cable or conduit had the higher temperature result. As seen below the conductors in conduit were found to have the greater temperature conditions.

The summary of 14 AWG Copper-Clad Aluminum ambient-temperature-corrected average core temperature and average insulation surface temperature for these conductors in free air is provided below.

Current (Amps)	Free Air	
	Average Core (Degrees C)	Average Insulation Surface (Degrees C)
5	32.40	32.20
10	36.52	36.22
15	42.16	41.20
20	51.77	49.71
25	61.51	58.50
30	75.91	71.02
35	92.67	86.68

[Ref. NSF Report pages: 7 - 9]

The following are the worst-case conductor core temperatures for conductors in free air at a 30ºC ambient.

The ampacity of 20 Amps for 60ºC insulations would have a core temperature of 50.79ºC

The ampacity of 25 Amps for 75ºC insulations would have a core temperature of 61.51ºC

The ampacity of 30 Amps for 90ºC insulations would have a core temperature of 75.91ºC

How does this compare to 14 AWG copper at 60, 75, and 90ºC? While the ampacity for a conductor with a given insulation should stand alone, testing was completed simultaneously with 14 AWG copper THHN conductors using the same procedure as summarized above. The comparison results are:

Insulation Temperature Rating	14 AWG Copper Clad Aluminum		14 AWG Copper	
	Proposed Ampacity	Core Temperature at Proposed Ampacity (Degrees C)	Ampacity from Table	Core Temperature at Table Ampacity (Degrees C)
60ºC	20	51.77	25	49.98
75ºC	25	61.51	30	58.69
90ºC	30	75.91	35	67.91

[Ref. NSF Report pages: (CCA) 7 - 9 and (Cu) 14 - 15]x

This testing demonstrates that for the proposed ampacities the Copper-Clad Aluminum conductor will operate at or just slightly above that of copper but well under the insulation temperature for each class.

How were the existing ampacity values determined? The current carrying capacity of a conductor has appeared in every National Electrical Code® since 1897 edition, which replaced

local electrical codes from the New York Board of Fire Underwriters, the Underwriters Association of the Middle Department, and others. Initial current carrying values were being determined by different groups as early as the 1880s with one of the first published tables in 1889. The first Code was also based on work from the National Underwriters Association which became Underwriters Laboratories in 1901.

In the late 1890s and early 1900s a consultant, Ira Henry, employed by National Underwriters Association developed requirements for rubber insulated wire which was replacing the various versions of cotton covered wire. These values remained stable for almost 30 years. In the late 1920s research was undertaken by several entities to update these current values because of improvements in rubber insulating material.

For one investigation, started in 1931, aging testing was done on multiple samples, using three wire sizes ranging from 14 AWG to 4/0 AWG of "code grade rubber insulation", initially from nine different manufacturers. These aging tests were done at a set temperature in an oven over various periods of time, much as insulation aging testing is done today. After the first round showed excessive deterioration, a second set of tests (with of the same sizes and two additional manufacturers contributing samples) was completed at a lower oven temperature. These tests were to find out how much temperature over time caused the rubber to deteriorate as measured by tensile strength and elongation. The result was that the insulation could withstand 50ºC for the expected life. The second part of the investigation then completed temperature testing at different currents was conducted to see how much current could be carried by each size wire and stay under 50ºC. This resulted in an AIEE paper published in 1938 and updates to the National Electrical Code® allowable current (ampacity) tables.

Later when thermoplastic insulation was introduced the current values were again updated to reflect the superior performance of thermoplastic compounds and the different insulation temperature values of 60, 75 and 90ºC were introduced based on the performance of the different insulation compound formulas. Later still, thermo-set insulations were introduced and again temperature testing was completed for current values for these insulations. The testing completed was based on **how much current a given size and material of conductor could carry before the insulation was impacted to deteriorate**. To complete the tables, mathematical formulas were developed from the 1930s into the late 1990s to account for the different conductor sizes and different installation conditions. The most widely used formulas were from or based on the work of Neher-McGrath, which were mostly used to address underground installations. This is what we call today "ampacity" as reflected in the Article 310 tables.

From the first Code edition allowing aluminum until the 1956 NEC®, the permitted current for aluminum was fixed at 84% of the table values for copper. The 1956 Code created the first separate tables, Tables 1A and 1B in Chapter 10, where aluminum conductors had values set, but a note still limited aluminum conductors to 84% of copper. The 84% limit was dropped in later Codes. Copper-Clad Aluminum was introduced in the 1971 NEC® in the second stage of code-making activities. This introduction was to provide an alternative to the problems being seen with the use of the 1350 alloy aluminum conductors in branch circuits.

The 1975 NEC® cycle added 18 AWG and 16 AWG copper conductors with values of 25 and 27 amps respectfully to Table 310-17. The proposal was from the code panel itself. The panel's substantiation for these additions was that these values were taken from the 1971

edition of NFPA 79, the standard for industrial electric machinery. The 1981 Code changed these ampacity values to 18 and 24 Amps in Table 310-16. These ampacity values are only in the 90ºC column and there are no values provided for 60 or 75ºC through up to and including the 2020 NEC®.

The ampacity adjustment that happened in the 2011 NEC® cycle was from a coordinated effort to align the National Electrical Code® and the Canadian Electrical Code, Part I. This activity had been underway for over 10 years. The basis for these changes was for an application of a temperature adjustment formula using the ampacities of existing size conductors at 75ºC. This temperature value was selected since both the NEC® and CEC were in essential agreement on the ampacity at this temperature and the working binational task group agreed with this as the starting point to apply the adjustment formula.

Presently there are no UL standards or UL-published test procedures to determine ampacity. The UL standards for wire and cable are primarily evaluating the insulation and how it performs in normal and abnormal conditions, as stated in the UL standards' Scopes "in accordance with NFPA Standard 70, National Electrical Code (NEC)". For most testing completed, the "ampacity" of the conductor is taken directly from the Code. Present IEEE standards utilize extensive tables, IEEE 835 has over 3000 pages of ampacity tables, with formulas to determine a different ampacity based on specific installation conditions. These tables address conductors for voltages from 600 volts to 500,000 volts. There is no formula or process to establish an ampacity for a new size conductor.

Testing laboratory qualifications. The NSF laboratory that completed the main temperature testing is an OSHA recognized electrical testing laboratory with 36 electrical UL standards that require the capability to test temperature for equipment, equipment terminals and conductors. They are also accredited by the Standards Council of Canada and have ISO registration for quality controls. The NSF report provided complete details of their recognitions.

References:

- National Electrical Code® – 1897 (replica), 1915, 1956, 1971, 1975, 1981, 2011, 2020 and related proposals, comments and panel statements as available.
- Behind the Code – NEC® History by W. Creighton Schwan and David E. Shapiro, third edition
- The National Electrical Code and Free Enterprise (A History), Merwin Brandon 1971 Published by the National Fire Protection Association
- The Current-Carrying Capacity of Rubber-Insulated Conductors, S.J. Rosch, AIEE Transactions, Vol. 57, March 1938
- J.H. Neher and M.H. McGrath, "The Calculation of the Temperature Rise and Load Capability of Cable Systems ", AIEE Transactions Part III - Power Apparatus and Systems, Vol. 76, October 1957, pp. 752-772.

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Description:	CCA –Cu Ampacity Comparison
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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

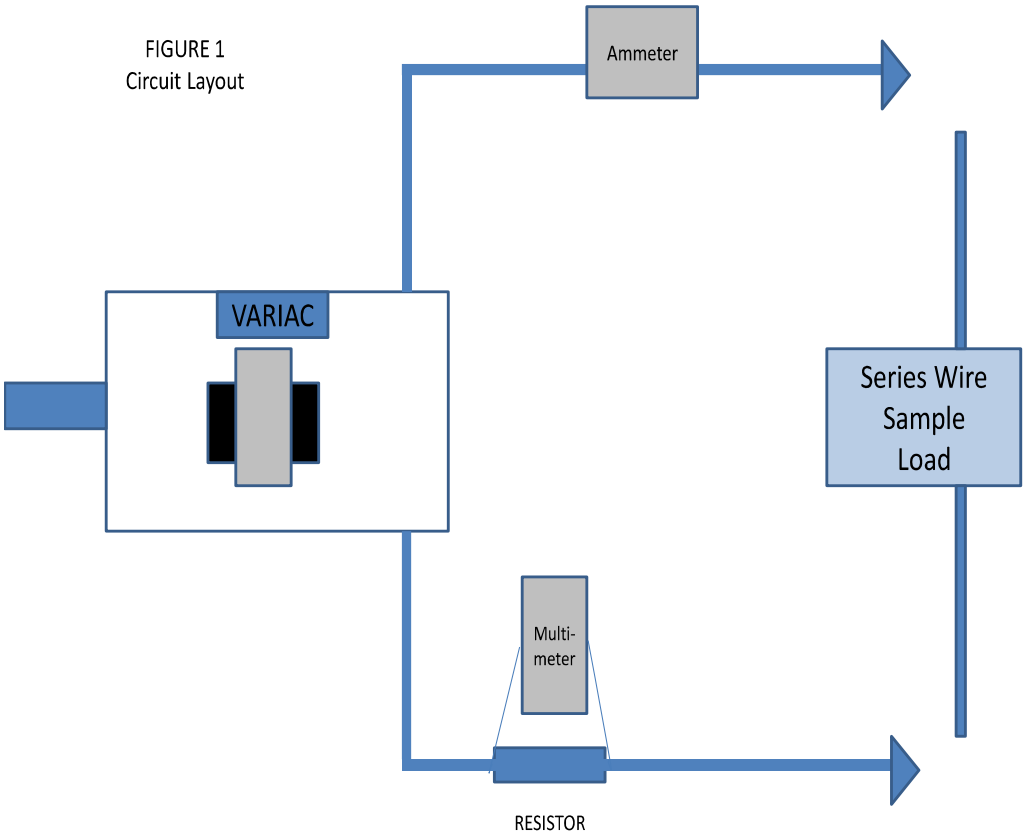
Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

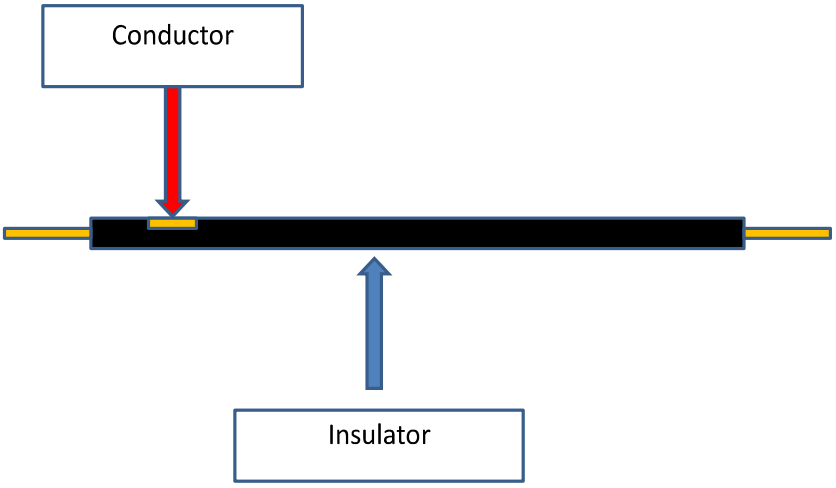
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FIGURE 1
Circuit Layout



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FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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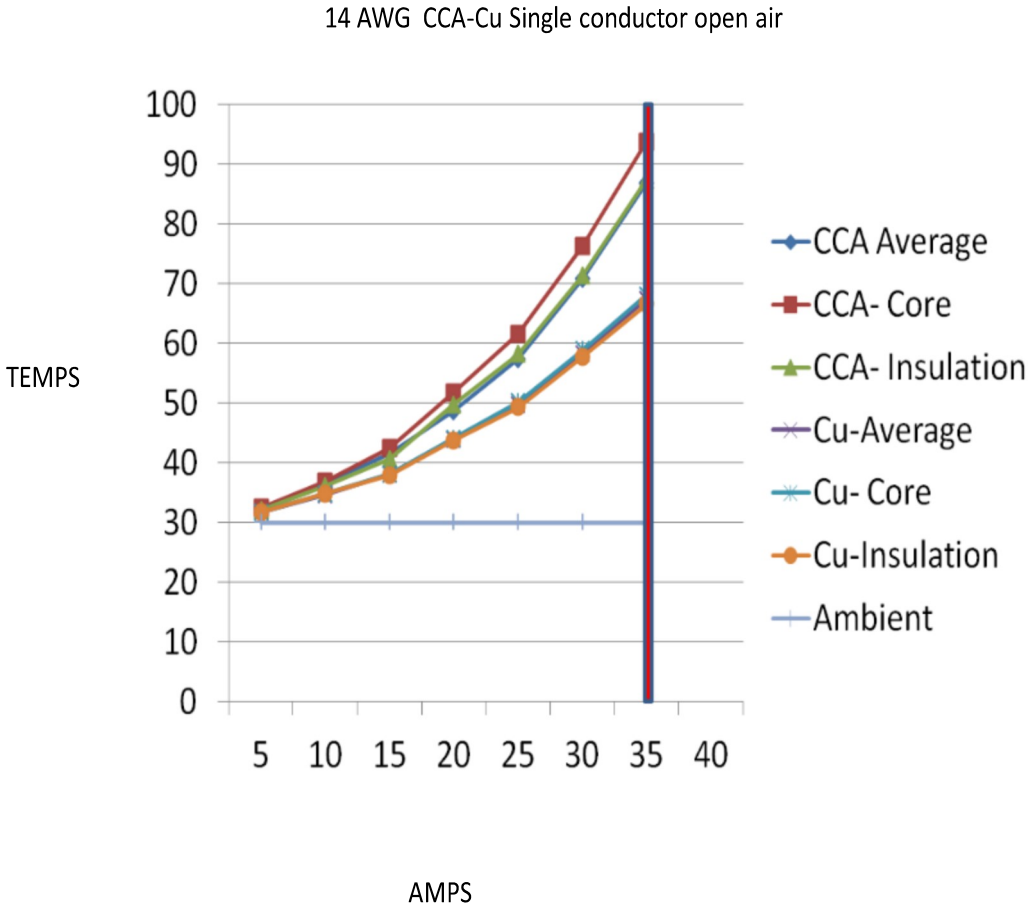
14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

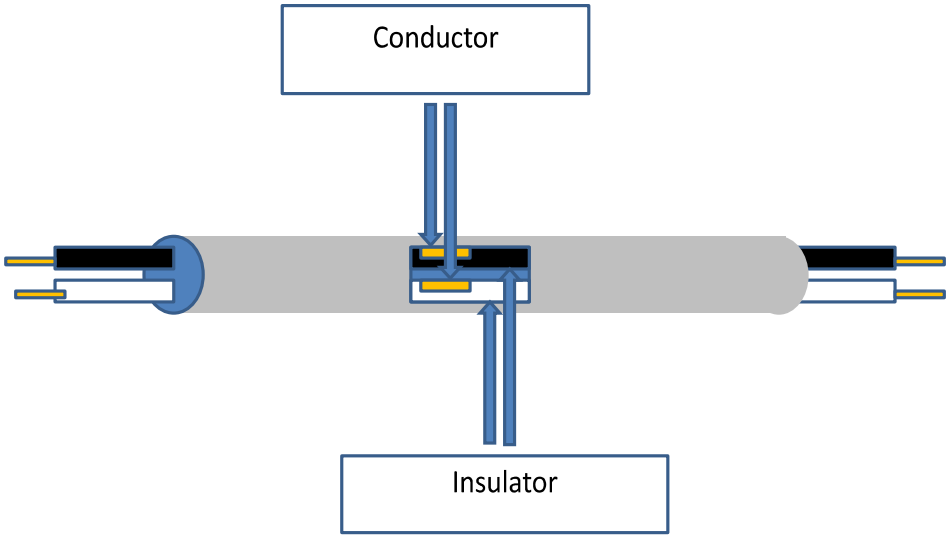
Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

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Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air
(Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air
(Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air
Page (2/2)

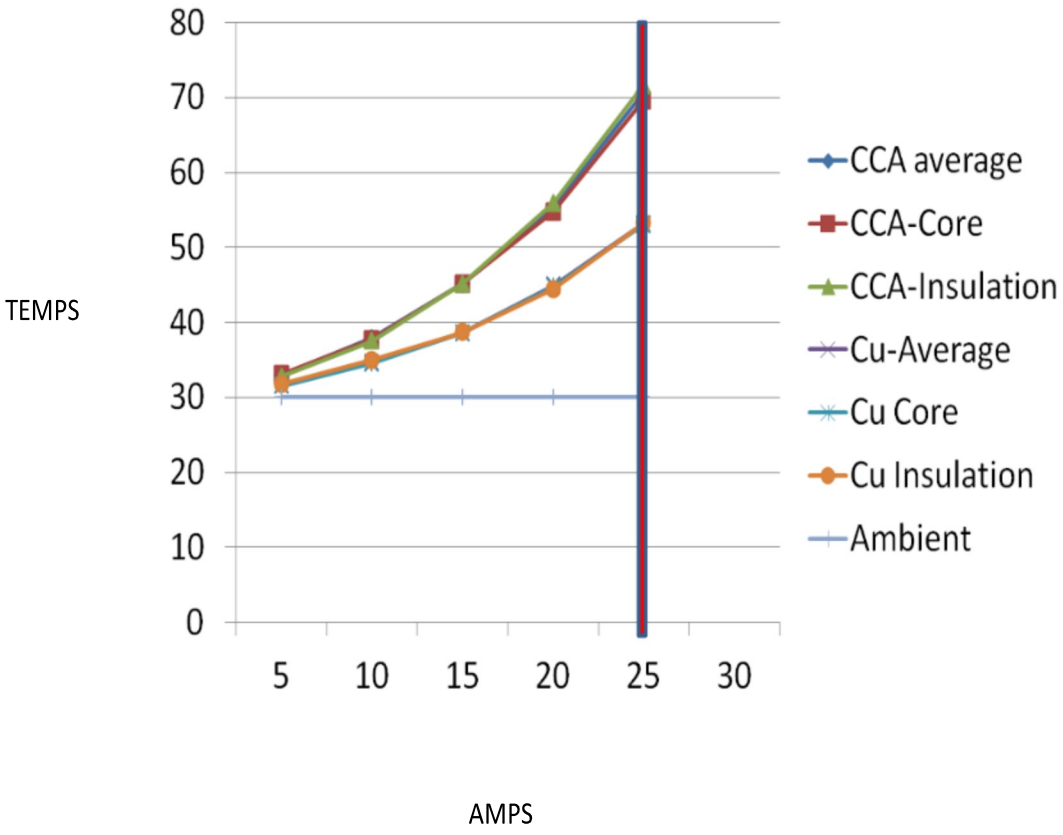
302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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14 AWG CCA-Cu NM Cable Open Air



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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

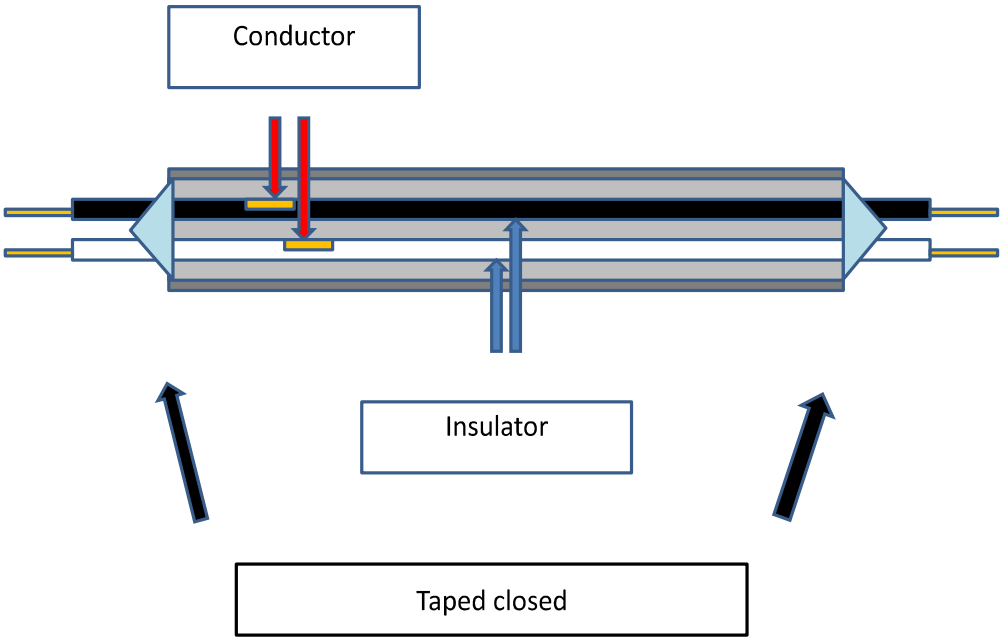
Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
Page(1/3)

	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit
Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit
Page(3/3)

211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit
Page 1/2)

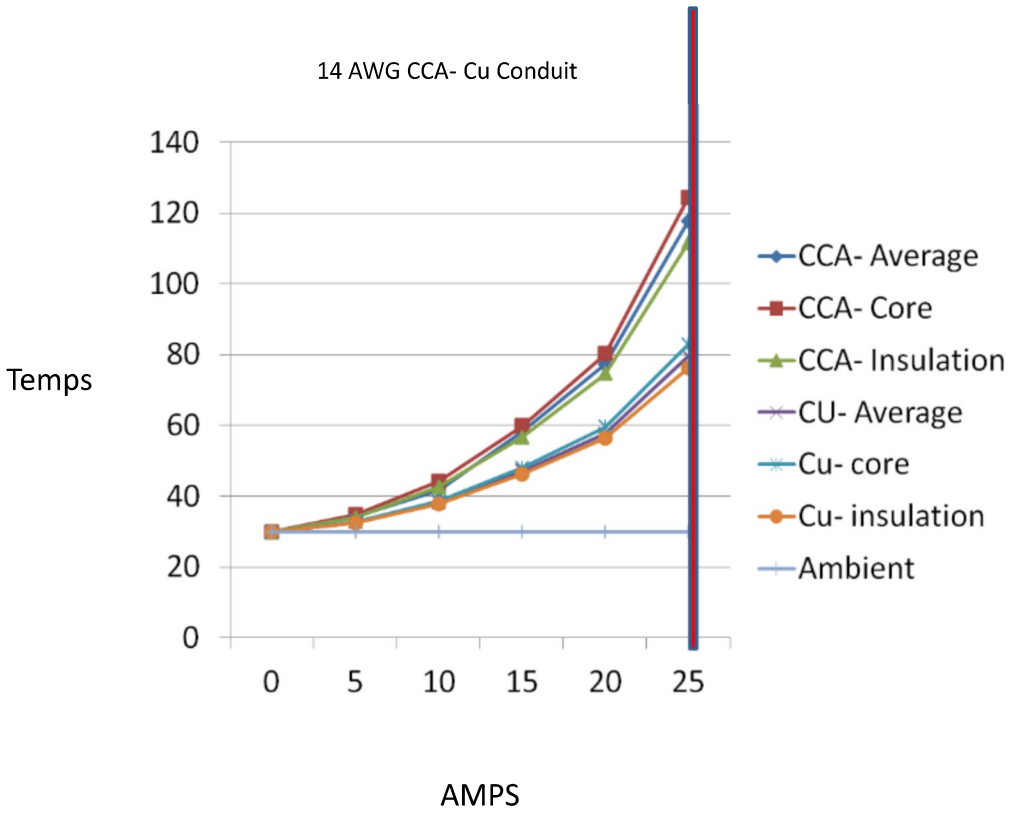
	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
Page (2/2)

318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
(Page 2 of 3)

112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

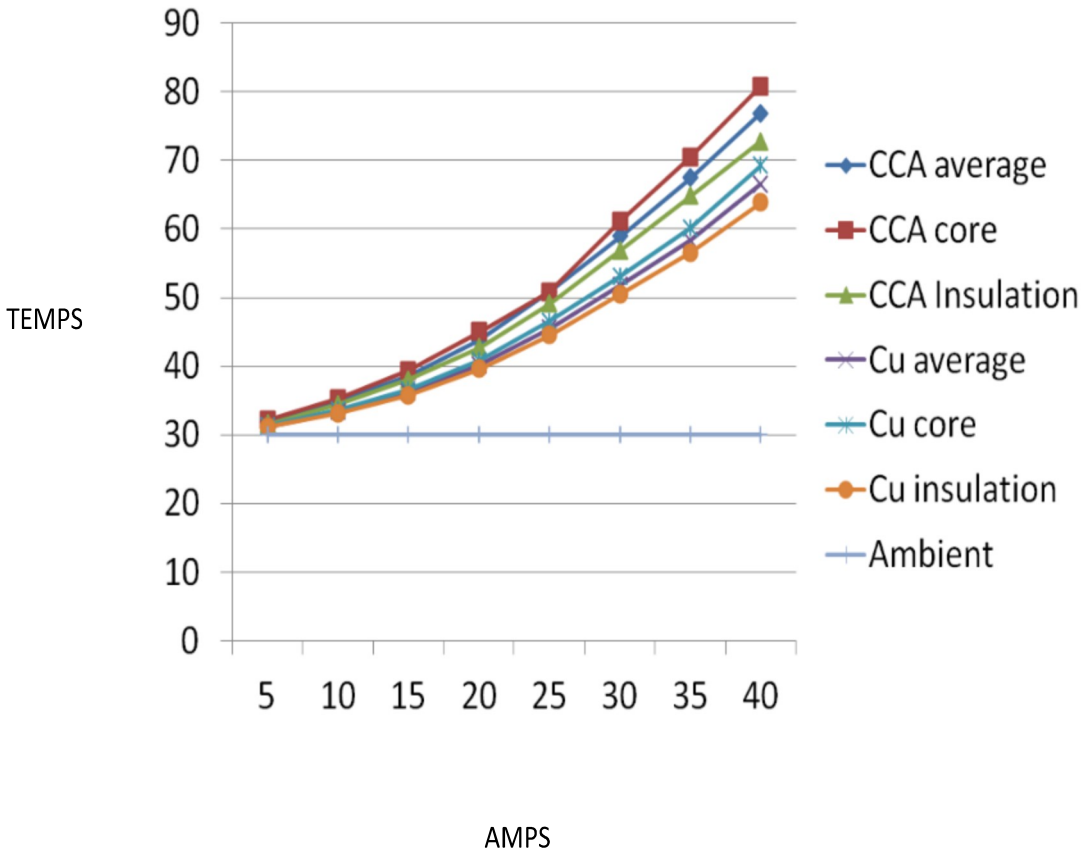
	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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12 AWG CCA Cu single conductor open air



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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 1 of 3)

Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)

(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 3of 3)

116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

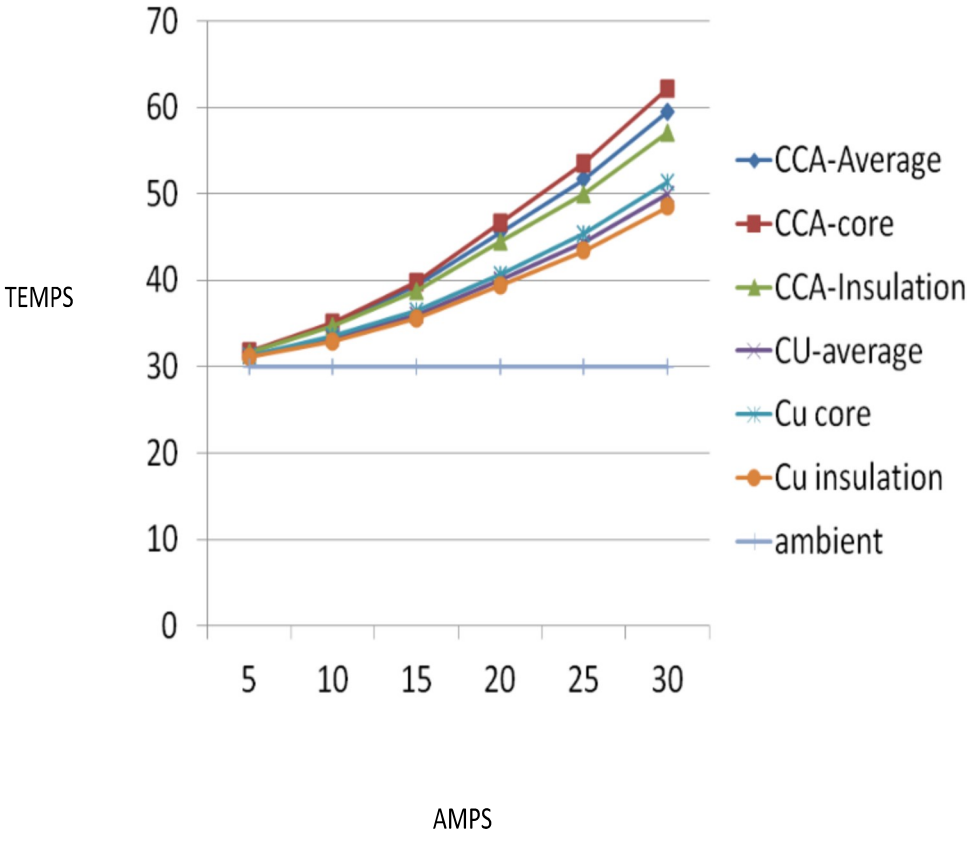
305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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12 AWG CCA-Cu NM Cable (2C)open air



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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
(Page 3 of 3)

315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

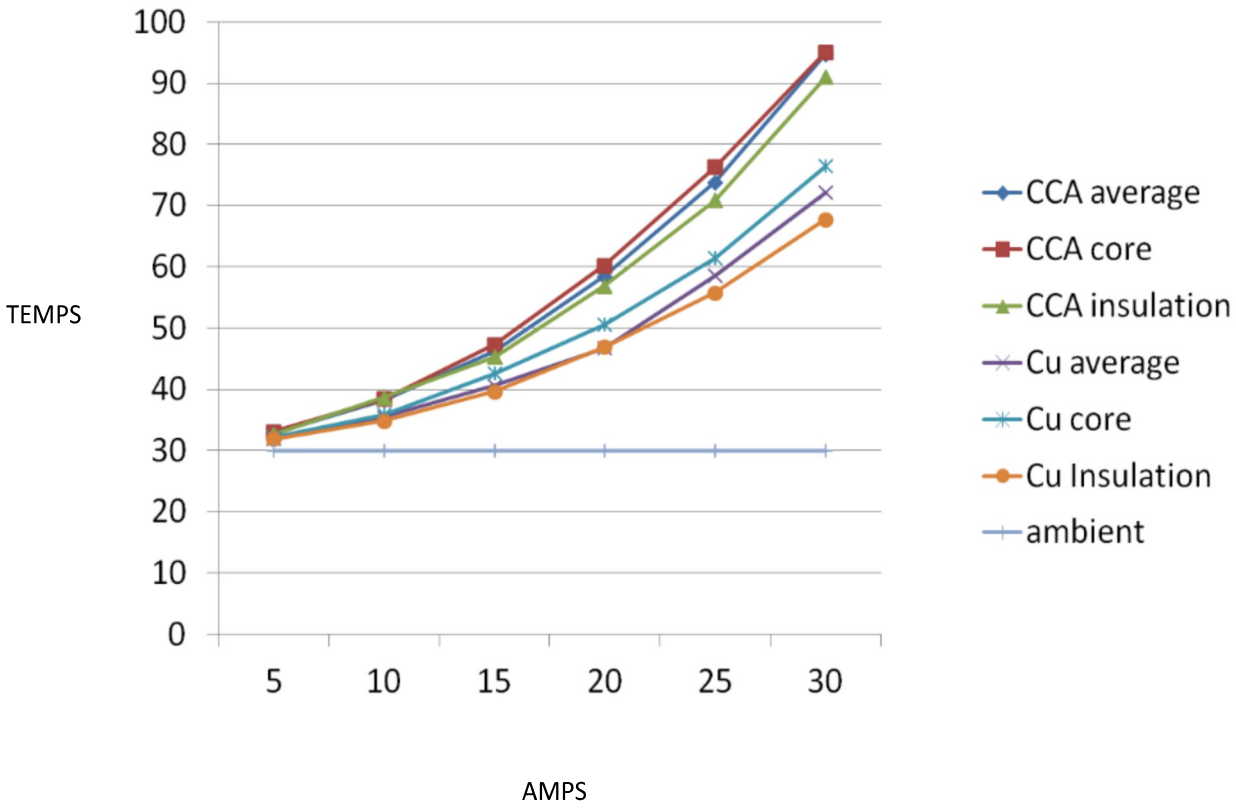
304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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12 AWG CCA-Cu in Conduit



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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
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Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
(Page 3 of 3)

113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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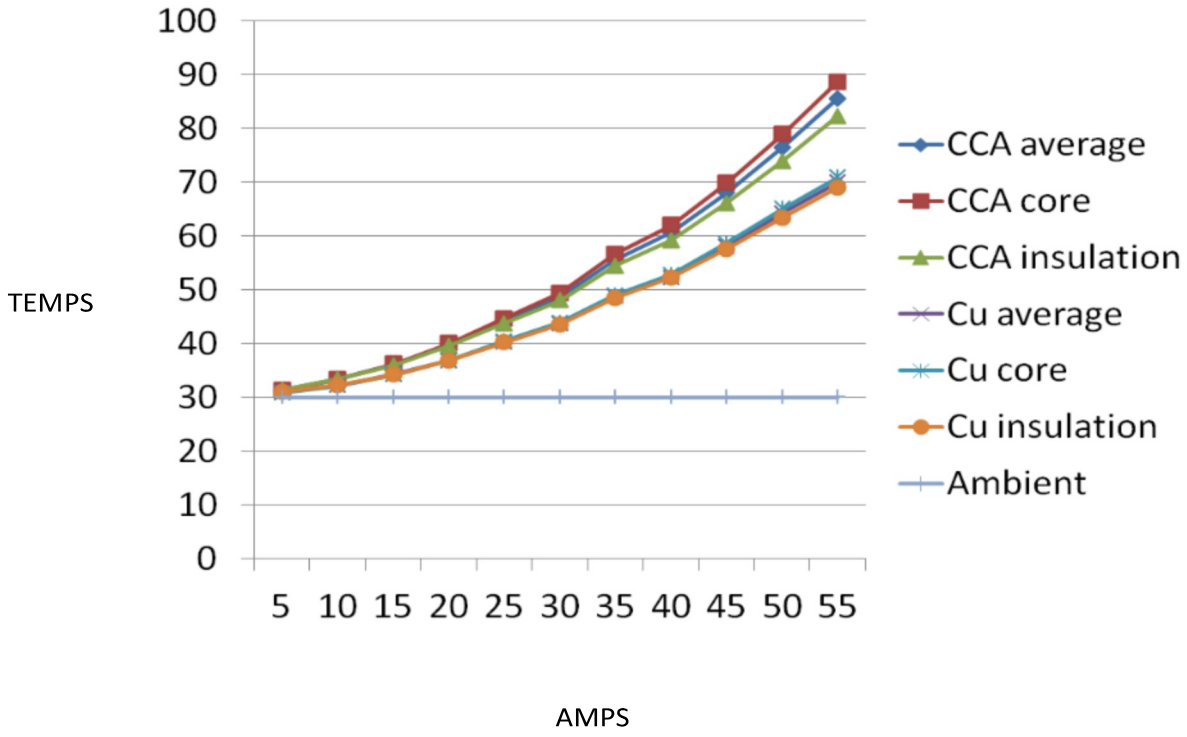
31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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10 AWG CCA CU Single Conductor open air



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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

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Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
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102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

(Page 3 of 3)

114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

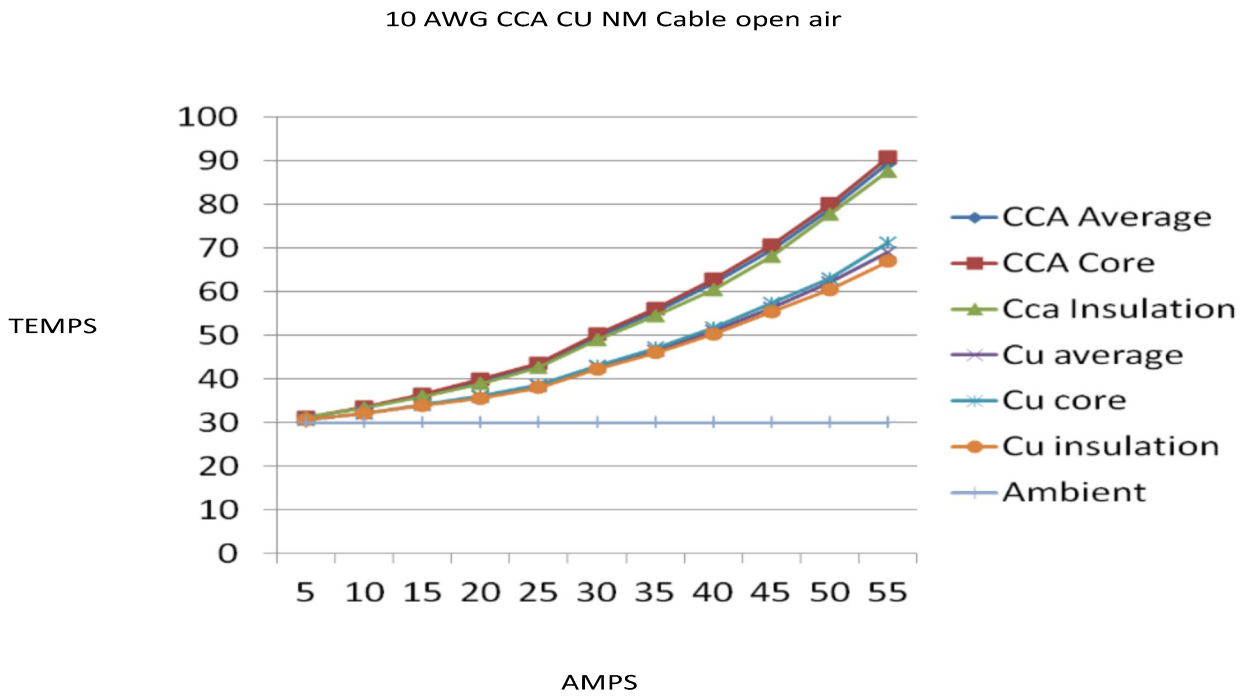
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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

(Page 1 of 3)

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)

(Page 2 of 3)

211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
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107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

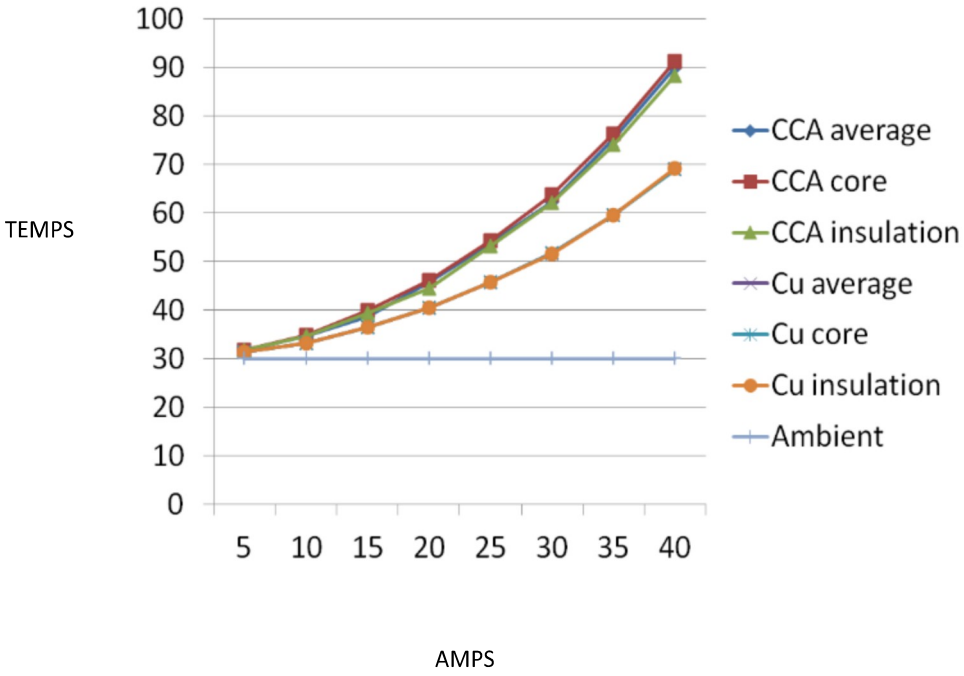
304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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10 AWG CCA Cu In conduit



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Summary

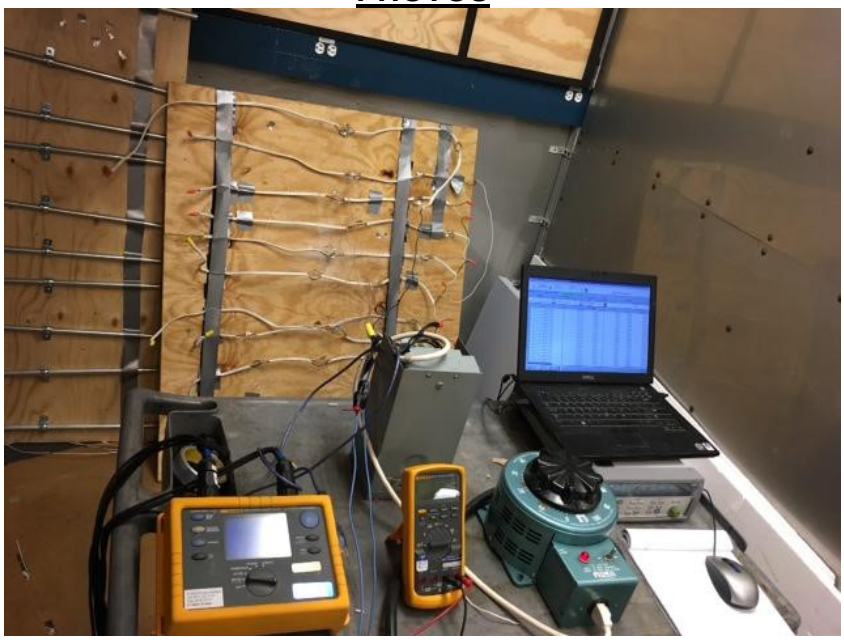
14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

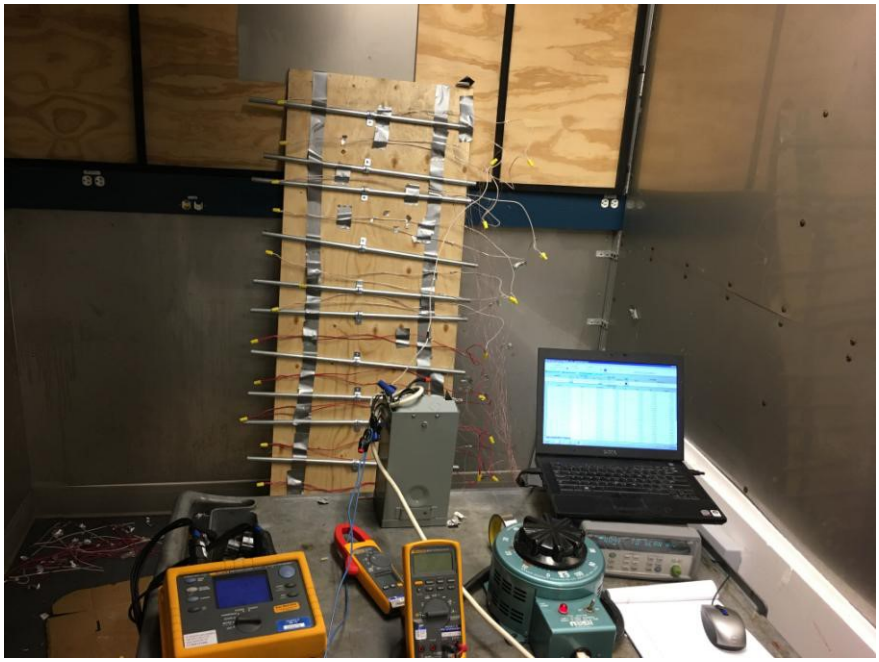
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APPENDIX A
PHOTOS

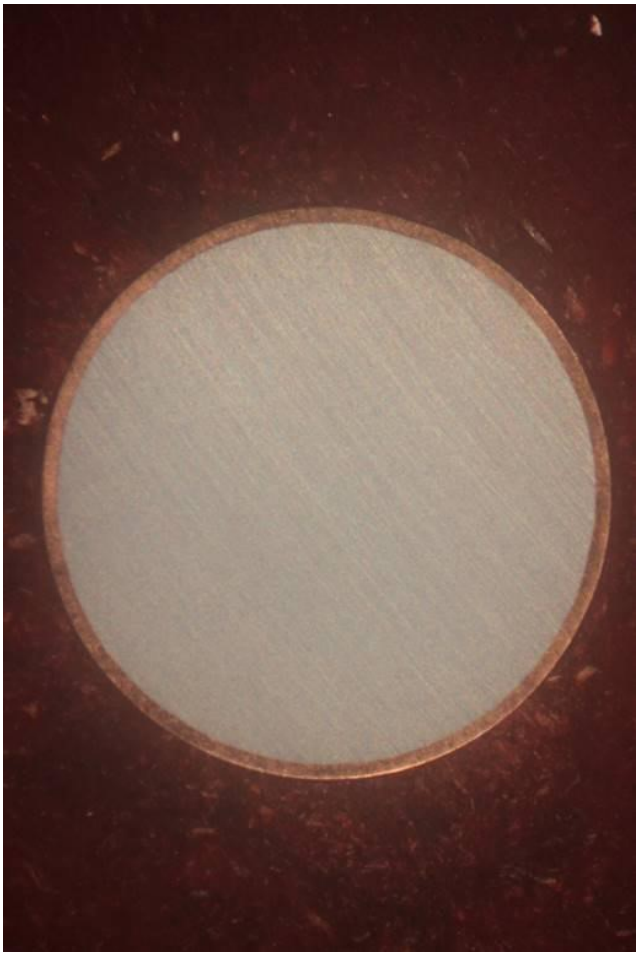




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Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: 3869120002 e W

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road
	Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: 3765740001 e W

17025 Accredited Certificate of Calibration

ACCREDITED
Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road
	Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 deg. F
Humidity:	20.00 %
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: 3869120002 e W

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road
	Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S0606032588B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced other than in full, without the specific written approval of Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Documen: 111.0 Revision 118 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 9/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found: Calibration data collected before the unit is adjusted and / or repaired.
- As - Left: Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left: Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µV/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by 'f'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017

S/N S0606032588B6

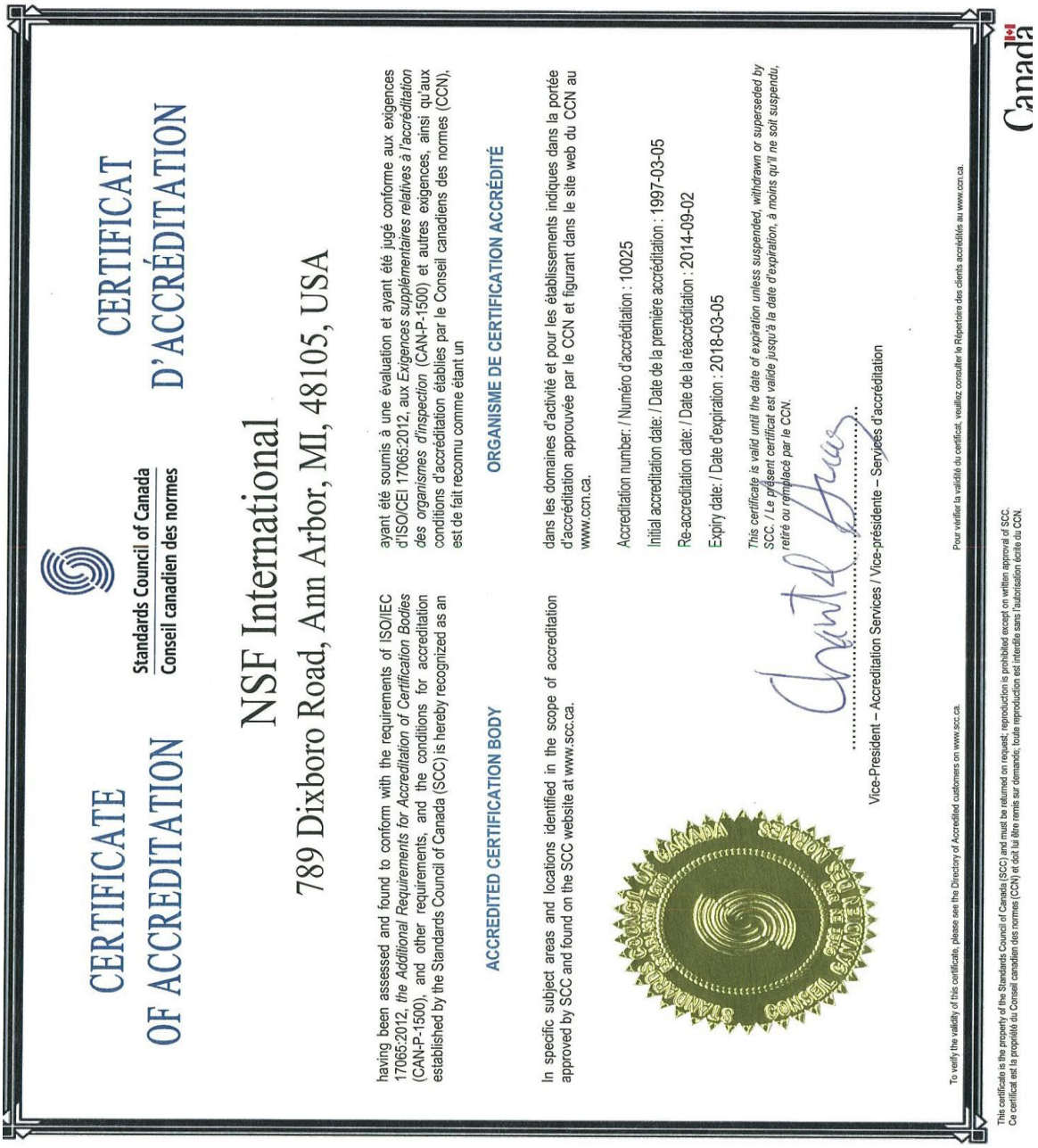
www.fluke.com

Cert # 322693
Date 28/2/2017

Calibration Technician

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APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

CERTIFICAT D'ACCRÉDITATION

Standards Council of Canada
Conseil canadien des normes

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ACCREDITED CERTIFICATION BODY

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ORGANISME DE CERTIFICATION ACCRÉDITÉ

dans les domaines d'activité et pour les établissements indiques dans la portée d'accréditation approuvée par le CCN et figurant dans le site web du CCN au www.ccn.ca.

Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

This certificate is valid until the date of expiration unless suspended, withdrawn or superseded by SCC. / Le présent certificat est valide jusqu'à la date d'expiration, à moins qu'il ne soit suspendu, retiré ou remplacé par le CCN.

Vice-President – Accreditation Services / Vice-présidente – Services d'accréditation

To verify the validity of this certificate, please see the Directory of Accredited customers on www.scc.ca.

Pour vérifier la validité du certificat, veuillez consulter le Répertoire des clients accrédités au www.ccn.ca.

This certificate is the property of the Standards Council of Canada (SCC) and must be returned on request; reproduction is prohibited except on written approval of SCC.
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Canada

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
United States

meets the requirements of the standard:

ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

Dr. Cem O. Onus
Managing Director, Business Assurance
DEKRA Certification, Inc.
1120 Welsh Road, Suite 210
North Wales, PA 19454 USA
(215) 997-4519
dekra-certification.us

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

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Occupational Safety and Health Administration
Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations*. This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

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Terminal and Conductor Temperature Testing of 14 AWG Copper-Clad Aluminum and 14 AWG Copper Conductors

Part I – Static Heating and Flexing Tests

For

Bimetallics Task Group

Conducted at

Eaton Laboratories
Menomonee Falls, Wisconsin

Report by

Chuck Mello
on behalf of Bimetallics Task Group

Report Date

August 28, 2020

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3.0 Materials for Testing 6
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C – Static Heating Test Data
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1.0 Introduction and Purpose

At the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23, a Bimetallics Task Group of balanced interest was appointed. The scope was to review the proposed changes to the 2020 edition of the *NEC*® that relate to copper-clad aluminum conductors and recommend changes through tentative interim amendment(s) and/or to provide public inputs for the next revision cycle.

As the task group conducted the work, it was determined that testing data had been provided substantiating the ampacity of 14 AWG copper-clad aluminum but a number of related questions about 14 AWG copper-clad aluminum applications arose regarding terminal temperatures when applied to circuit breakers, wire splicing devices and device terminals. A testing plan was developed, reviewed over several task group meetings, and accepted by the task group to address the terminal temperature questions. This testing was completed at the Eaton Corporation laboratory facilities in Menomonee Falls, Wisconsin. The helpful assistance of Mr. Tom Domitrovich, Mr. Kevin Arnold, Mr. James Parrett, and Mr. Steve Averbeck with Eaton Corporation is greatly appreciated in arranging for and executing the testing.

This test report provides the testing arrangement, testing procedures and results for the static heating and the flexing tests. The Part I testing detailed in this report commenced July 30, 2020 and completed on August 26, 2020. Thermocycling testing is presently being conducted and those test results will be provided in a separate report. The separation of the reports is necessary to meet the NFPA deadline of September 10, 2020 to submit public inputs and any supporting data.

The purpose of this testing is to provide data, as requested by the Bimetallics Task Group, to understand certain installation and operating conditions when considering the application of 14 AWG copper-clad aluminum conductors at the proposed ampacity for branch circuits. The testing being completed also includes 14 AWG copper conductors at its *NEC*® ampacity for comparison and performance. The basis for comparison is at the 60ºC ampacity rating for copper (15 amps) and the proposed 60ºC ampacity rating for copper-clad aluminum (10 amps). This testing is designed to represent a typical installation to determine the following:

1) The temperature (temperature rise) on the terminals and conductor immediately adjacent to a 10 Amp and 15 Amp molded case circuit breaker, under normal and identified abnormal conditions
2) The temperature (temperature rise) on wire-splicing devices (e.g., Ideal Wire Nuts® or similar), and conductor immediately adjacent, commonly used for splicing in junction or device boxes or attaching leads from utilization equipment, under normal and abnormal conditions
3) The temperature (temperature rise) on wiring devices (single receptacle as representative) and conductor immediately adjacent under normal and abnormal conditions
4) Conductor retention on wiring devices after abnormal thermal-cycling
5) The flexing durability of 14 AWG copper-clad aluminum when installed and removed from a single-gang device box

Since the various product standards do not presently have requirements, procedures or parameters for 14 AWG copper-clad aluminum, the testing being conducted is based on the 10-ampere branch circuit rating at 60°C and percentage multipliers taken from the applicable standards. Where the standard does not provide a percentage value, then the current for the testing was interpolated from the values for relative copper and/or aluminum conductors from the standard. The values for testing of 14 AWG copper are taken from the applicable product safety standards with an ampacity basis of 15 Amps at 60°C

It is to be understood this testing is only being conducted to provide specific performance data and information as requested by the task group. The testing does not provide performance or data for certification of any of the components used for the testing. If 14 AWG copper-clad aluminum is accepted into the 2023 *NEC*®, then numerous UL standards will need to be revised and testing completed under the requirements established in those standards. This testing for certification could be more extensive and take much more time to complete than what is provided here. The goal again is to provide information for a typical installation specific to terminal temperatures. The changes to UL standards will not begin to occur until 14 AWG copper-clad aluminum is recognized for installation in the *NEC*®.

To provide a basis to consider the test results for 14 AWG copper-clad aluminum, duplicate test set ups were constructed using 14 AWG copper conductors. The only difference in the setup for 14 AWG copper is the circuit breaker was rated 15 Amps and the testing values were based on the 15 Amp ampacity. This additional testing data provides a direct comparison in the same environment at the 60ºC ampacity values for these two conductor types and assemblies.

2.0 Testing Arrangement and Setup

The test was conducted in a suitable facility with environmental controls and documented monitoring. The facility was free from extraneous changes in ambient temperature and from having random air flow (drafts) through the testing area. Ambient temperature was maintained between 20ºC and 25°C and recorded with thermocouples positioned in the testing area while temperature testing was completed.

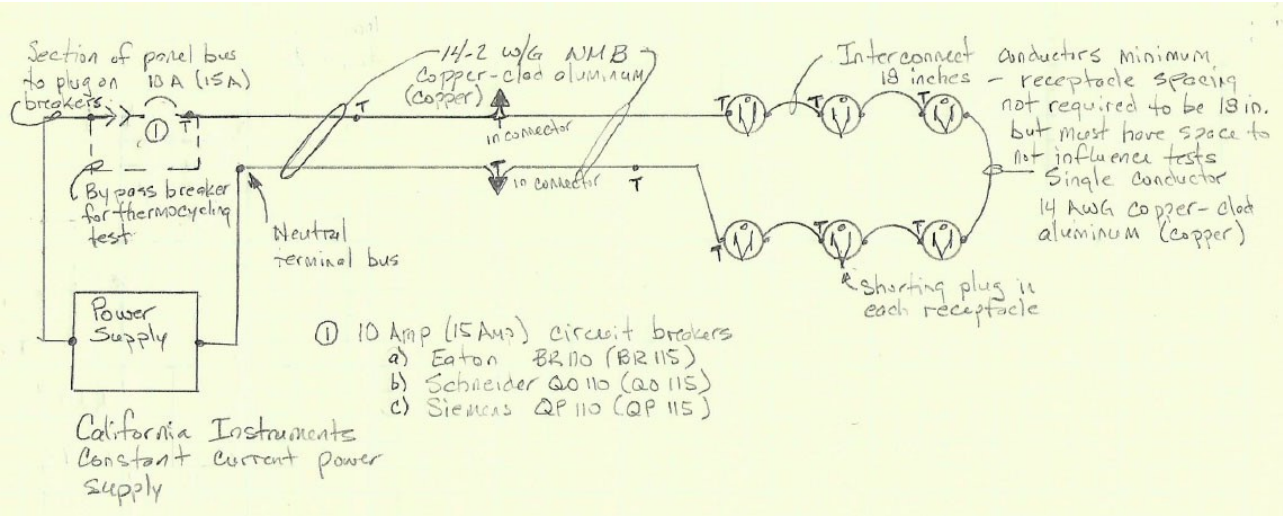


Figure 1 – Typical Test Circuit Diagram

The Eaton facility, being a division within a manufacturing company of wiring devices and circuit breakers, has laboratory technicians that are very familiar with testing of circuit components and equipment to UL standards.

The test circuit diagram shown in figure 1 above provides the basic layout of one (1) testing circuit consisting of one (1) circuit breaker, the conductor (14 AWG copper-clad aluminum or copper NM-B cable) two wire-splicing devices, and six (6) single receptacles. To complete tests 1 through 4 as described below, three (3) of these test circuits were assembled at a time. Photos 1 through 3 in Appendix A show the general test setup for completing the static heating testing. Each of the three (3) circuits have one of the manufacturer's (mfg. 1, mfg. 2, and mfg. 3) circuit breaker, the wire splicing devices on the black and white wire as described below, and three (3) each of receptacles from two of the manufacturers. Photos 4 through 7 show each of the setups with a sign indicating the circuit breaker, conductor material, wire splicing devices, and receptacles in that circuit.

For example, a setup had three (3) circuits with:

- Three different 10-amp circuit breakers (one each mfg. 1, mfg. 2, and mfg. 3)
- 14 AWG copper-clad aluminum NM-B conductors
- Mfg. 4 and mfg.5 wire splicing devices respectively, on the black and white conductors
- Three each of the mfg. 8 and mfg. 9 receptacles, and
- 14 AWG THHN copper-clad aluminum conductors for interconnection of the receptacles

These components were connected together to form a complete circuit. The second setup for 14 AWG copper-clad aluminum were same circuit breakers but with mfg.6 and mfg.7 wire spicing devices and with mfg. 10 and mfg.11 receptacles. The third and fourth setups were the same as 1 and 2 except using 15-amp circuit breakers and 14 AWG copper conductors.

Due to testing of several different circuit breakers, receptacles, and wire-splicing devices, the test arrangement was different than what may be used for certification testing of a single type of device. The test purpose was to approximate an actual installation under laboratory type conditions and not to establish certification type testing for any one device.

For tests 1 through 4 the three power supplies used were programmable constant current power supply sources. Each power supply was connected to one of the circuits and provided the current level specified for the tests being conducted.

For each of the four setups the following description is provided, see circuit diagram in figure 1 and Appendix A photos 1 through 7:

1) The three (3) circuits were mounted on an insulating sheet approximately 4 feet high and 8 feet wide. The partition had suitable framing to provide structural support for the partition to be in a vertical orientation to the floor.

2) During all testing, suitable barrier tape, safety cones, barriers, or other means was in place in accordance with the laboratory safety procedures to keep unauthorized persons out of the area and away from exposed live parts.

3) The individual conductors and devices were arranged horizontally with approximately 12 inches of vertical spacing between each horizontal assembly. Staples, or other fastening devices, such as cable ties, were used to keep the NM-B cable aligned with the respective test assembly.

4) For the circuit breaker testing the following was assembled:

   a) For the copper-clad aluminum conductors, three (3) 10-amp plug-on type panelboard circuit breakers were installed on sections of panelboard bus that are mounted onto the insulating board partition.

   b) For the copper conductors, three (3) 15-amp plug-on type panelboard circuit breakers were installed on sections of panelboard bus that are mounted onto the insulating board partition. The panelboard bus had a terminal for connection of one conductor from the power supply.

5) From the circuit breaker approximately 4 feet of 14-2 NM-B cable was installed and supported as provided above. From this center junction another 2 feet of 14-2 NM-B cable (copper-clad aluminum or copper as applicable) was installed. The junction in the middle had approximately 6 inches of exposed conductor and a splice completed with yellow wire-splicing devices as provided for the black, white and equipment grounding conductors. The following was applied to the two setups for the copper-clad aluminum conductors respectfully and repeated for the copper conductor setups.

   a) The black wire for the first circuit set of three used a mfg. 4 yellow wire-splicing devices

   b) The white wire for the first circuit set of three used an mfg. 5 yellow Wire Nuts®

   c) The black wire of the second circuit set of three used a mfg. 6 yellow wire-splicing devices

   d) The white wire of the second circuit set of three used a mfg. 7 yellow wire-splicing devices

   The manufacturer and location of the wire-splicing devices used was recorded for each test setup.

6) Six (6) receptacles were installed at the end of each horizontal assembly.

   a) The first set of circuits of copper-clad aluminum or of copper had three (3) mfg. 11 receptacles and then three (3) receptacles from mfg. 8 all connected in series.

   b) The second circuit of copper-clad aluminum or of copper had three (3) receptacles from mfg. 10 and then three (3) receptacles from mfg. 9 all connected in series.

   The receptacles were spaced a minimum of six (6) inches apart horizontally and/or vertically and were interconnected with a minimum of eighteen (18) inches of 14 AWG solid THHN copper-clad aluminum or copper conductors respectfully.

   The receptacles were mounted to the wall surface with screws, so that the face of the receptacle was approximately 1 1/2 inches from the insulating board partition surface.

   For each manufacturer the receptacles were connected to terminals as follows:

   a) One receptacle had the conductors installed at each wire binding screw and the conductors were wrapped counter-clockwise around the screw shank under the screw head, for 2/3 to 3/4 of wire binding screw circumference.

b) The second receptacle had the conductors installed into one side back terminal (entry hole) of the pressure plate terminal.

c) The third receptacle had two conductors installed into each back-side pressure plate terminal as follows: one conductor of the test circuit into each side (hot and neutral) of the pressure plate terminal and one additional short conductor of equal diameter and material into the other side (entry hole) of the same pressure plate terminal. The second conductor was to fill the slot only and is not required for any other purpose than to balance the mechanical clamping forces applied.

Each receptacle had a shorting plug installed as follows:

a) The ungrounded (BLACK) and grounded (WHITE) contacts of each receptacle being tested were connected together by a mated attachment plug having rigidly-attached solid blades.

b) The terminals of each attachment plug were short-circuited by the shortest feasible length of 14 AWG stranded copper conductor from type SJ flexible cord.

c) The flexible cord shorting conductor was mechanically terminated into the pressure plate terminals and the connection torqued to the manufacturer's specification.

7) The conductor from the neutral terminal of the last receptacle in the series was routed back using the white wire in the NM-B cable, through the wire-splicing devices and terminated at a terminal bar mounted to the support board for connection back to the power supply.

8) All connections were tightened as follows. Torquing tools were calibrated and calibration documented:

a) The circuit breaker terminals were torqued as specified on the circuit breaker nameplate.

b) The wire-splicing devices were torqued to the manufacturer's specification in the instructions. If there was no specification, then the 14 AWG copper-clad aluminum conductors were torqued to 2.47 lbf-in and the 14 AWG coper conductors were torqued to 4.11 lbf-in [Specification from UL 486C – 9.1.9.4]

c) The terminals of the receptacles and of the attachment plugs were torqued to the manufacturer's specification in the installation instructions. If there was no torque specification provided, then the terminals were torqued to 9 lbf-in.

9) Thermocouples were connected as shown in the diagram, figure 1 and as shown in Appendix A photos 8 and 11 through 14.

a) Thermocouples were installed on device terminals so that it did not interfere with the terminal.

For the wire-splicing devices, the thermocouples were attached into the wire bundle within the wire-splicing devices.

b) The thermocouples that measured center wire temperatures had a flap of the NM-B jacket and the conductor insulation peeled back to expose the conductor. The thermocouple was attached with thermo-cement to the conductor and the conductor insulation and jacket flap folded back to the original position with two wraps of black electrical tape wrapped to hold the flap in place.

c) A thermocouple was positioned midway in elevation to the test setup for each circuit and recorded the ambient temperature as testing was completed.

10) The power supply was a programable constant current power supply. The current was monitored and recorded by the data logger along with the temperature recordings. The power supply was connected to the lug on the panelboard bus serving the circuit breaker and to the neutral terminal bar where the return white conductor from the NM-B cable was terminated.

3.0 Materials for Testing

The generous support with the supplying of materials by Copperweld, Eaton, Hubbell, Legrand, Leviton, and Siemens are acknowledged and appreciated. The following materials were used to complete the setups as described above.

1) The circuit breakers for the copper-clad aluminum testing were single pole 10 Amp 120/240 Volt, 10,000 interrupting rating with five (5) each of the following (two (2) breakers to be used and the others as backup):
   a) Eaton BR110,
   b) Schneider QO110, and
   c) Siemens QP110.
2) The circuit breakers for the copper testing were single pole 15 Amp 120/240 Volt, 10,000 interrupting rating with five (5) each of the following (two (2) breakers to be used and the others as backup):
   a) Eaton BR115,
   b) Schneider QO115, and
   c) Siemens QP115.
3) The yellow wire-splicing devices were as follows:
   a) Gardner-Bender Ultra WingGard
   b) Ideal Wing-Twist
   c) 3M Performance Plus Red/Yellow+
   d) Commercial Electric WT4

4) The receptacles for both the copper-clad aluminum and copper testing were:
    a) Eaton (Cooper) model TR6250W, 5-15R single receptacle with wire binding screw and pressure plate terminals (back and side wired)
    b) Hubbell model HBL 5261, 5-15R single receptacle with both wire binding screw and pressure plate terminals (back and side wired)
    c) Legrand (Pass & Seymour) model TR 5251, 5-15R single receptacle with both wire binding screw and pressure plate terminals (back and side wired)
    d) Leviton model T 5015, 5-15R single receptacle with both wire binding screw and pressure plate terminals (back and side wired)
5) Thermocouples, UL calibrated, model UL 3055, with sufficient length to connect and route to datalogger recording device.
6) Datalogger recording device and laptop or another required device for the datalogger.
7) Programable power supplies from Eaton laboratory. Maximum current for the copper was 30 Amps and for the copper-clad aluminum was 20 amps.
8) Approximately 50 feet each of 14-2 w/ground copper-clad aluminum NM-B cable and of 14-2 w/ground copper NM-B cable.
9) Approximately 50 feet each of 14 AWG solid THHN copper-clad aluminum and 14 AWG solid THHN copper single conductors.

4.0 Test Procedures

4.1 Conductor Material Testing

A sample of each the 14-2 NM-B and 14 AWG THHN copper-clad aluminum conductors used for the testing was returned to the Copperweld factory laboratory for analysis. The testing was performed to confirm the conductors that were used for the testing at Eaton were in fact 14 AWG and met the requirements for copper-clad aluminum as specified in UL 83 Annex E and ASTM B566. The packaging was photo documented from the Eaton laboratory and the opening of the package at the Copperweld laboratory photo documented.

The Copperweld laboratory technician, who routinely performs the full ASTM B566 battery of testing, completed all the testing and documented it on a Copperweld laboratory test data sheet.

Standard materials testing was completed by Copperweld laboratory technicians including:

- DC resistance
- Copper thickness
- Copper Volume
- Tensile strength
- Elongation
- Adhesion
- Cohesion

The following tests, as completed by the Copperweld laboratory technician, were witnessed and documented by the UL Field Representative that normally completes follow-up inspections of copper-clad aluminum conductors as part of the recognized component program, under category DVVU2:

- DC resistance
- Copper thickness
- Tensile strength
- Elongation

4.2 Terminal Temperature Testing

The following test procedures, except the flexing test, used references from parts of UL 486(A)(B); UL 486(C); UL 489; UL 20; and UL 498.

As stated, the tests 1 through 4 were completed with all three (3) manufacturer's circuit breakers in three circuits at one time. These tests are identified with the test number from below with an "a", "b" or "c' representing the representative circuit breaker used:

a. mfg. 1 circuit breaker

b. mfg. 2 circuit breaker

c. mfg. 3 circuit breaker

This same nomenclature is used in the data sheets found in Appendix C. To minimize test setups, and the number of times terminations are completed or taken apart, all four (4) static heating tests were completed for the "a", "b", and "c" circuit setups. After these tests were completed, then the next setup was assembled by changing the wire splicing devices and receptacles or changing the conductors from copper-clad aluminum to copper as applicable.

All static heating tests, tests 1 through 4 commenced with all components at ambient temperature.

For all testing temperature equilibrium is three consecutive readings taken at no less than 5-minute intervals indicating no further rise in temperature above the ambient temperature. For tests where the circuit breaker trips, which may be before temperature equilibrium was attained, the last three recorded temperatures were recorded onto the data sheets.

Test #1 – Rated Current Temperature

Each circuit was operated at 100% of the branch circuit rating (CCA - 10 Amps or Cu - 15 Amps) until temperature equilibrium was achieved. The final temperatures were recorded. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at one-minute intervals.

Test #2 – Circuit Breaker Overload Temperature

Each circuit was operated at 135% of the branch circuit rating (CCA - 13.5 Amps or CU - 20.25 Amps) until temperature equilibrium was achieved or the circuit breaker tripped whichever came first. The circuit breaker elapsed trip time was recorded. Table 1, in section 4.3 below, provides the expected circuit breaker trip times from the manufacturer's time current curves. If the circuit breaker tripped, the last three recorded temperatures of the conductor, wire-splicing devices and wiring device were recorded on the datasheet. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at 20-second intervals.

Test #3 – Wiring Device Overload Temperature

Each circuit was operated at 150% of the branch circuit rating (CCA - 15 Amps, or CU - 22.5 Amps) until temperature equilibrium was achieved or the circuit breaker tripped whichever came first. The circuit breaker elapsed trip time was recorded. Expected circuit breaker trip times are in a table 1 below in section 4.3 of procedure. If the circuit breaker tripped, the last three recorded temperatures of the conductor, wire-splicing devices and wiring device were recorded on the datasheet. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at 10 second intervals.

Test #4 – Circuit Breaker Overload Temperature

Each circuit was operated at 200% of the branch circuit rating (CCA - 20 Amps, or CU 30 Amps) until temperature equilibrium was achieved or the circuit breaker trip tripped whichever came first. The circuit breaker elapsed trip time was recorded. Expected circuit breaker trip times are in a table 1 below in section 4.3 of procedure. If the circuit breaker tripped, the last three recorded temperatures of the conductor, wire-splicing devices and wiring device were recorded on the datasheet. All terminations were inspected for evidence of thermal damage. Temperature measurements were recorded at 7 second intervals.

Test #5 – Wiring Device Thermal Cycling

The thermocycling testing is underway at the time this report is being written. In order to meet NFPA public input deadlines, this report is for all testing completed at this time. A subsequent report will be written for the thermocycling testing.

Test # 6 – Conductor Flexing Test

a) A standard 2 x 3 device box was mounted to a wood stud fixed to a table for support. See Appendix A photo 15. The device box was mounted with screws through the back of the box.

b) A length of 14-2 AWG copper-clad aluminum NM-B cable was installed into the device box using NM cable clamps. The NM-B had a minimum of 1/4 inch of cable jacket projecting into the box past the clamping device.

c) The outside end of the NM-B cable was connected to a digital multimeter to indicate continuity of the circuit through the receptacle, see Appendix A photo 16.

d) The NM-B cable jacket was stripped and cut to length so that 6 inches of conductor projected beyond the cable entry to the box and 3 inches beyond the front edge of the device box. A receptacle was terminated to the NM-B cable conductors and the conductors shaped to fit back in the box so the receptacle yoke mated with the box front edge.

e) For the first test, the NM-B conductors were installed using the wire binding screw with the conductors wrapped counter-clockwise around the screw shank under the screw head, for 2/3 to 3/4 of wire binding screw circumference.

f) A shorting plug was installed into the receptacle.

g) The 6-32 screws were removed and approximately 4-inch-long 10-32 screws were fixed to the device box ears and through the yoke of the receptacle providing a guideway for repeated insertion and removal. The 10-32 screws had nuts installed in the inside and outside of the device box ears to make rigid to the box, see Appendix A photo 15.

h) With the assembly complete, the receptacle was pushed into and retracted from the box for 10 cycles and the continuity monitored on the digital multimeter, see Appendix A photos 17 through 19.

i) Steps ‘b’ through ‘h’ were repeated two more times with new lengths of 14-2 NM-B copper-clad aluminum cable.

- For the second test the receptacle was assembled with the back-wiring pressure plate terminal and a single conductor.
- For the third test the receptacle was assembled with the back-wiring pressure plate terminal and two conductors for mechanical balance on the wiring terminal.

4.3 Bimetallics Testing Circuit Breaker Trip Times

The below table provides the expected trip times based on the manufacturers time current curves at 40°C. The testing for this project was completed at about 22°C, based on the ambient temperatures recorded. Therefore, the trip times recorded from this testing may be somewhat higher but should not exceed the limits set in the UL Standard.

The UL standard specifies that calibration testing be competed at an ambient temperature of 25°C. The UL standard calibration testing at 25°C specifies that at:

- 135% of rating the maximum trip time for a 0 - 50-amp circuit breaker is 1 hour
- 200% of rating the maximum trip time for a breaker 0 – 30 amps is 2 minutes.

Table 1

Manufacturer	Catalog No.	Trip Time Range in Seconds @ 40°C			
		100% rated current	135% rated current	150% rated current	200% rated current
Eaton	BR110	No trip	35 - 3600	20 - 500	12 - 40
	BR115	No trip	35 - 3600	20 - 500	12 - 40
Schneider	QO110	No trip	40 - 500	26 - 240	10 - 60
	QO115	No trip	30 - 210	21 - 100	8 - 28
Siemens	QP110	No trip	60 -800	40 - 450	19 - 150
	QP115	No trip	30 - 250	20 - 100	9 - 38

5.0 Test Results

5.1 Copper-Clad Aluminum Conductor Material Testing

After the static heating testing was completed, Eaton laboratory technicians packed and shipped samples of the copper-clad aluminum conductor, NM-B cable and THHN single conductor, that had been used for the testing to Copperweld's laboratory for verification testing. Appendix A photos 22 to 24 show the samples the Eaton laboratory technicians packaged into the bag and shipped to the Copperweld laboratory. Note the date on these photos as August 24, 2020. Appendix B pages B1 and B2 show photos of the received package and opening of that package with these samples for the testing.

The samples of the 14 AWG copper-clad aluminum NM-B cable and the 14 AWG copper-clad aluminum THHN single conductors were tested in the Copperweld factory laboratory on August 27, 2020. The Copperweld laboratory testing data is provided in Appendix B page B3 and the calibration of the test equipment on pages B4 through B6.

The UL field engineer that routinely completes the quarterly follow-up inspections for the copper-clad aluminum conductor witnessed the testing required under the UL standard follow-up program that was completed on August 27, 2020. As shown in Appendix B, page B7, the UL field engineer confirmed that "*the 14 Awg from the NMB and THHN samples passed the UL tests for DVVUs, including Tensile, Elongation, copper thickness and DC resistance*"

The test results for the copper-clad aluminum confirm that the conductors used for this testing were 14 AWG and that the material tested met the requirements in ASTM B566.

5.2 Test Setup and Torquing

The test setups were as described in Section 2.0 of this report and shown with photographs in Appendix A. The terminations were tightened to the applicable torque value with a calibrated torque wrench. For the static heating testing the following tables show the torque values applied for each setup and device terminal.

Copper-Clad Aluminum conductors with mfg. 11 and mfg. 8 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 4 wire splicing device	2.47	no	yes
mfg. 5 wire splicing device	2.47	no	yes
mfg. 11 receptacles	9	no	yes
mfg. 8 receptacles	12	yes	no

Copper-Clad Aluminum conductors with mfg. 10 and mfg. 9 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 6wire splicing device	2.47	no	yes
mfg. 7 wire splicing device	2.47	no	yes
mfg. 10 receptacles	9	no	yes
mfg. 9 receptacles	9	no	yes

Copper conductors with mfg. 11 and mfg. 8 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 4 wire splicing device	4.11	no	yes
mfg. 5 wire splicing device	4.11	no	yes
mfg. 11 receptacle	9	no	yes
mfg. 8 receptacle	12	yes	no

Copper conductors with mfg. 10 and mfg. 9 Receptacles

Torques applied:

Item being torqued	in/lbs	mfr. spec	default
mfg. 1 brkr	20	yes	no
mfg. 2 brkr	36	yes	no
mfg. 3 brkr	25	yes	no
mfg. 6wire splicing device	4.11	no	yes
mfg. 7 wire splicing device	4.11	no	yes
mfg. 10 receptacle	9	no	yes
mfg. 9 receptacle	9	no	yes

5.3 Static Heating Test

The following are the results of the static heating testing, tests 1 through 4 with references to the applicable appendix pages. For all the testing data, the final three recorded temperature values are shown at either temperature equilibrium or the final three temperatures recorded before a circuit breaker tripped. All testing commenced with all test measurement points at ambient temperature. Also shown in the tables in the appendix are:

- The elapsed time from the start of the test,
- The ambient temperature recorded at the time of the recorded values, and
- The current at the time of the recorded values.

Since the UL standards reference temperature rise for most of the devices, those calculated values are shown immediately adjacent to the recorded values. The temperature rise was calculated by taking the recorded temperature and subtracting the ambient temperature recorded for that time.

Since the method of termination on each the three receptacles from one manufacturer was different (wire binding screw, back wired with pressure plate with one conductor and back wired with pressure plate with two conductors) exact data comparison of terminal temperature needs to be done line by line. For example, from appendix page C1 – 1, the line 1a for copper-clad aluminum, top table, needs to compare with line 1a for copper, bottom table.

Otherwise, data in general for terminal temperatures of specific devices, circuit breakers, wire splicing devices and receptacles as well as the conductor, can be compared in general. To facilitate ease of comparison, the pages in appendices C1 though C4 have been arranged so that each page has the copper-clad aluminum data in the top table and the related copper data in the bottom table.

5.3.1 Static Heating at 100% Rated Current

The data for the static heating testing at 100 percent of rated current are shown in Appendix C1. The recorded values are all after the temperatures being recorded had achieved temperature equilibrium. As can be seen in line by line or with general comparisons, the terminal and conductor temperatures for the copper-clad aluminum were less than those recorded for copper when operating at rated current. All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.2 Static Heating at 135% Rated Current

The data for the static heating testing at 135 percent of rated current are shown in Appendix C2. The 135 percent current level is a calibration point for circuit breakers, rated up to 50 amps, where they are required to trip within 1 hour. The recorded values are the last three recorded temperatures before the circuit breaker tripped.

In doing analysis consideration must be given to the fact the temperatures recorded were still rising when the circuit breaker tripped. Therefore, when doing line by line or general comparisons, the circuit breaker trip time must be considered. It is noted the mfg. 1 10-amp circuit breaker tripped approximately twice as fast as the 15-amp circuit breaker, 8 vs. 19 seconds, and this resulted in higher recorded temperatures for copper. The test results with the mfg. 2 circuit breakers was reversed with the 15-amp breaker tripping in approximately half the time of the 10-amp circuit breaker, 3.5 vs. 5.5 seconds. Even with this time disparity the copper-clad aluminum with the longer time recorded lower temperatures than the copper. The trip times for the mfg. 3 circuit breakers had the 10-amp breaker tripping 3 times longer than the 15-amp breaker, but the copper-clad aluminum terminal temperatures still were less than or near to the copper terminal temperatures.

All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.3 Static Heating at 150% Rated Current

The data for the static heating testing at 150 percent of rated current are shown in Appendix C3. The 150 percent current level is a static heating test current for wiring devices. The recorded values are the last three recorded temperatures before the circuit breaker tripped.

In doing analysis consideration must be given to the fact the temperatures recorded were still rising when the circuit breaker tripped. Therefore, when doing line by line or general comparisons, the circuit breaker trip time must be considered. The test data results shown in appendix C3 generally follow that same pattern as occurred with the 135 percent testing.

All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.4 Static Heating at 200% Rated Current

The data for the static heating testing at 200 percent of rated current are shown in Appendix C4. The 200 percent current level is a calibration point for circuit breakers, rated up to 30 amps, where they are required to trip within 2 minutes. The recorded values are the last three recorded temperatures before the circuit breaker tripped.

In doing analysis consideration must be given to the fact the temperatures recorded were still rising when the circuit breaker tripped. Therefore, when doing line by line or general comparisons, the circuit breaker trip time must be considered. The test data results shown in appendix C4 generally follows the same pattern as occurred with the 135 percent and 150 percent testing.

All temperatures recorded were less than the allowances in the applicable UL standards.

5.3.5 Static Heating at 135% Rated Current – Circuit Breaker Did Not Trip

The first attempt at the 135 percent testing found the mfg. 2 10-amp circuit breaker not to trip within the required 1-hour time. The data for this static heating test at 100 percent and at 135 percent of rated current are shown in Appendix C5. The top table on this appendix page is the 100 percent test data and the bottom table is the 135 percent test data. As stated before, the 135 percent current level is a calibration point for circuit breakers, rated up to 50 amps, where they are required to trip within 1 hour.

Since the circuit breaker failed to trip the test was stopped shortly after the 1-hour time had elapsed. Analysis of the 135 percent data recorded found that after 1-hour at this current level, above the proposed rated current, none of the terminal or conductor temperatures had risen above UL standards allowances.

5.3.6 Flexing Tests

The data for the flexing testing is shown in Appendix D. There is no UL or other known industry standard for this specific test and the test process used was established and agreed to by the task group to represent an installation condition. Three tests were conducted, one with the receptacle terminated with the 14 AWG copper-clad aluminum wrapped around the wiring binding screw, the second with a single conductor back wired into the pressure plate and the third with two conductors back wired into the pressure plate.

The test results found that after 10 cycles of fully inserting and removing the receptacle to the full extended position, the copper-clad aluminum

conductors for the back wired assemblies did not break and therefore passed this test.

For the wire binding screw termination, the first test found the flexing for the 10 cycles passed where the conductors did not break. But when the conductors were being removed both the black and white conductors broke off near the end of the insulation, see Appendix A photo 20. A second test was conducted and the black conductor was found to break off near the end of the insulation on the eighth cycle. A third test was completed, using a 14 AWG NM-B sample from another coil, and this assembly passed the 10 cycles and removal of conductors with no breaking or signs of weakening in the stripped portion of the conductor, see Appendix A photo 21.

As stated, there is no industry standard for completing this flexing test and the test was conducted due to specific questions asked by members of the task group. The results demonstrate that there may be limits to the amount of flexing these conductors can withstand, but it should be noted that in normal installations the insertion and removal of a wiring device occurs far less than the eight to ten times as conducted in this test.

6.0 Conclusions

The results from the temperature testing conducted in this project found the 14 AWG copper-clad aluminum to have terminal and conductor temperatures generally less than copper when tested at the 60°C ampacity values. In all cases, the temperature and temperature rise recorded were below those provided in the referenced UL standards. The flexing testing found that there may be some limitations to the number of flexing operations a 14 AWG copper-clad aluminum conductor can withstand, but the number of flexing operations to breakage is above those normally encountered in any installation.

As stated in the introduction, this testing project was to answer specific questions raised by the Bimetallics Task Group regarding temperature performance of 14 AWG copper-clad aluminum compared with 14 AWG copper in typical applications. **While testing conducted followed parts of several UL standards, it is to be understood the testing was only conducted to provide specific performance data and information as requested by the task group. The testing does not provide performance or data for certification of any of the components used for the testing.**

7.0 Test Equipment and Calibration

The following test and measurement equipment was used for the testing. The certificates of calibration for each of the above items is provided in Appendix E.

Description	manufacturer	Eaton Asset #	Cal Date	Cal Due
Thermocouples	Pacific Test and Measurement	N/A	7/10/2020	N/A
DACQ datalogger	Agilent (HP)	EM7054	7/16/2020	7/16/2021
DVM	Fluke	EM4437	7/16/2020	7/16/2021
DVM	Fluke	EM7014	7/16/2020	7/16/2021
DVM	Fluke	EM7024	7/16/2020	7/16/2021
CT	AEMC	EM6996	7/16/2020	7/16/2021
CT	AEMC	EM6997	7/16/2020	7/16/2021
CT	AEMC	EM8032	7/16/2020	7/16/2021
Torque wrench	CDI	EM8363	7/14/2020	7/14/2021
Tape measure	Stanley	EM6927	7/16/2020	7/16/2021

Appendix A - Photos



Photo 1 – Laboratory View



Photo 2 – Test Board and Test Equipment Arrangement

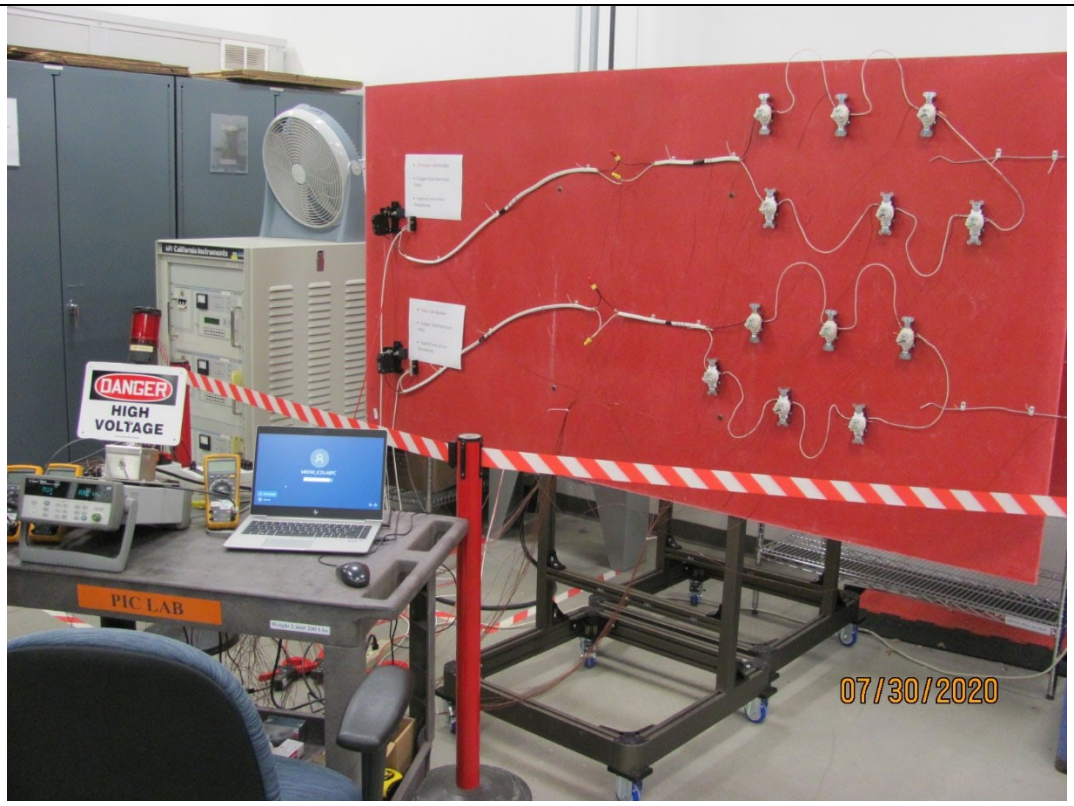


Photo 3 – Test Board and Test Equipment Arrangement



Photo 4 – Copper-Clad Aluminum with Eaton and Hubbell Receptacles

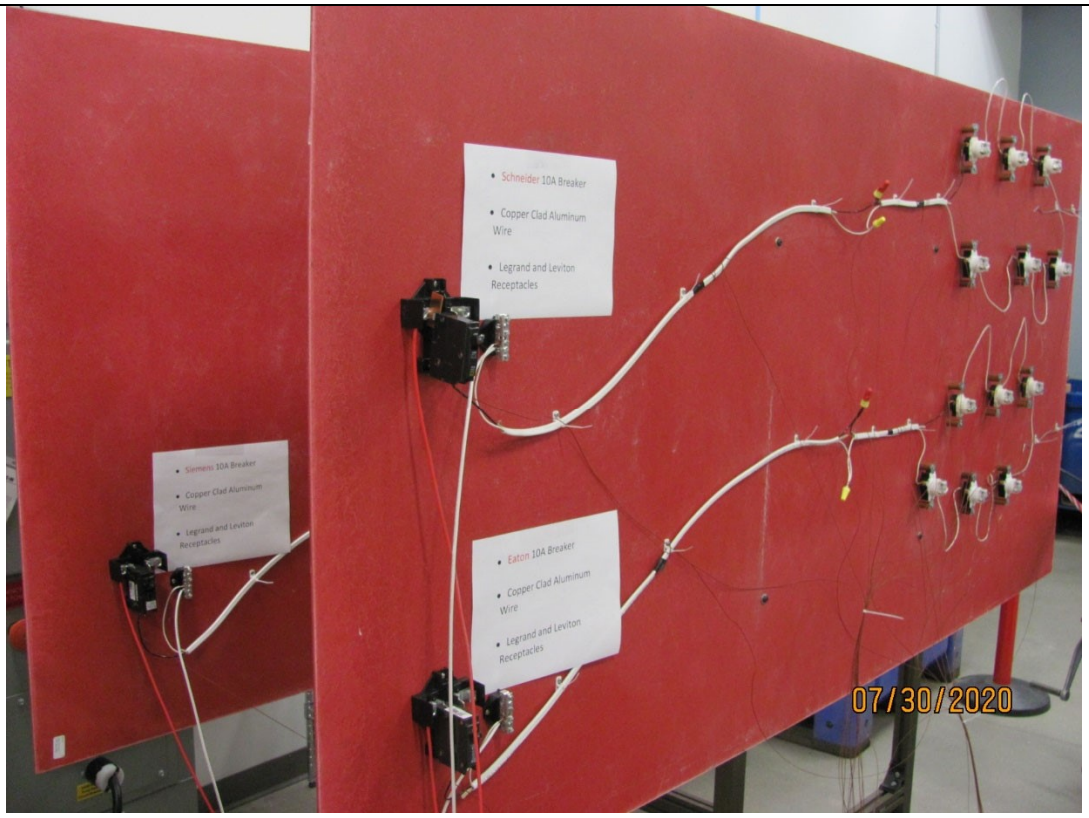


Photo 5 – Copper-Clad Aluminum with Legrand and Leviton Receptacles



Photo 6 – Copper with Eaton and Hubbell Receptacles

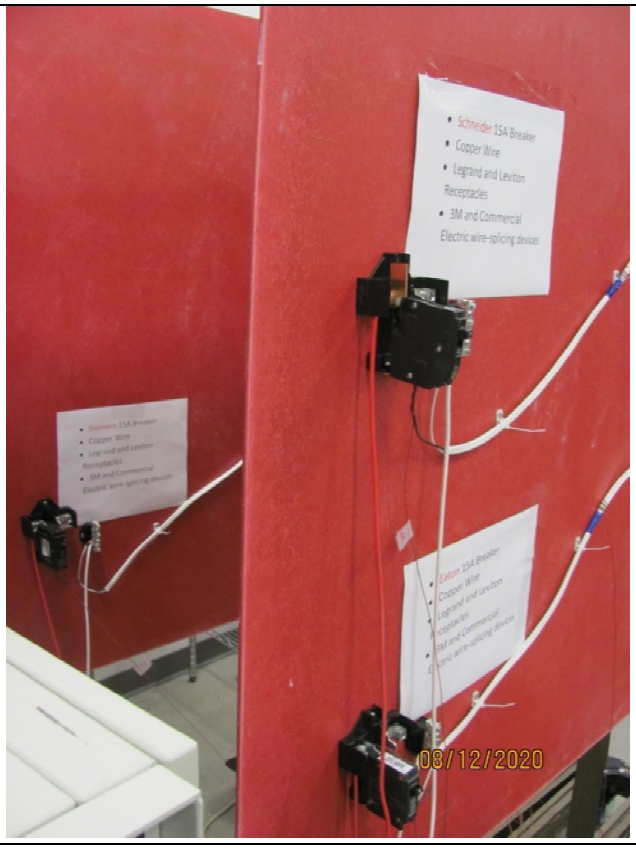


Photo 7 – Copper with Legrand and Leviton Receptacles

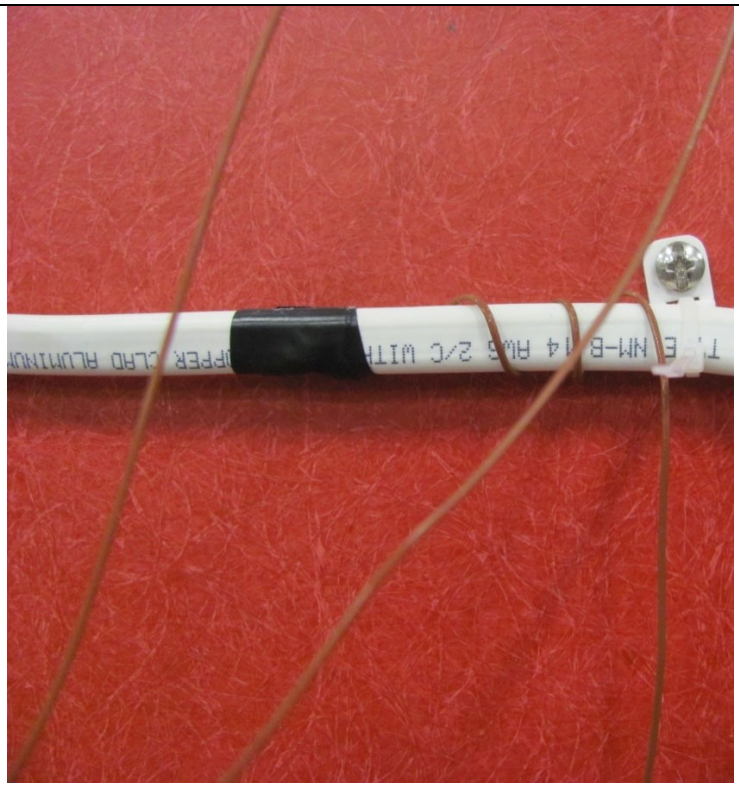


Photo 8 – Copper-Clad Aluminum NM-B Cable

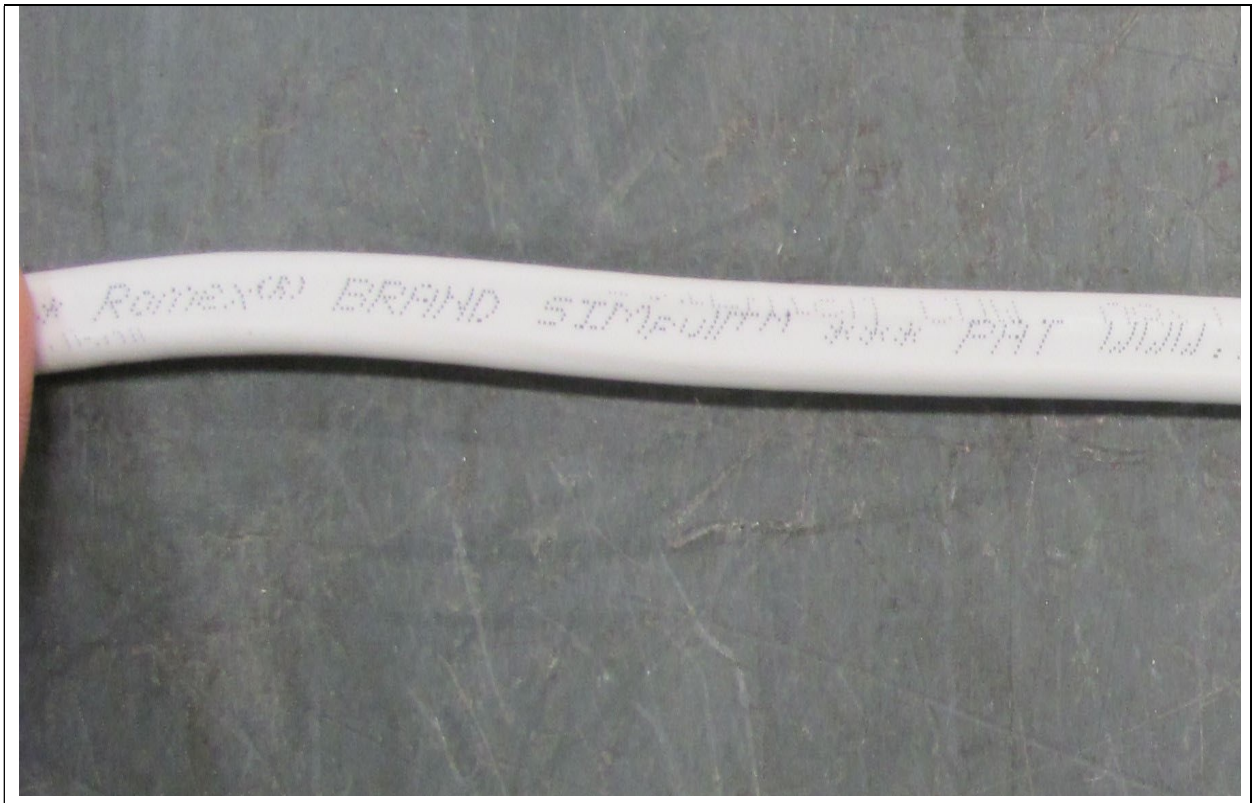


Photo 9 – Copper NM-B Cable



Photo 10 – Copper NM-B Cable Packaging

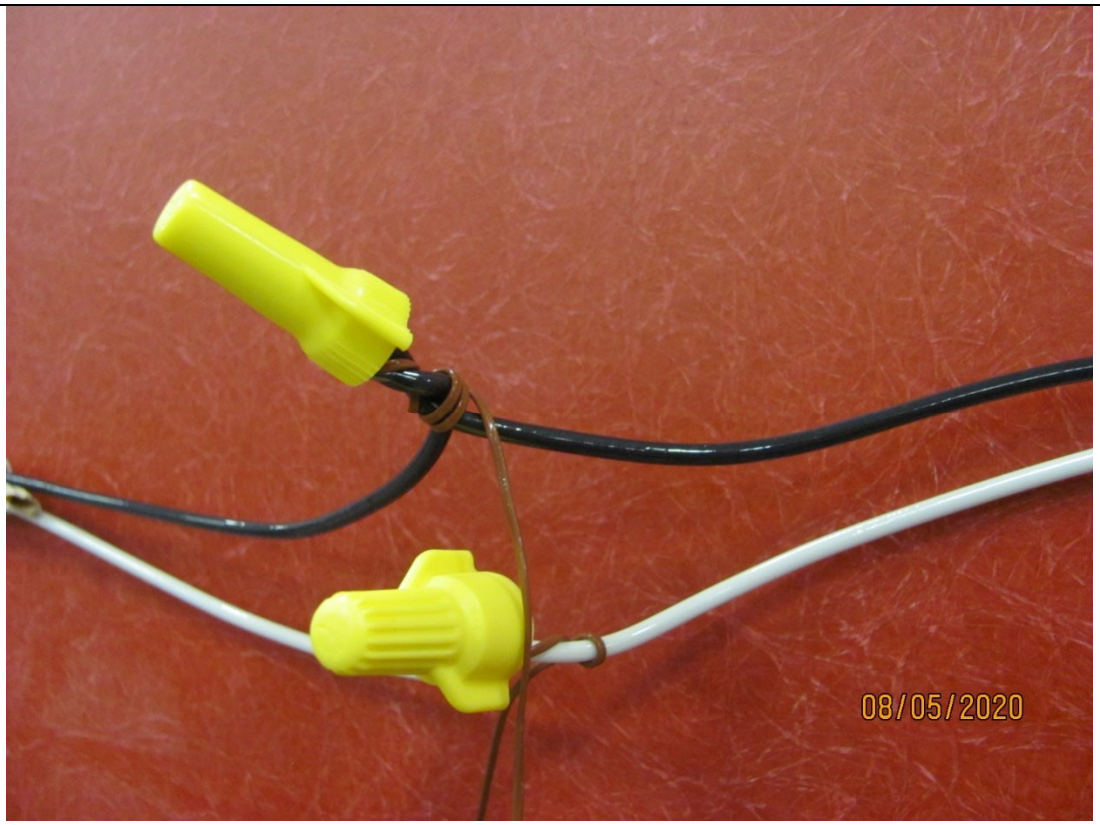


Photo 11 – Typical Installation of Wire Splicing Devices with Thermocouple



Photo 12 – Typical Installation of Receptacle using Wire Binding Screw

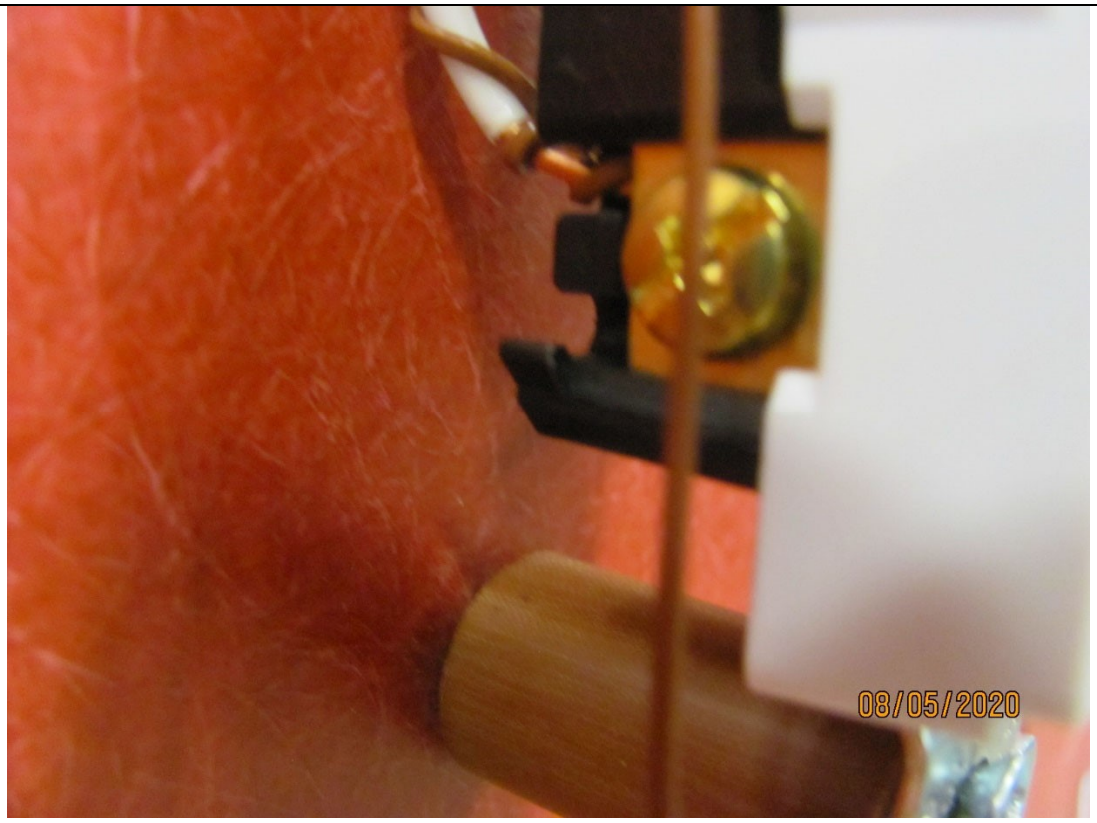


Photo 13 – Typical Installation of Receptacle Since Conductor Back Wired



Photo 14 – Typical Installation of Receptacle Two Conductors Back Wired

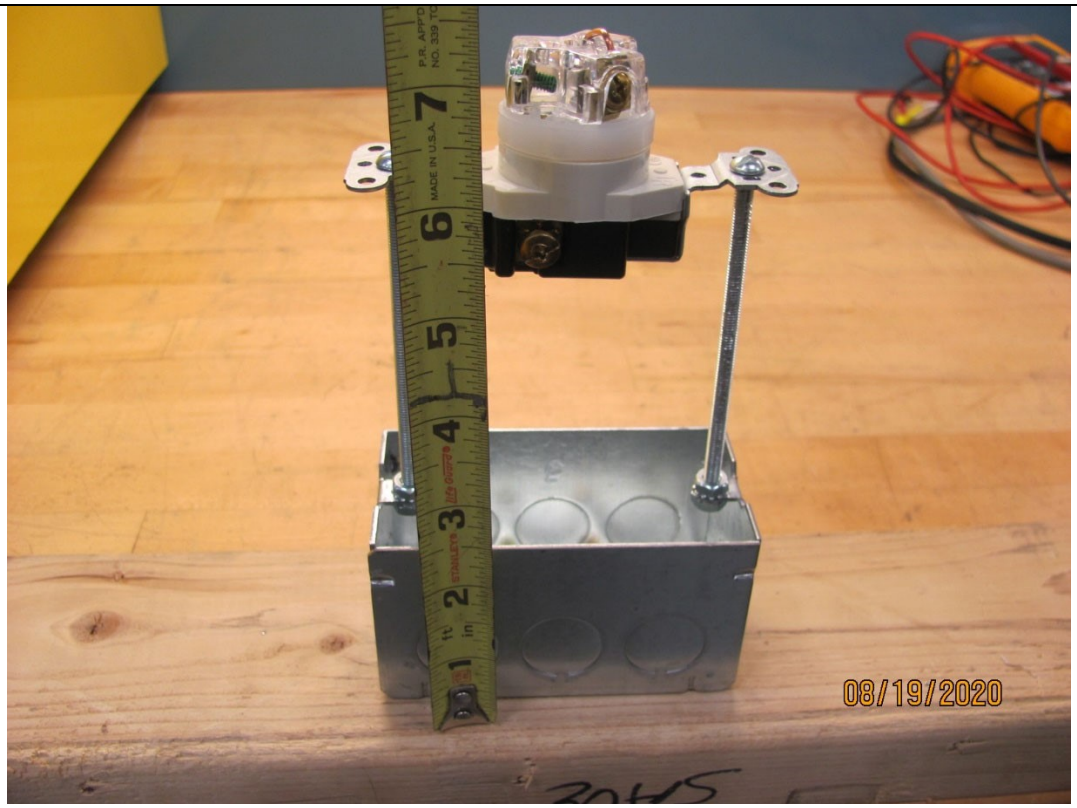


Photo 15 – Flexing Test Setup

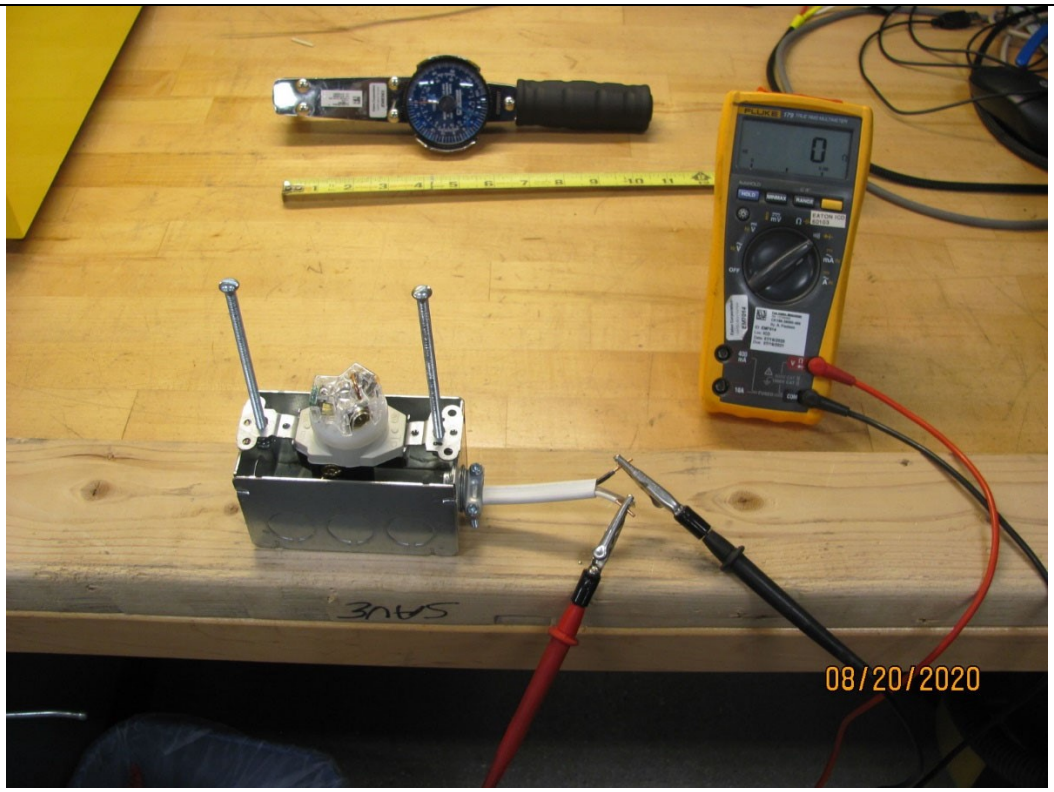


Photo 16 – Flexing Test Setup

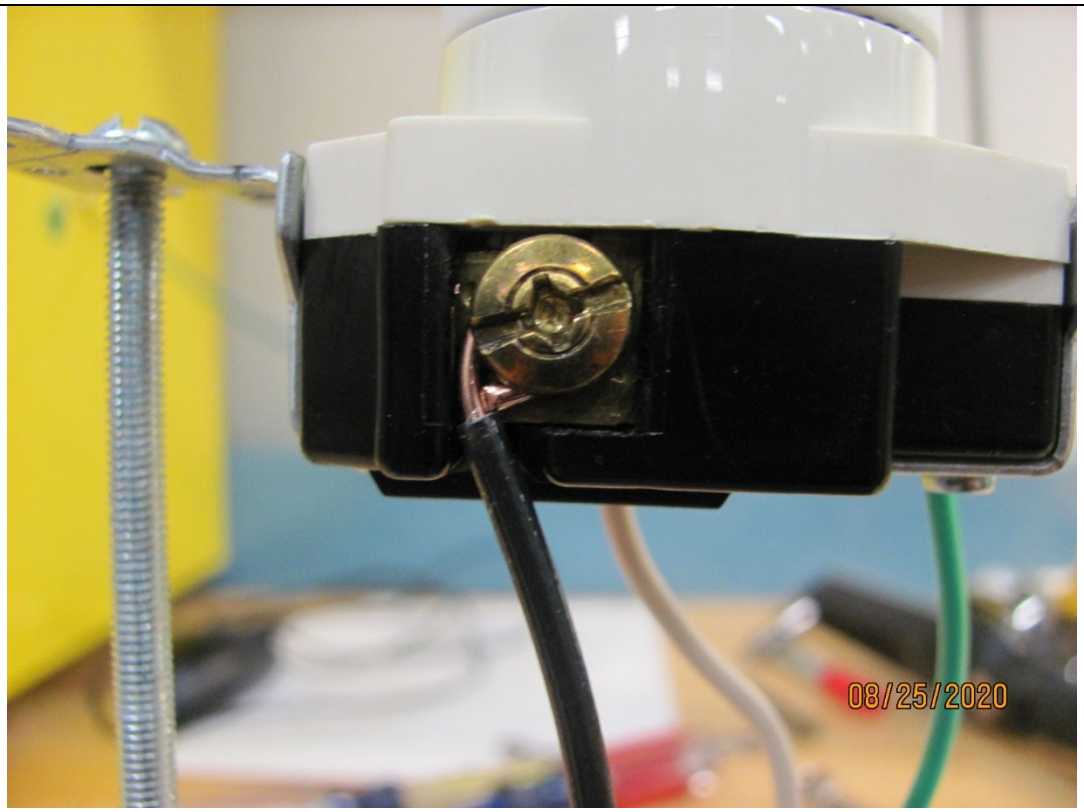


Photo 17 – Flexing Test Fully Extended

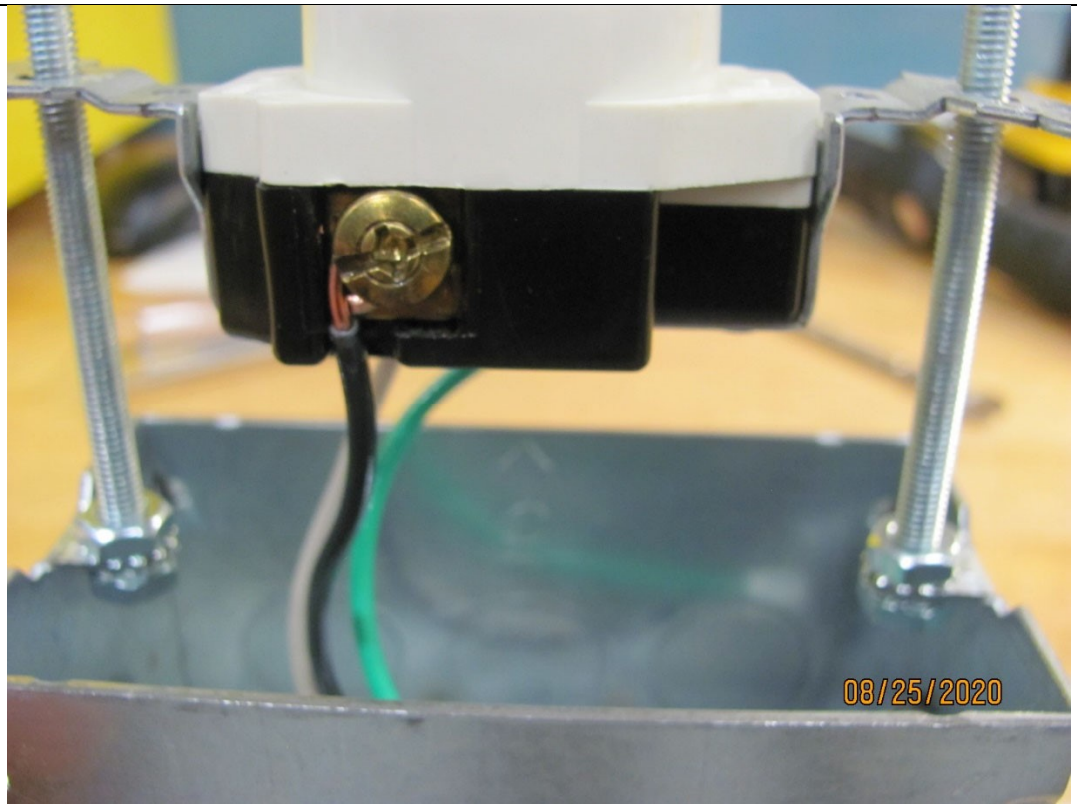


Photo 18 – Flexing Test Partial Insertion

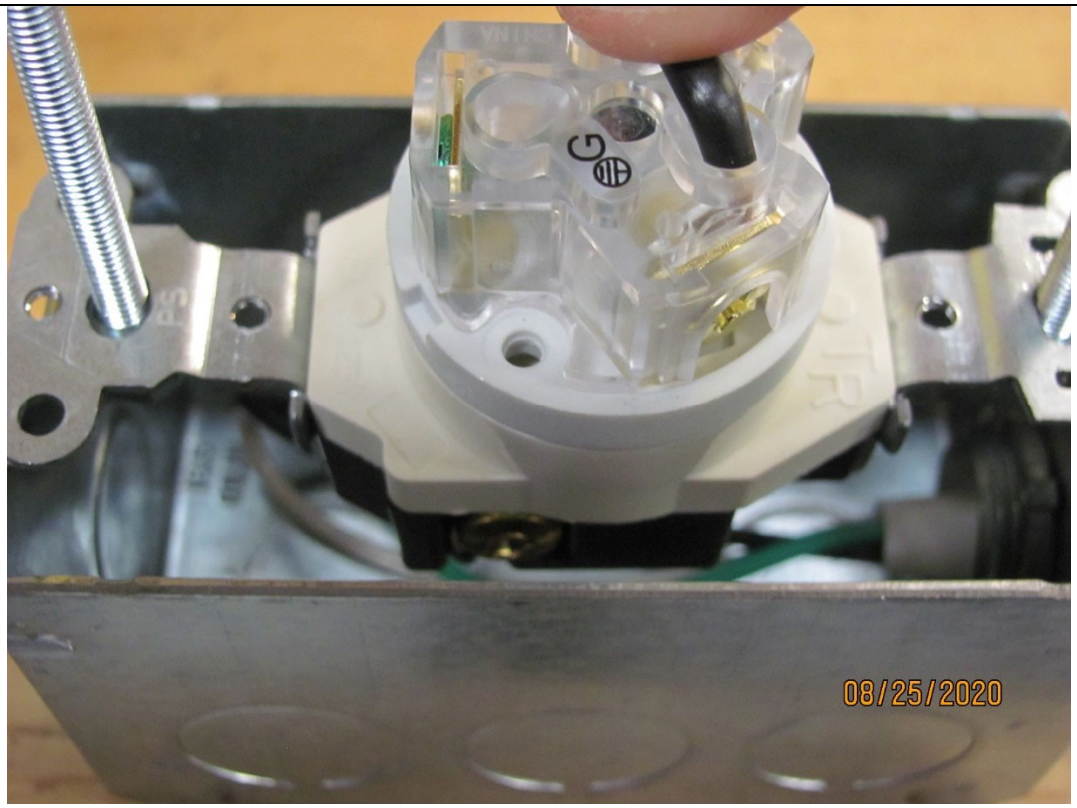


Photo 19 – Flexing Test Fully Inserted



Photo 20 – Flexing Test Broken Conductors When Removing

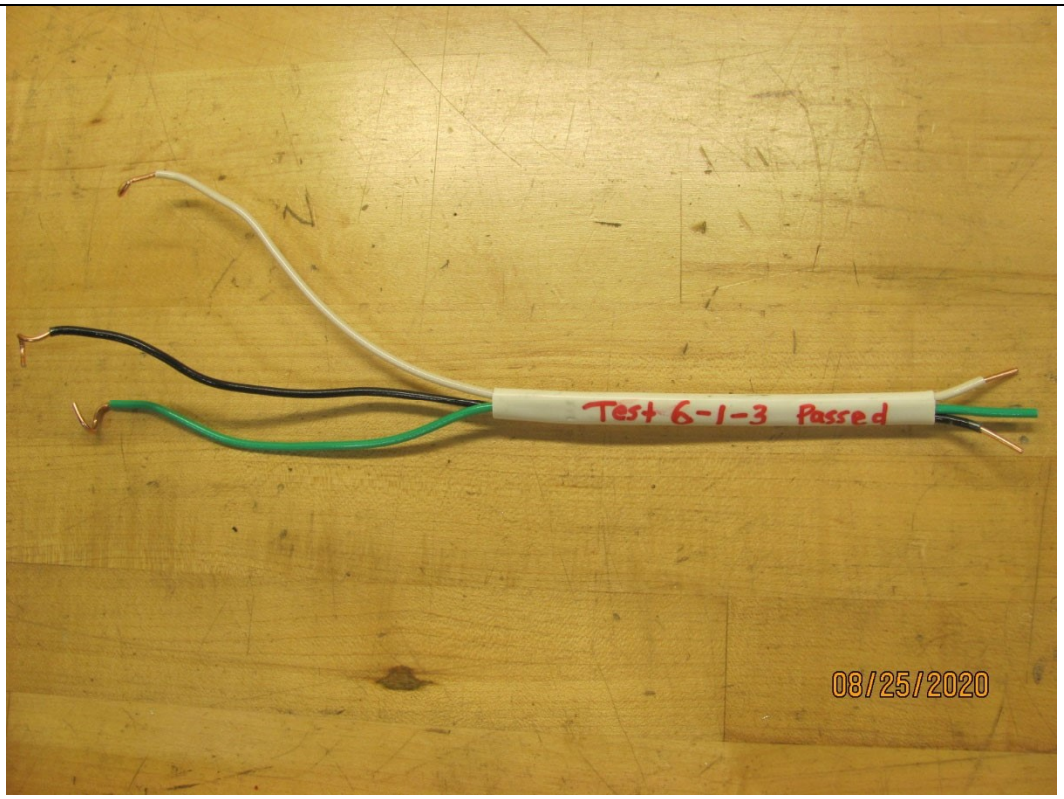


Photo 21 – Flexing Test Repeat No Conductor Breakage

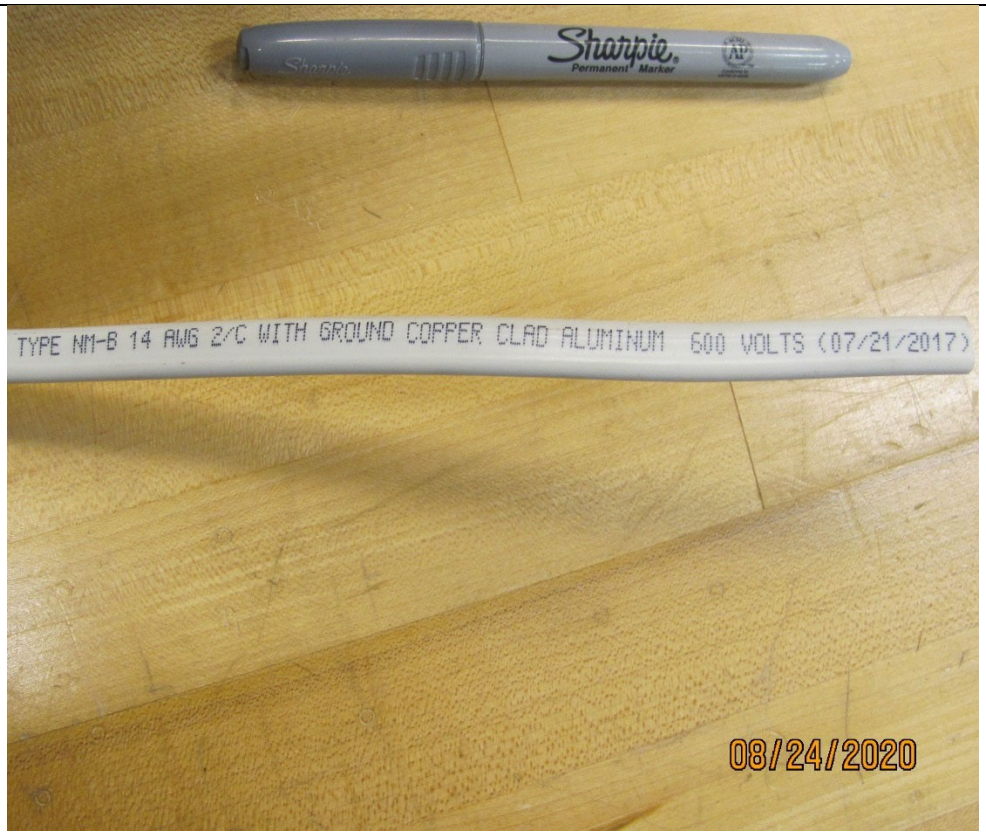


Photo 22 – Copper-Clad Aluminum NM-B Sample Packaging at Eaton

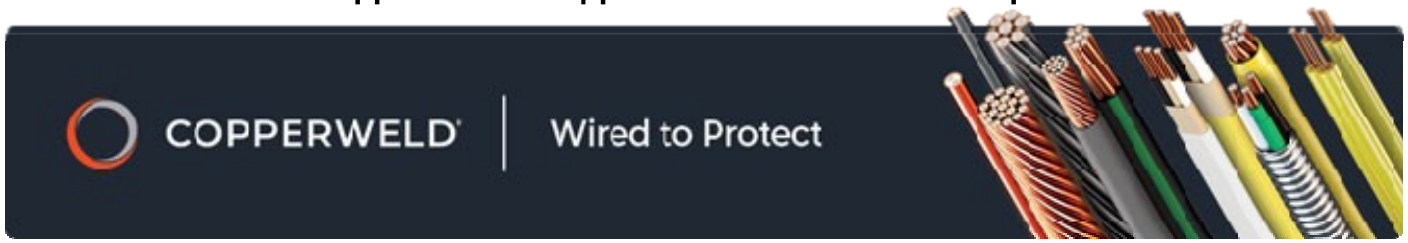


Photo 23 – Copper-Clad Aluminum THHN Sample Packaging at Eaton



Photo 24 – Copper-Clad Aluminum Sample Packaging at Eaton

Appendix B - Copper-Clad Aluminum Lab Report



The power of two

Metallurgical Laboratory Report

Customer:	**NEC Bimetallics Task Group**		
Subject:	**14 AWG Building Wire—NMB and THHN**		
Date:	**8-27-2020**	**Report No:**	**456**

Analysis By:	**Sammy Hampton --Metallographer**
Authored By:	**Sammy Hampton –Metallographer**
Approved By:	**Bill Lewey– QA Manager**

Tested to ASTM Designation: B 566-- 04a

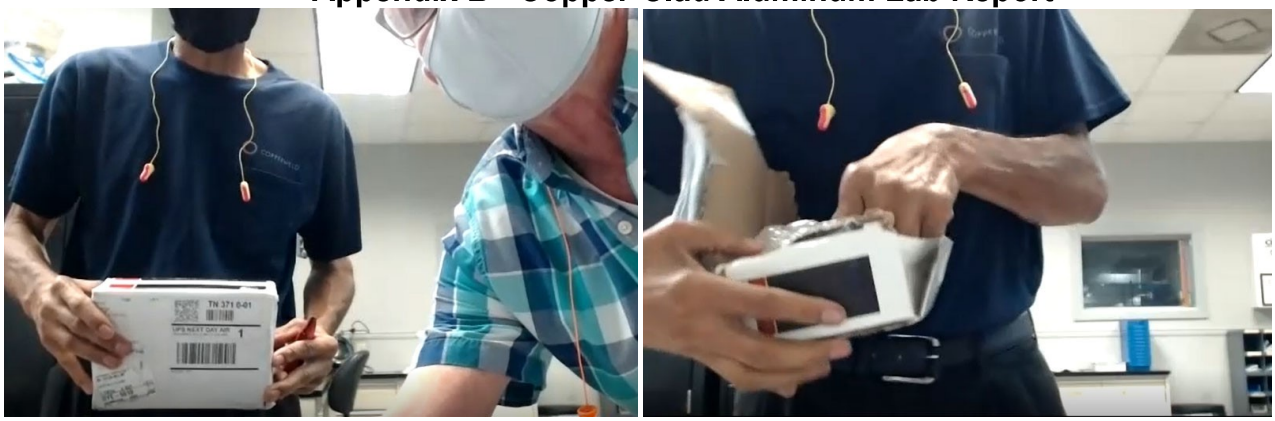
The NM and THHN class samples in this report were sent to Copperweld via a sealed package by Eaton Menomonee Falls test lab. The chain of custody was not broken. The testing was witnessed by a third party as part of routine auditing service. The witnessing session was recorded. The copper clad aluminum conductor material from these samples that was tested on August 27, 2020 by the Copperweld Metallurgical Lab was manufactured by Copperweld Bimetallics to ASTM B566 standards.





Package as received from Eaton

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Opening the Package



Package Contents

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Appendix B - Copper-Clad Aluminum Lab Report

The wire consists of a core of aluminum with a continuous outer cladding of copper metallurgically bonded to the core throughout and meets the requirements of this specification (5.1).

Test required	Test result	ASTM B 566 requirement	Result
Diameter	**0.0641”**	**± 0.0001 0.0640” minimum 0.0642” maximum**	**Pass**
Break load (lbs.)	55 pounds	64.4 pounds maximum	**Pass**
Tensile strength (psi)	17195 psi	20000 (psi) maximum	**Pass**
% elongation	22.78%	15.0% minimum	**Pass**
Copper thickness (minimum)	0.00148” = 4.6% of wire radius	minimum copper thickness= 3.5% of wire radius	**Pass**
Copper volume	10.05%	8% minimum 12% maximum	**Pass**
Adhesion test	No separation (see attached image 1)	The wire shall be repeatedly reverse bent to fracture by any convenient means. The copper clad aluminum wire shall be free from cladding delamination.	**Pass**
Cohesion test	No seams or splits (see attached images 2 and 3)	The copper clad aluminum wire shall be free from seams or splits	**Pass**

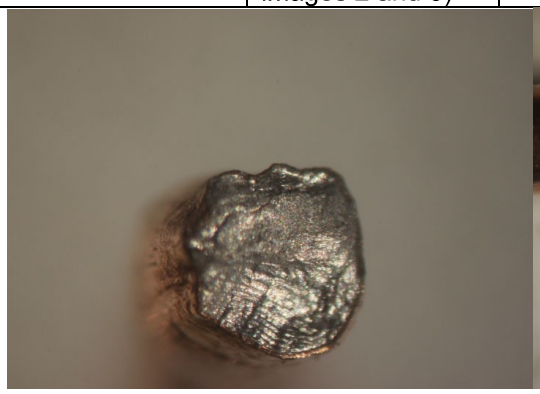


Image 1: adhesion test

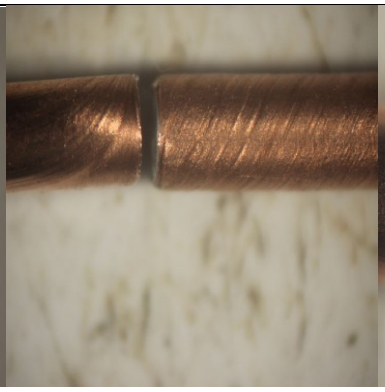


Image 2: cohesion test (torsion)

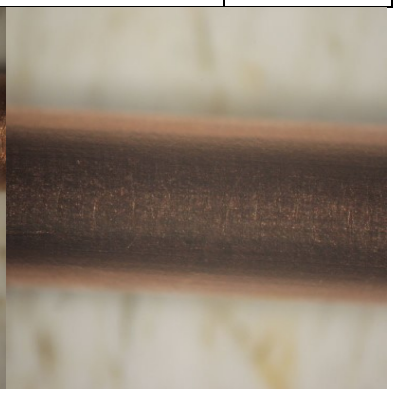


image 3: cohesion test (reverse torsion)

Test and measurement equipment

Equipment	Gauge ID	In calibration	Next due calibration
Micrometer	**CP-01**	**Yes**	**April 2021**
Tensile tester	**1755-2000**	**Yes**	**January 2022**
Ohmmeter	**62-1625**	**Yes**	**December 2020**
Calibration Certificates Attached below			

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107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID CP-01
Description Micrometer
Calibrated 8/3/2020
Performed At Customer Location

Manufacturer Mitutoyo
Model Number 293-344-30
Serial Number 66936496
Cal Procedure QS0003JB2010
Location Main
Building 254 Cotton Mill Rd. Fayetteville, TN 37334
Department Quality
Status In Service
Frequency Semi-Annual
Certificate # CO080320JM-03
Temp 73°F
Humidity 59%

Calibration Specifications

Group # 1
Group Name OD

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	End As	Left As	In Tol
0.25000 / 0.25000	Inch	Plus / Minus	0.000000	±0.00010	0.25000	Inch	0.25000	0.25000	Yes
0.50000 / 0.50000	Inch	Plus / Minus	0.000000	±0.00010	0.50000	Inch	0.50000	0.50000	Yes
1.00000 / 1.00000	Inch	Plus / Minus	0.000000	±0.00010	1.00000	Inch	1.00000	1.00000	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-GA-010 GAGE BLCK SET STD SHOP	Gage Block 81pc Set Standard	China	Rectangular Steel	E1599	4/8/2016	4/30/2021

Notes about this calibration

Uncertainty = ± (64.9+5.2L) µin (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By James Meadows
Date Finalized 8/3/2020 9:19:05AM

Total expanded measurement uncertainties expressed are based on a confidence level of 95%, coverage factor of (k=2). Decision Rule: The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. This is considered "shared responsibility." This calibration was conducted using standards traceable to the SI through NIST. The results on this certificate of accuracy apply only to the item described above. Accredited to ISO/IEC 17025: 2017.

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Revision Date:05/08/2020
Rev: 04

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QF0016

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Phone: 866-521-3823
Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID 1755-2000
Description Tensile Tester (2 Load cells)
Calibrated 8/4/2020
Performed At Customer Location

Manufacturer Thwing-Albert Instruments
Model Number EJA
Serial Number 1755-2000
Cal Procedure QS0033BG2013
Location Main
Building 254 Cotton Mill Rd. Fayetteville, TN 37334
Department Quality
Status In Service
Frequency Semi-Annual
Certificate # CO080420JM-13
Temp 70°F
Humidity 57%

Calibration Specifications

Group # 1
Group Name 0-11lb Load Cell 627022

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
1 / 1	lbf	Pct of Range	0.500000	0.00	1.00	lbf	1.01	1.01	Yes
2 / 2	lbf	Pct of Range	0.500000	0.00	2.00	lbf	2.01	2.01	Yes
3 / 3	lbf	Pct of Range	0.500000	0.00	3.00	lbf	3.01	3.01	Yes
5 / 5	lbf	Pct of Range	0.500000	0.00	5.00	lbf	5.02	5.02	Yes
7 / 7	lbf	Pct of Range	0.500000	0.00	7.00	lbf	7.03	7.03	Yes
10 / 10	lbf	Pct of Range	0.500000	0.00	10.00	lbf	10.04	10.04	Yes

Group # 2
Group Name 0-225 lb Load cell 608236

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
5 / 5	lbf	Pct of Range	0.500000	0.00	5.00	lbf	5.00	5.00	Yes
20.446 / 20.446	lbf	Pct of Range	0.500000	0.00	20.45	lbf	20.48	20.48	Yes
50.414 / 50.414	lbf	Pct of Range	0.500000	0.00	50.41	lbf	50.48	50.48	Yes
88.532 / 88.532	lbf	Pct of Range	0.500000	0.00	88.53	lbf	88.64	88.64	Yes
99.044 / 99.044	lbf	Pct of Range	0.500000	0.00	99.04	lbf	99.15	99.15	Yes
117.60 / 117.60	lbf	Pct of Range	0.500000	0.00	117.60	lbf	117.73	117.73	Yes
131.71 / 131.71	lbf	Pct of Range	0.500000	0.00	131.71	lbf	131.83	131.83	Yes
151.04 / 151.04	lbf	Pct of Range	0.500000	0.00	151.04	lbf	151.22	151.22	Yes
161.19 / 161.19	lbf	Pct of Range	0.500000	0.00	161.19	lbf	161.38	161.38	Yes
207.76 / 207.76	lbf	Pct of Range	0.500000	0.00	207.76	lbf	207.99	207.99	Yes

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INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID 1755-2000
Description Tensile Tester (2 Load cells)
Calibrated 8/4/2020
Performed At Customer Location

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-LO-005 5K LOAD CELL	Load Cell, 5000lb, Tension & Compression	Futek	LSB453	575093	1/7/2020	1/31/2022
Z-WE-003 HANGING WEIGHTS	Weight Set, 1-20lbs, Cast Iron	Rice Lake	ASTM Class 6	D7-D10 (20), D1-D4 (10), D1-D2 (2), 8MD8 (1), 8MB4 (2),8MB5 (5)	3/26/2019	3/31/2021

Notes about this calibration
Uncertainty = ± 0.23% of Reading (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By James Meadows
Date Finalized 8/4/2020 1:12:08PM

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). Decision Rule: The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. This is considered "shared responsibility." This calibration was conducted using standards traceable to the SI through NIST. The results on this certificate of accuracy apply only to the item described above. Accredited to ISO/IEC 17025: 2017.

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Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID 62-1625
Description Micro Ohm Meter
Calibrated 8/4/2020
Performed At Customer Location

Manufacturer Valhalla Scientific
Model Number 4176
Serial Number 62-1625
Cal Procedure QS0011JB2010
Location Main
Building 254 Cotton Mill Rd. Fayetteville, TN 37334
Department Quality
Status In Service
Frequency Semi-Annual
Certificate # CO080420JM-03
Temp 70°F
Humidity 57%

Calibration Specifications

Group # 1
Group Name Ohm - Source

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
1.000 / 1.000	Ohm	Pct of Reading	0.040000	0.0000	1.0000	Ohm	0.9998	0.9998	Yes
10.000 / 10.000	Ohm	Pct of Reading	0.040000	0.000	10.000	Ohm	9.999	9.999	Yes
100.000 / 100.000	Ohm	Pct of Reading	0.040000	0.00	100.00	Ohm	99.99	99.99	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-EL-020 DECADE RESISTANCE BOX	General Radio Small Decade Resistance Box	General Radio	1433-U	2545	12/18/2018	12/31/2020

Notes about this calibration

Uncertainty = ± 2 mOhm (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By James Meadows
Date Finalized 8/4/2020 12:47:33PM

Total expanded measurement uncertainties expressed are based on a confidence level of 95%, coverage factor of (k=2). Decision Rule: The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. This is considered "shared responsibility." This calibration was conducted using standards traceable to the SI through NIST. The results on this certificate of accuracy apply only to the item described above. Accredited to ISO/IEC 17025: 2017.

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Follow-up Service Inspection Report
E491185 1200827165202

INSPECTION DETAILS			
Date:	2020-08-27	File Number.:	E491185
Responsible Office:	Melville	Volume:	1
Inspection Center:	232	CCN:	DVVU2
Product Type:	CCA Conductor	UL Rep Name:	Gregory Cornett
Deliverable Type:	Recognized	UL Rep ID:	20708
Party Site Number:	1626131	Subscriber Factory No.:	
Manufacturer Name:	Copperweld Bimetallics LLC	Factory Rep Name	Mr. Sammy Hampton
Manufacturer Address:	254 Cotton Mill Rd Fayetteville, TN 37334	Factory Rep Phone:	931-433-0495
		Factory Rep Email:	shampton@copperweld.com
Nature of visit:	Regular Inspection	Sample Status:	Sample requirements fulfilled for sample period
UL Marks Used?	Yes	UL Marks Removed?	No
Variation Notice Issued?	No	Inspection Conducted Remotely?	Yes
Comments After Submission:			

PRODUCT DOCUMENTS/PRODUCTION READY VISIT			
Model	**Product**	**Section**	**Multiple Listed**
14 Awg Class 10A	Copper Clad Aluminum	1	No

SAMPLE DOCUMENTS			
If samples are required to be sent to UL, indicate below. If required samples are not sent, explain in the Comments area.			
No Samples			
Additional Comments	14 Awg conductors from the NMB and THHN samples passed the UL tests for DVVU2, including Tensile, Elongation, copper thickness and DC Resistance.		

In addition to the requirements specified in the applicable UL Services agreement and Follow-Up Service Procedure, UL further defines responsibilities, duties and requirements for both manufacturers and UL representatives in the document titled "UL Mark Surveillance Requirements" that can be located at www.ul.com/fus, and in accordance with the applicable terms and conditions of the document at www.ul.com/responsibilities. Manufacturers without Internet access may obtain the current versions of these documents from their local UL customer service representative or UL field representative.

UL LLC
333 Pfingsten Road, Northbrook, IL 60062-2096 USA
T: 847.272.8800 / F: 847.272.8129 / W: ul.com

Appendix C1 Static Heating Testing at 100% Rated Current

Test 1a - thru Mfg. 1 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		124	129	134			
time (HH:MM:SS) →		1:53:00	1:58:00	2:03:00			
1a	Mfg. 11 - 1	28.70	28.86	28.73	6.47	6.63	6.50
2a	Mfg. 11 - 2	28.89	29.01	28.84	6.66	6.78	6.61
3a	Mfg. 11 - 3	27.88	28.00	27.72	5.65	5.77	5.49
4a	Mfg. 8 - 1	29.18	29.27	29.25	6.95	7.04	7.02
5a	Mfg. 8 - 2	28.99	29.11	28.99	6.76	6.88	6.76
6a	Mfg. 8 - 3	29.00	29.15	28.92	6.77	6.92	6.69
7a	circuit breaker	32.68	32.65	32.75	10.45	10.42	10.52
8a	line wire	32.25	32.29	32.43	10.02	10.06	10.20
9a	line wire splicing device	29.84	29.65	29.07	7.61	7.42	6.84
10a	load wire	30.67	30.92	30.94	8.44	8.69	8.71
11a	load wire splicing device	30.11	29.88	29.27	7.88	7.65	7.04
12a	room ambient	22.39	22.44	21.87			
13a	current (amps)	10.03	10.03	10.03			

Test 1a - thru Mfg. 1 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		80	85	90			
time (HH:MM:SS) →		1:17:00	1:22:00	1:27:00			
1a	Mfg. 11 - 1	33.06	33.61	33.40	11.02	11.58	11.36
2a	Mfg. 11 - 2	33.64	33.95	33.94	11.60	11.91	11.90
3a	Mfg. 11 - 3	31.05	31.56	31.60	9.01	9.52	9.56
4a	Mfg. 8 - 1	34.10	34.15	34.23	12.06	12.11	12.19
5a	Mfg. 8 - 2	33.60	34.20	33.86	11.56	12.16	11.82
6a	Mfg. 8 - 3	32.94	33.68	33.29	10.91	11.64	11.25
7a	circuit breaker	40.86	40.44	40.64	18.82	18.41	18.60
8a	line wire	33.93	34.21	33.87	11.89	12.17	11.83
9a	line wire splicing device	36.89	37.11	36.82	14.85	15.07	14.78
10a	load wire	32.70	33.48	32.99	10.66	11.44	10.95
11a	load wire splicing device	32.72	33.49	32.70	10.68	11.45	10.66
12a	room ambient	21.84	22.27	22.01			
13a	current (amps)	15.02	15.01	15.02			

Test 1b - thru Mfg. 2 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		124	129	134			
time (HH:MM:SS) →		1:53:00	1:58:00	2:03:00			
1b	Mfg. 11 - 1	28.57	28.60	28.36	6.49	6.52	6.27
2b	Mfg. 11 - 2	28.65	28.68	28.48	6.57	6.60	6.40
3b	Mfg. 11 - 3	27.37	27.39	27.10	5.28	5.31	5.02
4b	Mfg. 8 - 1	29.14	29.23	29.15	7.05	7.15	7.07
5b	Mfg. 8 - 2	30.65	30.75	30.48	8.57	8.66	8.40
6b	Mfg. 8 - 3	28.04	28.10	27.73	5.96	6.02	5.64
7b	circuit breaker	36.63	36.79	37.20	14.55	14.70	15.12
8b	line wire	30.98	31.03	30.93	8.90	8.95	8.85
9b	line wire splicing device	28.97	28.69	28.06	6.89	6.61	5.98
10b	load wire	28.60	28.55	28.00	6.52	6.47	5.92
11b	load wire splicing device	28.64	28.49	27.92	6.56	6.41	5.84
12b	room ambient	22.35	22.28	21.62			
13b	current (amps)	10.00	10.00	10.00			

Test 1b - thru Mfg. 2 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		80	85	90			
time (HH:MM:SS) →		1:17:00	1:22:00	1:27:00			
1b	Mfg. 11 - 1	33.38	33.85	33.55	11.43	11.89	11.59
2b	Mfg. 11 - 2	33.29	33.49	33.67	11.34	11.54	11.72
3b	Mfg. 11 - 3	30.94	31.47	31.45	8.99	9.52	9.49
4b	Mfg. 8 - 1	34.03	34.28	34.44	12.07	12.32	12.48
5b	Mfg. 8 - 2	33.61	34.03	33.75	11.66	12.08	11.80
6b	Mfg. 8 - 3	33.00	33.71	33.25	11.05	11.75	11.29
7b	circuit breaker	44.97	44.86	45.02	23.02	22.91	23.06
8b	line wire	33.21	33.70	33.32	11.25	11.74	11.37
9b	line wire splicing device	30.81	31.77	30.80	8.86	9.82	8.85
10b	load wire	32.53	33.49	32.83	10.58	11.54	10.88
11b	load wire splicing device	31.51	32.52	31.43	9.56	10.56	9.47
12b	room ambient	21.76	22.22	21.88			
13b	current (amps)	15.01	15.01	15.01			

Test 1c - thru Mfg. 3 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		124	129	134			
time (HH:MM:SS) →		1:53:00	1:58:00	2:03:00			
1c	Mfg. 11 - 1	29.46	29.56	29.18	7.40	7.50	7.12
2c	Mfg. 11 - 2	28.97	29.12	28.68	6.91	7.06	6.62
3c	Mfg. 11 - 3	27.82	28.02	27.47	5.76	5.96	5.41
4c	Mfg. 8 - 1	29.30	29.40	29.33	7.24	7.34	7.27
5c	Mfg. 8 - 2	28.68	28.72	28.43	6.62	6.66	6.37
6c	Mfg. 8 - 3	28.19	28.27	27.81	6.13	6.21	5.75
7c	circuit breaker	35.04	35.28	35.13	12.98	13.22	13.07
8c	line wire	31.23	31.27	30.87	9.17	9.21	8.81
9c	line wire splicing device	28.59	28.61	27.53	6.53	6.55	5.47
10c	load wire	30.74	30.84	30.26	8.68	8.78	8.20
11c	load wire splicing device	29.74	29.67	28.50	7.68	7.61	6.44
12c	room ambient	22.29	22.23	21.67			
13c	current (amps)	10.01	10.01	10.01			

Test 1c - thru Mfg. 3 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		80	85	90			
time (HH:MM:SS) →		1:17:00	1:22:00	1:27:00			
1c	Mfg. 11 - 1	32.95	33.38	33.25	11.06	11.48	11.36
2c	Mfg. 11 - 2	33.50	33.89	33.73	11.61	12.00	11.84
3c	Mfg. 11 - 3	32.27	32.60	32.50	10.38	10.71	10.61
4c	Mfg. 8 - 1	33.33	33.66	33.62	11.44	11.77	11.72
5c	Mfg. 8 - 2	33.87	34.28	34.11	11.98	12.39	12.21
6c	Mfg. 8 - 3	32.50	32.88	32.80	10.61	10.99	10.91
7c	circuit breaker	42.51	42.65	42.50	20.62	20.75	20.60
8c	line wire	31.74	32.44	32.16	9.84	10.54	10.27
9c	line wire splicing device	32.46	33.55	32.53	10.57	11.66	10.64
10c	load wire	32.23	33.29	32.70	10.34	11.40	10.81
11c	load wire splicing device	29.96	31.50	30.18	8.07	9.61	8.29
12c	room ambient	21.65	22.13	21.90			
13c	current (amps)	15.02	15.02	15.02			

Test 1a - thru Mfg. 1 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		67	72	77			
time (HH:MM:SS) →		1:04:00	1:09:00	1:14:00			
1a	Mfg. 10 - 1	33.35	33.09	33.35	11.17	10.90	11.17
2a	Mfg. 10 - 2	29.93	29.88	29.88	7.75	7.70	7.70
3a	Mfg. 10 - 3	28.83	28.80	28.74	6.65	6.62	6.56
4a	Mfg. 9 - 1	28.96	28.89	28.94	6.78	6.71	6.76
5a	Mfg. 9 - 2	29.33	29.07	29.09	7.15	6.89	6.91
6a	Mfg. 9 - 3	28.20	28.02	27.93	6.01	5.84	5.75
7a	circuit breaker	32.75	32.55	32.65	10.57	10.37	10.47
8a	line wire	32.76	32.27	32.44	10.58	10.09	10.26
9a	line wire splicing device	29.85	29.45	29.15	7.67	7.27	6.97
10a	load wire	31.09	30.73	31.01	8.91	8.55	8.83
11a	load wire splicing device	30.90	30.16	30.15	8.72	7.98	7.97
12a	room ambient	22.53	22.20	21.82			
13a	current (amps)	10.02	10.02	10.02			

Test 1a - thru Mfg. 1 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		122	127	132			
time (HH:MM:SS) →		2:00:00	2:05:00	2:10:00			
1a	Mfg. 10 - 1	38.41	38.10	38.31	17.09	16.78	16.99
2a	Mfg. 10 - 2	39.48	39.23	39.28	18.16	17.91	17.96
3a	Mfg. 10 - 3	34.47	34.18	34.12	13.15	12.87	12.80
4a	Mfg. 9 - 1	37.47	37.35	37.38	16.16	16.03	16.06
5a	Mfg. 9 - 2	38.46	38.17	38.12	17.14	16.85	16.80
6a	Mfg. 9 - 3	31.54	31.29	31.18	10.22	9.97	9.86
7a	circuit breaker	40.70	40.66	40.65	19.38	19.34	19.33
8a	line wire	34.07	34.00	34.12	12.75	12.69	12.80
9a	line wire splicing device	35.66	35.31	35.13	14.34	13.99	13.81
10a	load wire	32.81	32.43	32.75	11.49	11.11	11.43
11a	load wire splicing device	33.16	32.96	32.94	11.84	11.64	11.62
12a	room ambient	21.37	21.31	21.27			
13a	current (amps)	15.02	15.02	15.02			

Test 1b - thru Mfg. 2 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		129	134	139			
time (HH:MM:SS) →		2:06:07	2:11:06	2:16:07			
1b	Mfg. 10 - 1	31.13	31.54	31.37	9.64	10.05	9.88
2b	Mfg. 10 - 2	30.12	30.39	30.44	8.63	8.90	8.95
3b	Mfg. 10 - 3	28.95	29.13	29.19	7.46	7.64	7.70
4b	Mfg. 9 - 1	28.47	28.67	28.85	6.98	7.18	7.36
5b	Mfg. 9 - 2	28.62	29.01	28.85	7.13	7.52	7.36
6b	Mfg. 9 - 3	29.94	30.21	30.11	8.45	8.72	8.62
7b	circuit breaker	41.81	41.46	41.80	20.32	19.97	20.31
8b	line wire	31.66	31.83	32.15	10.17	10.34	10.66
9b	line wire splicing device	29.57	30.02	30.13	8.08	8.53	8.64
10b	load wire	28.92	29.64	29.57	7.43	8.15	8.08
11b	load wire splicing device	30.62	31.06	31.03	9.13	9.57	9.54
12b	room ambient	21.30	21.89	21.28			
13b	current (amps)	10.01	10.01	10.01			

Test 1b - thru Mfg. 2 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		122	127	132			
time (HH:MM:SS) →		2:00:00	2:05:00	2:10:00			
1b	Mfg. 10 - 1	39.02	38.87	38.81	17.86	17.72	17.65
2b	Mfg. 10 - 2	38.54	38.42	38.37	17.38	17.26	17.22
3b	Mfg. 10 - 3	35.00	34.94	34.56	13.84	13.78	13.40
4b	Mfg. 9 - 1	34.32	34.17	34.19	13.16	13.01	13.03
5b	Mfg. 9 - 2	33.68	33.52	33.44	12.52	12.36	12.29
6b	Mfg. 9 - 3	32.62	32.41	32.27	11.46	11.25	11.11
7b	circuit breaker	44.60	44.48	44.38	23.44	23.32	23.22
8b	line wire	33.27	33.12	33.14	12.11	11.96	11.98
9b	line wire splicing device	31.50	31.19	31.26	10.34	10.03	10.10
10b	load wire	31.96	31.65	31.72	10.81	10.49	10.56
11b	load wire splicing device	30.27	29.89	29.93	9.12	8.73	8.78
12b	room ambient	21.26	21.14	21.08			
13b	current (amps)	15.01	15.01	15.01			

Test 1c - thru Mfg. 3 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		67	72	77			
time (HH:MM:SS) →		1:04:00	1:09:00	1:14:00			
1c	Mfg. 10 - 1	31.05	30.92	30.45	9.04	8.91	8.44
2c	Mfg. 10 - 2	32.97	32.85	32.26	10.96	10.84	10.25
3c	Mfg. 10 - 3	29.07	28.94	28.28	7.06	6.93	6.27
4c	Mfg. 9 - 1	29.52	29.28	29.21	7.51	7.27	7.20
5c	Mfg. 9 - 2	30.06	29.90	29.40	8.05	7.89	7.39
6c	Mfg. 9 - 3	28.41	28.41	27.55	6.40	6.40	5.54
7c	circuit breaker	34.97	34.66	34.67	12.96	12.65	12.66
8c	line wire	31.77	31.18	30.88	9.76	9.17	8.87
9c	line wire splicing device	28.89	28.20	27.63	6.88	6.19	5.62
10c	load wire	31.27	30.69	30.26	9.26	8.68	8.25
11c	load wire splicing device	31.39	30.47	29.53	9.38	8.46	7.52
12c	room ambient	22.35	21.99	21.69			
13c	current (amps)	10.01	10.01	10.01			

Test 1c - thru Mfg. 3 15-amp breaker at 100% current (15A * 100% = 15A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		122	127	132			
time (HH:MM:SS) →		2:00:00	2:05:00	2:10:00			
1c	Mfg. 10 - 1	36.19	35.94	35.85	15.02	14.77	14.68
2c	Mfg. 10 - 2	39.95	39.76	39.70	18.78	18.59	18.53
3c	Mfg. 10 - 3	39.01	39.15	38.69	17.85	17.98	17.52
4c	Mfg. 9 - 1	33.32	33.13	33.09	12.15	11.96	11.92
5c	Mfg. 9 - 2	34.01	33.90	33.74	12.84	12.74	12.57
6c	Mfg. 9 - 3	32.95	32.95	32.64	11.78	11.78	11.47
7c	circuit breaker	41.75	41.55	41.58	20.59	20.38	20.41
8c	line wire	30.73	30.68	30.61	9.56	9.51	9.44
9c	line wire splicing device	32.20	31.82	31.87	11.04	10.65	10.70
10c	load wire	31.34	31.12	31.14	10.17	9.95	9.97
11c	load wire splicing device	29.64	29.52	29.42	8.47	8.35	8.25
12c	room ambient	21.29	21.13	21.09			
13c	current (amps)	15.01	15.01	15.01			

Test 2a - thru Mfg. 1 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →							
time (MM:SS) →		7:20	7:40	8:00			
	Breaker trip time	8:20					
1a	Mfg. 11 - 1	30.60	30.69	30.76	8.65	8.73	8.80
2a	Mfg. 11 - 2	30.73	30.83	30.87	8.78	8.88	8.92
3a	Mfg. 11 - 3	29.72	29.82	29.85	7.76	7.87	7.89
4a	Mfg. 8 - 1	30.66	30.77	30.88	8.70	8.81	8.93
5a	Mfg. 8 - 2	30.87	30.96	31.05	8.91	9.01	9.09
6a	Mfg. 8 - 3	30.39	30.50	30.55	8.43	8.54	8.59
7a	circuit breaker	34.21	34.43	34.65	12.26	12.47	12.70
8a	line wire	38.55	38.70	38.80	16.59	16.74	16.85
9a	line wire splicing device	34.64	34.68	34.50	12.68	12.72	12.55
10a	load wire	36.44	36.44	36.36	14.49	14.48	14.40
11a	load wire splicing device	35.04	35.05	34.84	13.09	13.09	12.88
12a	room ambient	22.00	21.97	21.91			
13a	current (amps)	13.52	13.52	13.52			

Test 2a - thru Mfg. 1 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		60	61	62			
time (MM:SS) →		18:20	18:40	19:00			
	Breaker trip time	19:20					
1a	Mfg. 11 - 1	39.87	39.91	39.90	18.05	18.09	18.08
2a	Mfg. 11 - 2	40.66	40.69	40.70	18.84	18.87	18.88
3a	Mfg. 11 - 3	36.77	36.77	36.76	14.95	14.95	14.94
4a	Mfg. 8 - 1	40.83	40.88	40.89	19.01	19.06	19.07
5a	Mfg. 8 - 2	40.41	40.45	40.47	18.59	18.63	18.65
6a	Mfg. 8 - 3	39.06	39.09	39.15	17.24	17.27	17.33
7a	circuit breaker	51.78	51.96	52.02	29.96	30.14	30.20
8a	line wire	43.47	43.51	43.49	21.65	21.69	21.67
9a	line wire splicing device	48.83	48.80	48.22	27.02	26.99	26.40
10a	load wire	41.01	41.02	41.12	19.19	19.20	19.30
11a	load wire splicing device	42.69	42.60	42.48	20.87	20.78	20.66
12a	room ambient	21.84	21.84	21.78			
13a	current (amps)	19.97	19.97	20.24			

Test 2b - thru Mfg. 2 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		4:20	4:40	5:00			
	Breaker trip time	5:20					
1b	Mfg. 11 - 1	29.25	29.41	29.55	6.91	7.07	7.21
2b	Mfg. 11 - 2	28.86	29.03	29.22	6.52	6.69	6.88
3b	Mfg. 11 - 3	28.34	28.44	28.54	6.00	6.10	6.20
4b	Mfg. 8 - 1	29.37	29.59	29.79	7.03	7.25	7.45
5b	Mfg. 8 - 2	30.27	30.43	30.67	7.93	8.09	8.33
6b	Mfg. 8 - 3	28.84	28.97	29.10	6.50	6.63	6.76
7b	circuit breaker	34.99	35.63	36.29	12.65	13.29	13.95
8b	line wire	34.20	34.58	34.92	11.86	12.24	12.58
9b	line wire splicing device	33.21	33.11	33.12	10.87	10.77	10.78
10b	load wire	30.95	31.14	31.38	8.61	8.80	9.04
11b	load wire splicing device	32.76	32.73	32.78	10.42	10.39	10.44
12b	room ambient	22.40	22.34	22.29			
13b	current (amps)	13.51	13.51	13.51			

Test 2b - thru Mfg. 2 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		13	14	15			
time (MM:SS) →		2:20	2:40	3:00			
	Breaker trip time	3:20					
1b	Mfg. 11 - 1	31.85	32.56	33.17	9.91	10.62	11.23
2b	Mfg. 11 - 2	31.27	32.00	32.64	9.33	10.05	10.70
3b	Mfg. 11 - 3	30.01	30.61	31.08	8.07	8.67	9.14
4b	Mfg. 8 - 1	31.78	32.43	33.07	9.84	10.49	11.13
5b	Mfg. 8 - 2	32.35	32.97	33.48	10.41	11.03	11.54
6b	Mfg. 8 - 3	31.74	32.37	32.83	9.80	10.42	10.89
7b	circuit breaker	36.50	38.10	39.50	14.56	16.16	17.56
8b	line wire	32.89	33.90	34.83	10.95	11.96	12.89
9b	line wire splicing device	34.98	35.61	36.11	13.04	13.67	14.17
10b	load wire	33.90	34.76	35.58	11.96	12.82	13.64
11b	load wire splicing device	35.84	36.48	37.04	13.90	14.54	15.10
12b	room ambient	21.94	21.93	21.96			
13b	current (amps)	20.28	20.27	20.27			

Test 2c - thru Mfg. 3 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		59	60	61			
time (MM:SS) →		18:40	19:00	19:20			
	Breaker trip time	19:40					
1c	Mfg. 11 - 1	34.08	34.15	34.18	11.70	11.78	11.81
2c	Mfg. 11 - 2	33.23	33.27	33.31	10.85	10.89	10.93
3c	Mfg. 11 - 3	31.22	31.25	31.28	8.85	8.87	8.90
4c	Mfg. 8 - 1	33.48	33.50	33.56	11.10	11.13	11.19
5c	Mfg. 8 - 2	32.68	32.75	32.80	10.31	10.37	10.42
6c	Mfg. 8 - 3	31.96	32.03	32.09	9.58	9.66	9.71
7c	circuit breaker	43.05	43.08	43.19	20.67	20.71	20.81
8c	line wire	38.04	38.09	38.14	15.67	15.72	15.76
9c	line wire splicing device	33.55	33.75	33.89	11.17	11.38	11.51
10c	load wire	37.55	37.62	37.70	15.17	15.24	15.33
11c	load wire splicing device	35.83	36.09	36.28	13.46	13.71	13.91
12c	room ambient	22.51	22.28	22.34			
13c	current (amps)	13.51	13.51	13.51			

Test 2c - thru Mfg. 3 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		20	21	22			
time (MM:SS) →		5:00	5:20	5:40			
	Breaker trip time	6:00					
1c	Mfg. 11 - 1	34.62	34.96	35.21	12.63	12.97	13.22
2c	Mfg. 11 - 2	35.65	35.96	36.17	13.65	13.97	14.18
3c	Mfg. 11 - 3	33.85	34.05	34.25	11.85	12.05	12.25
4c	Mfg. 8 - 1	34.94	35.23	35.47	12.95	13.24	13.48
5c	Mfg. 8 - 2	35.87	36.13	36.37	13.87	14.13	14.38
6c	Mfg. 8 - 3	34.38	34.60	34.74	12.38	12.61	12.75
7c	circuit breaker	42.69	43.47	44.15	20.69	21.47	22.16
8c	line wire	36.07	36.49	36.77	14.08	14.50	14.78
9c	line wire splicing device	38.93	39.23	39.49	16.94	17.24	17.49
10c	load wire	37.64	37.92	38.15	15.64	15.92	16.16
11c	load wire splicing device	35.65	35.84	35.95	13.66	13.85	13.96
12c	room ambient	21.95	22.09	21.93			
13c	current (amps)	20.19	20.19	20.17			

Test 2a - thru Mfg. 1 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		26	27	28			
time (MM:SS) →		7:40	8:00	8:20			
	Breaker trip time	8:40					
1a	Mfg. 10 - 1	33.38	33.55	33.72	11.54	11.72	11.89
2a	Mfg. 10 - 2	32.41	32.50	32.60	10.58	10.67	10.77
3a	Mfg. 10 - 3	30.50	30.58	30.68	8.66	8.75	8.85
4a	Mfg. 9 - 1	30.51	30.62	30.74	8.67	8.79	8.91
5a	Mfg. 9 - 2	30.63	30.73	30.86	8.80	8.89	9.02
6a	Mfg. 9 - 3	29.45	29.52	29.63	7.62	7.69	7.79
7a	circuit breaker	34.35	34.60	34.84	12.51	12.77	13.00
8a	line wire	38.69	38.85	39.02	16.85	17.01	17.18
9a	line wire splicing device	34.03	34.11	34.24	12.19	12.27	12.40
10a	load wire	36.42	36.48	36.58	14.59	14.65	14.74
11a	load wire splicing device	36.28	36.41	36.59	14.45	14.58	14.76
12a	room ambient	21.84	21.90	21.76			
13a	current (amps)	13.52	13.52	13.52			

Test 2a - thru Mfg. 1 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		65	66	67			
time (MM:SS) →		20:00	20:20	20:40			
	Breaker trip time	21:00					
1a	Mfg. 10 - 1	47.14	47.05	47.05	26.19	26.10	26.09
2a	Mfg. 10 - 2	49.33	49.35	49.30	28.38	28.39	28.35
3a	Mfg. 10 - 3	43.32	43.29	43.14	22.36	22.34	22.19
4a	Mfg. 9 - 1	45.67	45.67	45.73	24.72	24.71	24.78
5a	Mfg. 9 - 2	46.98	46.95	46.85	26.03	25.99	25.90
6a	Mfg. 9 - 3	38.91	38.80	38.65	17.95	17.84	17.69
7a	circuit breaker	52.18	52.30	52.40	31.23	31.34	31.45
8a	line wire	43.36	43.34	43.31	22.40	22.39	22.35
9a	line wire splicing device	46.95	46.94	46.87	26.00	25.99	25.91
10a	load wire	41.51	41.36	41.20	20.56	20.41	20.25
11a	load wire splicing device	42.93	42.85	42.57	21.97	21.89	21.62
12a	room ambient	20.94	20.94	20.98			
13a	current (amps)	20.29	20.28	20.28			

Test 2b - thru Mfg. 2 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		21	22	23			
time (MM:SS) →		5:40	6:00	6:20			
	Breaker trip time	6:40					
1b	Mfg. 10 - 1	31.86	32.13	32.38	9.94	10.21	10.46
2b	Mfg. 10 - 2	32.09	32.28	32.45	10.17	10.36	10.53
3b	Mfg. 10 - 3	30.06	30.24	30.38	8.14	8.32	8.46
4b	Mfg. 9 - 1	29.45	29.60	29.73	7.53	7.68	7.81
5b	Mfg. 9 - 2	30.16	30.32	30.49	8.23	8.40	8.57
6b	Mfg. 9 - 3	29.34	29.52	29.64	7.42	7.60	7.72
7b	circuit breaker	37.11	37.68	38.17	15.19	15.76	16.25
8b	line wire	35.37	35.59	35.81	13.44	13.67	13.88
9b	line wire splicing device	32.21	32.37	32.46	10.28	10.45	10.54
10b	load wire	31.36	31.58	31.73	9.44	9.66	9.80
11b	load wire splicing device	35.28	35.40	35.49	13.36	13.47	13.56
12b	room ambient	21.93	21.95	21.88			
13b	current (amps)	13.50	13.50	13.50			

Test 2b - thru Mfg. 2 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		13	14	15			
time (MM:SS) →		2:40	3:00	3:20			
	Breaker trip time	3:40					
1b	Mfg. 10 - 1	34.43	35.44	36.33	13.42	14.43	15.32
2b	Mfg. 10 - 2	35.56	36.51	37.33	14.56	15.51	16.33
3b	Mfg. 10 - 3	33.00	33.73	34.31	12.00	12.73	13.30
4b	Mfg. 9 - 1	32.70	33.42	34.00	11.69	12.41	13.00
5b	Mfg. 9 - 2	32.65	33.31	33.89	11.64	12.30	12.89
6b	Mfg. 9 - 3	30.85	31.44	31.99	9.85	10.43	10.98
7b	circuit breaker	36.44	37.96	39.35	15.44	16.96	18.34
8b	line wire	32.46	33.42	34.28	11.45	12.41	13.28
9b	line wire splicing device	35.23	35.84	36.40	14.22	14.84	15.39
10b	load wire	33.42	34.26	35.03	12.42	13.26	14.02
11b	load wire splicing device	33.28	33.92	34.50	12.27	12.91	13.49
12b	room ambient	20.93	21.01	21.08			
13b	current (amps)	20.28	20.28	20.28			

Test 2c - thru Mfg. 3 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		53	54	55			
time (MM:SS) →		16:20	16:40	17:00			
	Breaker trip time	17:20					
1c	Mfg. 10 - 1	35.58	35.62	35.62	13.37	13.41	13.41
2c	Mfg. 10 - 2	36.59	36.62	36.62	14.38	14.41	14.41
3c	Mfg. 10 - 3	32.94	32.95	32.98	10.73	10.74	10.77
4c	Mfg. 9 - 1	33.08	33.07	33.07	10.87	10.86	10.86
5c	Mfg. 9 - 2	33.95	33.93	33.90	11.73	11.72	11.69
6c	Mfg. 9 - 3	31.62	31.62	31.58	9.40	9.41	9.37
7c	circuit breaker	41.72	41.81	41.92	19.51	19.60	19.71
8c	line wire	38.68	38.60	38.52	16.47	16.39	16.31
9c	line wire splicing device	33.41	33.23	33.04	11.19	11.02	10.83
10c	load wire	37.53	37.41	37.27	15.31	15.20	15.06
11c	load wire splicing device	38.23	37.83	37.38	16.01	15.62	15.17
12c	room ambient	22.28	22.22	22.14			
13c	current (amps)	13.50	13.50	13.50			

Test 2c - thru Mfg. 3 15-amp breaker at 135% current (15A * 135% = 20.25A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature		Rise (°C)
scan # →		22	23	24			
time (MM:SS) →		5:40	6:00	6:20			
	Breaker trip time	6:40					
1c	Mfg. 10 - 1	37.66	38.19	38.64	16.09	16.61	17.07
2c	Mfg. 10 - 2	44.95	45.50	45.96	23.38	23.93	24.39
3c	Mfg. 10 - 3	44.95	45.37	45.69	23.38	23.80	24.12
4c	Mfg. 9 - 1	35.48	35.83	36.20	13.90	14.26	14.63
5c	Mfg. 9 - 2	38.33	38.69	39.10	16.75	17.12	17.52
6c	Mfg. 9 - 3	36.86	37.22	37.59	15.28	15.65	16.02
7c	circuit breaker	42.83	43.50	44.14	21.26	21.93	22.56
8c	line wire	35.89	36.21	36.61	14.32	14.64	15.04
9c	line wire splicing device	40.91	41.17	41.52	19.33	19.60	19.95
10c	load wire	37.99	38.35	38.72	16.42	16.78	17.15
11c	load wire splicing device	39.30	39.51	39.86	17.72	17.93	18.29
12c	room ambient	21.55	21.59	21.59			
13c	current (amps)	20.30	20.26	20.27			

Appendix C3 Static Heating Tests at 150% Rated Current

Test 3a - thru Mfg. 1 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		19	20	21			
time (MM:SS) →		2:00	2:10	2:20			
	Breaker trip time	2:30					
1a	Mfg. 11 - 1	27.90	28.21	28.45	5.51	5.83	6.06
2a	Mfg. 11 - 2	27.85	28.17	28.44	5.46	5.79	6.06
3a	Mfg. 11 - 3	27.44	27.71	27.97	5.05	5.32	5.58
4a	Mfg. 8 - 1	28.03	28.30	28.55	5.64	5.91	6.17
5a	Mfg. 8 - 2	28.67	28.93	29.21	6.28	6.55	6.83
6a	Mfg. 8 - 3	28.12	28.37	28.63	5.73	5.98	6.24
7a	circuit breaker	29.23	29.65	30.04	6.84	7.27	7.65
8a	line wire	33.45	33.99	34.55	11.06	11.60	12.16
9a	line wire splicing device	33.38	33.88	34.38	10.99	11.49	11.99
10a	load wire	32.35	32.80	33.28	9.96	10.41	10.89
11a	load wire splicing device	34.69	35.13	35.60	12.30	12.74	13.21
12a	room ambient	22.40	22.39	22.37			
13a	current (amps)	15.02	15.02	15.02			

Test 3a - thru Mfg. 1 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		31	32	33			
time (MM:SS) →		3:40	3:50	4:00			
	Breaker trip time	4:10					
1a	Mfg. 11 - 1	36.08	36.34	36.60	13.46	13.72	13.98
2a	Mfg. 11 - 2	36.41	36.67	36.97	13.79	14.05	14.35
3a	Mfg. 11 - 3	34.72	34.88	35.08	12.10	12.26	12.46
4a	Mfg. 8 - 1	36.33	36.58	36.86	13.71	13.96	14.24
5a	Mfg. 8 - 2	37.14	37.38	37.62	14.53	14.76	15.00
6a	Mfg. 8 - 3	36.40	36.56	36.84	13.78	13.94	14.22
7a	circuit breaker	40.83	41.35	41.83	18.21	18.73	19.21
8a	line wire	39.85	40.31	40.75	17.23	17.69	18.13
9a	line wire splicing device	49.53	49.93	50.18	26.91	27.31	27.56
10a	load wire	40.21	40.60	40.99	17.60	17.98	18.37
11a	load wire splicing device	45.48	45.83	46.22	22.86	23.21	23.60
12a	room ambient	22.65	22.62	22.58			
13a	current (amps)	22.56	22.53	22.53			

Test 3b - thru Mfg. 2 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		19	20	21			
time (MM:SS) →		2:00	2:10	2:20			
	Breaker trip time	2:30					
1b	Mfg. 11 - 1	28.11	28.40	28.72	5.67	5.96	6.28
2b	Mfg. 11 - 2	27.73	27.97	28.26	5.29	5.53	5.82
3b	Mfg. 11 - 3	27.57	27.80	28.05	5.12	5.36	5.60
4b	Mfg. 8 - 1	28.38	28.63	28.91	5.93	6.19	6.47
5b	Mfg. 8 - 2	29.23	29.50	29.82	6.79	7.06	7.37
6b	Mfg. 8 - 3	28.00	28.25	28.53	5.56	5.81	6.09
7b	circuit breaker	30.38	30.93	31.50	7.94	8.48	9.06
8b	line wire	31.30	31.79	32.30	8.85	9.34	9.86
9b	line wire splicing device	32.82	33.29	33.71	10.38	10.84	11.27
10b	load wire	28.66	29.10	29.50	6.21	6.66	7.06
11b	load wire splicing device	33.26	33.63	33.95	10.82	11.18	11.51
12b	room ambient	22.47	22.43	22.43			
13b	current (amps)	15.01	15.01	15.01			

Test 3b - thru Mfg. 2 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		13	14	15			
time (MM:SS) →		:40	:50	1:00			
	Breaker trip time	1:10					
1b	Mfg. 11 - 1	26.84	27.76	28.60	4.39	5.31	6.15
2b	Mfg. 11 - 2	26.26	27.11	27.94	3.81	4.66	5.49
3b	Mfg. 11 - 3	26.03	26.75	27.44	3.58	4.30	4.99
4b	Mfg. 8 - 1	26.61	27.54	28.41	4.16	5.09	5.96
5b	Mfg. 8 - 2	27.59	28.55	29.46	5.14	6.10	7.01
6b	Mfg. 8 - 3	27.23	28.09	28.93	4.78	5.64	6.48
7b	circuit breaker	27.33	28.59	29.90	4.88	6.14	7.45
8b	line wire	26.59	27.53	28.44	4.14	5.08	5.99
9b	line wire splicing device	29.28	30.58	31.77	6.83	8.13	9.32
10b	load wire	27.88	28.93	29.91	5.43	6.48	7.46
11b	load wire splicing device	29.84	31.22	32.45	7.39	8.77	10.00
12b	room ambient	22.46	22.43	22.45			
13b	current (amps)	22.51	22.49	22.49			

Test 3c - thru Mfg. 3 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		37	38	39			
time (MM:SS) →		5:00	5:10	5:20			
	Breaker trip time	5:30					
1c	Mfg. 11 - 1	32.34	32.46	32.62	9.83	9.96	10.12
2c	Mfg. 11 - 2	31.80	31.94	32.06	9.30	9.44	9.56
3c	Mfg. 11 - 3	29.96	30.07	30.17	7.46	7.56	7.67
4c	Mfg. 8 - 1	31.82	31.94	32.07	9.32	9.44	9.57
5c	Mfg. 8 - 2	31.64	31.77	31.86	9.13	9.26	9.36
6c	Mfg. 8 - 3	31.07	31.17	31.31	8.57	8.67	8.81
7c	circuit breaker	37.24	37.53	37.80	14.74	15.03	15.30
8c	line wire	38.50	38.75	39.00	16.00	16.25	16.50
9c	line wire splicing device	35.73	35.83	35.94	13.23	13.33	13.43
10c	load wire	37.84	38.06	38.26	15.33	15.56	15.75
11c	load wire splicing device	38.75	38.81	38.93	16.24	16.31	16.43
12c	room ambient	22.50	22.49	22.52			
13c	current (amps)	15.01	15.01	15.01			

Test 3c - thru Mfg. 3 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		23	24	25			
time (MM:SS) →		2:20	2:30	2:40			
	Breaker trip time	2:50					
1c	Mfg. 11 - 1	32.80	33.29	33.73	10.40	10.89	11.33
2c	Mfg. 11 - 2	34.13	34.67	35.12	11.73	12.27	12.72
3c	Mfg. 11 - 3	32.29	32.77	33.17	9.89	10.37	10.77
4c	Mfg. 8 - 1	33.21	33.67	34.07	10.81	11.27	11.67
5c	Mfg. 8 - 2	34.62	35.08	35.48	12.22	12.68	13.08
6c	Mfg. 8 - 3	32.76	33.21	33.64	10.36	10.81	11.24
7c	circuit breaker	37.29	38.07	38.83	14.89	15.67	16.43
8c	line wire	33.28	33.93	34.55	10.88	11.53	12.15
9c	line wire splicing device	40.01	40.55	41.07	17.61	18.15	18.67
10c	load wire	36.15	36.74	37.30	13.75	14.34	14.90
11c	load wire splicing device	37.79	38.32	38.82	15.39	15.92	16.42
12c	room ambient	22.38	22.41	22.41			
13c	current (amps)	22.43	22.44	22.42			

Test 3a - thru Mfg. 1 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		23	24	25			
time (MM:SS) →		2:20	2:30	2:40			
	Breaker trip time	2:50					
1a	Mfg. 10 - 1	29.81	30.21	30.55	7.56	7.96	8.30
2a	Mfg. 10 - 2	29.70	30.02	30.29	7.44	7.77	8.04
3a	Mfg. 10 - 3	28.37	28.62	28.85	6.12	6.37	6.60
4a	Mfg. 9 - 1	28.22	28.46	28.69	5.97	6.21	6.44
5a	Mfg. 9 - 2	28.46	28.71	28.94	6.21	6.46	6.69
6a	Mfg. 9 - 3	27.73	27.96	28.13	5.48	5.71	5.88
7a	circuit breaker	29.83	30.21	30.53	7.58	7.96	8.28
8a	line wire	34.40	34.90	35.38	12.15	12.65	13.13
9a	line wire splicing device	32.53	32.88	33.18	10.28	10.63	10.93
10a	load wire	33.43	33.88	34.25	11.17	11.63	12.00
11a	load wire splicing device	37.25	37.47	37.66	15.00	15.22	15.41
12a	room ambient	22.28	22.24	22.24			
13a	current (amps)	15.02	15.02	15.02			

Test 3a - thru Mfg. 1 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		38	39	40			
time (MM:SS) →		4:00	4:10	4:20			
	Breaker trip time	4:30					
1a	Mfg. 10 - 1	40.53	40.89	41.27	18.74	19.10	19.48
2a	Mfg. 10 - 2	42.28	42.67	43.05	20.49	20.88	21.26
3a	Mfg. 10 - 3	39.25	39.54	39.81	17.46	17.75	18.02
4a	Mfg. 9 - 1	39.03	39.37	39.68	17.24	17.58	17.89
5a	Mfg. 9 - 2	40.06	40.40	40.75	18.27	18.61	18.96
6a	Mfg. 9 - 3	35.92	36.14	36.35	14.14	14.35	14.56
7a	circuit breaker	41.66	42.13	42.62	19.87	20.34	20.83
8a	line wire	40.15	40.56	40.91	18.36	18.77	19.12
9a	line wire splicing device	47.60	47.94	48.23	25.81	26.16	26.44
10a	load wire	40.83	41.12	41.46	19.04	19.33	19.67
11a	load wire splicing device	46.50	46.62	46.74	24.72	24.83	24.95
12a	room ambient	21.81	21.79	21.76			
13a	current (amps)	22.35	22.35	22.35			

Test 3b - thru Mfg. 2 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		21	22	23			
time (MM:SS) →		2:00	2:10	2:20			
	Breaker trip time	2:30					
1b	Mfg. 10 - 1	28.72	29.12	29.50	6.58	6.98	7.36
2b	Mfg. 10 - 2	29.55	29.94	30.33	7.41	7.80	8.19
3b	Mfg. 10 - 3	28.01	28.30	28.56	5.87	6.16	6.42
4b	Mfg. 9 - 1	27.72	28.02	28.27	5.58	5.88	6.13
5b	Mfg. 9 - 2	27.97	28.28	28.55	5.83	6.14	6.41
6b	Mfg. 9 - 3	27.58	27.82	28.09	5.44	5.68	5.95
7b	circuit breaker	30.55	31.13	31.74	8.41	8.99	9.60
8b	line wire	31.18	31.69	32.20	9.04	9.55	10.06
9b	line wire splicing device	31.46	31.83	32.14	9.32	9.69	10.00
10b	load wire	28.42	28.81	29.21	6.28	6.67	7.07
11b	load wire splicing device	36.24	36.63	36.93	14.10	14.49	14.79
12b	room ambient	22.20	22.13	22.09			
13b	current (amps)	15.00	15.00	15.00			

Test 3b - thru Mfg. 2 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		18	19	20			
time (MM:SS) →		:40	:50	1:00			
	Breaker trip time	1:10					
1b	Mfg. 10 - 1	25.84	26.82	27.77	4.13	5.12	6.06
2b	Mfg. 10 - 2	29.58	31.10	32.54	7.88	9.40	10.83
3b	Mfg. 10 - 3	32.64	34.09	35.41	10.93	12.39	13.71
4b	Mfg. 9 - 1	25.84	26.77	27.65	4.14	5.07	5.94
5b	Mfg. 9 - 2	27.74	28.90	29.94	6.03	7.19	8.24
6b	Mfg. 9 - 3	27.36	28.35	29.32	5.65	6.65	7.62
7b	circuit breaker	26.69	27.90	29.05	4.98	6.20	7.35
8b	line wire	25.29	26.13	26.94	3.59	4.42	5.23
9b	line wire splicing device	28.85	30.25	31.50	7.14	8.54	9.80
10b	load wire	27.35	28.42	29.40	5.65	6.72	7.70
11b	load wire splicing device	29.03	30.42	31.68	7.33	8.71	9.98
12b	room ambient	21.68	21.70	21.73			
13b	current (amps)	22.56	22.55	22.52			

Test 3c - thru Mfg. 3 10-amp breaker at 150% current (10A * 150% = 15A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		44	45	46			
time (MM:SS) →		5:50	6:00	6:10			
	Breaker trip time	6:20					
1c	Mfg. 10 - 1	33.95	34.06	34.18	12.26	12.38	12.49
2c	Mfg. 10 - 2	34.86	35.03	35.17	13.17	13.34	13.48
3c	Mfg. 10 - 3	32.06	32.16	32.23	10.37	10.47	10.55
4c	Mfg. 9 - 1	31.67	31.77	31.89	9.98	10.08	10.20
5c	Mfg. 9 - 2	31.89	31.99	32.07	10.20	10.30	10.39
6c	Mfg. 9 - 3	30.51	30.58	30.63	8.82	8.89	8.94
7c	circuit breaker	37.51	37.73	37.94	15.82	16.04	16.25
8c	line wire	38.17	38.32	38.46	16.48	16.63	16.77
9c	line wire splicing device	33.48	33.53	33.58	11.79	11.84	11.89
10c	load wire	37.25	37.38	37.51	15.57	15.70	15.82
11c	load wire splicing device	39.05	39.08	39.09	17.36	17.39	17.40
12c	room ambient	21.68	21.69	21.69			
13c	current (amps)	15.00	15.00	15.00			

Test 3c - thru Mfg. 3 15-amp breaker at 150% current (15A * 150% = 22.5A); max temps, reading every 10s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		28	29	30			
time (MM:SS) →		2:20	2:30	2:40			
	Breaker trip time	2:50					
1c	Mfg. 10 - 1	28.08	27.72	27.38	6.22	5.87	5.53
2c	Mfg. 10 - 2	27.85	27.43	27.08	5.99	5.58	5.23
3c	Mfg. 10 - 3	26.82	26.45	26.13	4.97	4.59	4.27
4c	Mfg. 9 - 1	26.62	26.30	26.02	4.76	4.45	4.17
5c	Mfg. 9 - 2	26.78	26.44	26.12	4.92	4.58	4.27
6c	Mfg. 9 - 3	26.00	25.71	25.47	4.15	3.86	3.62
7c	circuit breaker	30.09	29.81	29.54	8.23	7.95	7.68
8c	line wire	27.46	27.28	27.08	5.61	5.42	5.22
9c	line wire splicing device	27.03	26.55	26.12	5.18	4.69	4.26
10c	load wire	27.36	27.10	26.84	5.50	5.24	4.98
11c	load wire splicing device	27.70	27.09	26.53	5.84	5.23	4.67
12c	room ambient	21.89	21.86	21.82			
13c	current (amps)	22.40	22.39	22.39			

Test 4a - thru Mfg. 1 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		10	11	12			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1a	Mfg. 11 - 1	24.11	24.67	25.32	2.07	2.62	3.28
2a	Mfg. 11 - 2	24.06	24.59	25.25	2.02	2.55	3.20
3a	Mfg. 11 - 3	24.07	24.57	25.16	2.03	2.52	3.12
4a	Mfg. 8 - 1	24.08	24.69	25.40	2.03	2.64	3.35
5a	Mfg. 8 - 2	24.66	25.33	26.11	2.61	3.28	4.06
6a	Mfg. 8 - 3	24.22	24.83	25.55	2.17	2.79	3.50
7a	circuit breaker	24.11	24.82	25.62	2.07	2.77	3.57
8a	line wire	27.40	28.75	30.11	5.35	6.71	8.06
9a	line wire splicing device	25.44	26.76	28.29	3.40	4.72	6.24
10a	load wire	26.61	27.77	28.96	4.57	5.72	6.91
11a	load wire splicing device	26.63	28.24	30.08	4.59	6.20	8.04
12a	room ambient	22.05	22.06	22.03			
13a	current (amps)	19.99	20.01	20.01			

Test 4a - thru Mfg. 1 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		20	21	22			
time (MM:SS) →		:28	:35	:42			
	Breaker trip time	:49					
1a	Mfg. 11 - 1	27.71	28.87	30.04	5.22	6.37	7.55
2a	Mfg. 11 - 2	27.71	28.87	30.05	5.22	6.38	7.56
3a	Mfg. 11 - 3	27.95	28.97	30.04	5.46	6.47	7.54
4a	Mfg. 8 - 1	27.60	28.90	30.19	5.11	6.40	7.70
5a	Mfg. 8 - 2	28.56	29.91	31.25	6.06	7.42	8.76
6a	Mfg. 8 - 3	29.13	30.23	31.51	6.63	7.73	9.02
7a	circuit breaker	27.85	29.29	30.80	5.35	6.80	8.30
8a	line wire	29.17	30.44	31.74	6.68	7.95	9.24
9a	line wire splicing device	36.20	38.78	41.38	13.71	16.28	18.89
10a	load wire	29.69	31.07	32.48	7.20	8.58	9.98
11a	load wire splicing device	36.64	39.18	41.65	14.14	16.69	19.15
12a	room ambient	22.48	22.48	22.52			
13a	current (amps)	29.87	29.79	29.76			

Test 4b - thru Mfg. 2 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		10	11	12			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1b	Mfg. 11 - 1	23.92	24.53	25.23	2.00	2.60	3.30
2b	Mfg. 11 - 2	23.87	24.40	25.03	1.95	2.48	3.10
3b	Mfg. 11 - 3	24.04	24.56	25.19	2.11	2.64	3.27
4b	Mfg. 8 - 1	24.03	24.67	25.43	2.11	2.74	3.51
5b	Mfg. 8 - 2	24.81	25.54	26.38	2.89	3.62	4.46
6b	Mfg. 8 - 3	24.09	24.69	25.38	2.17	2.77	3.46
7b	circuit breaker	23.99	24.68	25.52	2.07	2.75	3.60
8b	line wire	25.64	26.65	27.71	3.72	4.73	5.78
9b	line wire splicing device	25.15	26.44	27.96	3.22	4.52	6.03
10b	load wire	23.65	24.33	25.10	1.73	2.41	3.18
11b	load wire splicing device	26.05	27.55	29.19	4.13	5.63	7.27
12b	room ambient	21.94	21.92	21.90			
13b	current (amps)	20.00	20.00	20.00			

Test 4b - thru Mfg. 2 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		:00	:09	:15			
	Breaker trip time	:21					
1b	Mfg. 11 - 1	22.78	24.58	25.64	0.28	2.08	3.14
2b	Mfg. 11 - 2	22.55	23.95	24.94	0.05	1.45	2.44
3b	Mfg. 11 - 3	22.78	24.32	25.15	0.28	1.82	2.65
4b	Mfg. 8 - 1	22.67	24.22	25.26	0.17	1.72	2.76
5b	Mfg. 8 - 2	23.01	25.35	26.56	0.52	2.85	4.06
6b	Mfg. 8 - 3	23.06	25.22	26.32	0.57	2.72	3.83
7b	circuit breaker	22.89	24.64	25.66	0.39	2.15	3.17
8b	line wire	22.78	24.14	25.26	0.28	1.64	2.76
9b	line wire splicing device	22.80	25.27	27.08	0.30	2.77	4.59
10b	load wire	22.73	25.29	26.72	0.23	2.79	4.22
11b	load wire splicing device	22.84	25.76	27.75	0.34	3.26	5.26
12b	room ambient	22.49	22.49	22.51			
13b	current (amps)	29.72	29.67	29.65			

Test 4c - thru Mfg. 3 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		:56	1:03	1:10			
	Breaker trip time	1:17					
1c	Mfg. 11 - 1	27.91	28.45	29.02	5.96	6.50	7.07
2c	Mfg. 11 - 2	27.83	28.34	28.85	5.88	6.39	6.90
3c	Mfg. 11 - 3	26.46	26.84	27.26	4.51	4.89	5.31
4c	Mfg. 8 - 1	28.33	28.89	29.46	6.38	6.94	7.51
5c	Mfg. 8 - 2	28.77	29.28	29.81	6.82	7.33	7.86
6c	Mfg. 8 - 3	27.76	28.25	28.71	5.81	6.30	6.76
7c	circuit breaker	30.95	31.72	32.52	8.99	9.77	10.56
8c	line wire	32.07	32.86	33.68	10.12	10.91	11.73
9c	line wire splicing device	31.50	32.36	33.19	9.54	10.41	11.24
10c	load wire	32.53	33.29	34.09	10.58	11.34	12.14
11c	load wire splicing device	36.35	37.44	38.34	14.40	15.49	16.39
12c	room ambient	22.03	21.91	21.92			
13c	current (amps)	20.00	20.00	20.00			

Test 4c - thru Mfg. 3 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		18	19	20			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1c	Mfg. 11 - 1	24.86	25.82	26.97	2.56	3.52	4.67
2c	Mfg. 11 - 2	25.87	27.00	28.27	3.57	4.70	5.97
3c	Mfg. 11 - 3	25.45	26.38	27.49	3.15	4.08	5.19
4c	Mfg. 8 - 1	25.11	26.19	27.48	2.81	3.89	5.18
5c	Mfg. 8 - 2	26.49	27.73	29.14	4.19	5.43	6.85
6c	Mfg. 8 - 3	25.08	26.08	27.24	2.78	3.78	4.94
7c	circuit breaker	25.44	26.60	28.04	3.14	4.30	5.74
8c	line wire	24.49	25.44	26.52	2.20	3.15	4.22
9c	line wire splicing device	27.39	29.24	31.37	5.09	6.95	9.07
10c	load wire	26.18	27.74	29.43	3.88	5.44	7.13
11c	load wire splicing device	26.21	27.89	29.79	3.91	5.59	7.49
12c	room ambient	22.31	22.30	22.29			
13c	current (amps)	29.59	29.78	29.83			

Test 4a - thru Mfg. 1 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		27	28	29			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1a	Mfg. 10 - 1	24.20	24.89	25.74	2.53	3.23	4.07
2a	Mfg. 10 - 2	24.11	24.81	25.65	2.45	3.14	3.99
3a	Mfg. 10 - 3	23.82	24.42	25.12	2.16	2.76	3.45
4a	Mfg. 9 - 1	23.70	24.28	24.96	2.04	2.62	3.29
5a	Mfg. 9 - 2	23.89	24.51	25.23	2.22	2.84	3.57
6a	Mfg. 9 - 3	23.66	24.22	24.90	1.99	2.55	3.23
7a	circuit breaker	23.81	24.47	25.29	2.14	2.80	3.63
8a	line wire	26.99	28.37	29.76	5.32	6.71	8.09
9a	line wire splicing device	24.05	25.15	26.46	2.39	3.48	4.79
10a	load wire	26.61	27.85	29.13	4.94	6.19	7.47
11a	load wire splicing device	28.24	30.24	32.42	6.58	8.58	10.75
12a	room ambient	21.68	21.67	21.66			
13a	current (amps)	20.02	20.03	20.03			

Test 4a - thru Mfg. 1 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		17	18	19			
time (MM:SS) →		:28	:35	:42			
	Breaker trip time	:49					
1a	Mfg. 10 - 1	27.27	28.75	30.17	5.77	7.24	8.67
2a	Mfg. 10 - 2	28.89	30.53	32.07	7.38	9.02	10.56
3a	Mfg. 10 - 3	27.89	29.33	30.74	6.38	7.82	9.24
4a	Mfg. 9 - 1	27.16	28.54	29.90	5.66	7.04	8.39
5a	Mfg. 9 - 2	28.09	29.55	30.97	6.58	8.05	9.46
6a	Mfg. 9 - 3	27.93	29.14	30.27	6.43	7.64	8.77
7a	circuit breaker	26.82	28.27	29.71	5.32	6.77	8.20
8a	line wire	28.15	29.45	30.67	6.65	7.95	9.17
9a	line wire splicing device	34.08	36.63	38.99	12.57	15.13	17.49
10a	load wire	28.54	29.95	31.29	7.03	8.45	9.79
11a	load wire splicing device	35.97	38.68	41.18	14.47	17.17	19.67
12a	room ambient	21.49	21.52	21.51			
13a	current (amps)	29.88	29.83	29.82			

Test 4b - thru Mfg. 2 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		27	28	29			
time (MM:SS) →		:15	:21	:28			
	Breaker trip time	:35					
1b	Mfg. 10 - 1	23.68	24.31	25.08	2.15	2.79	3.55
2b	Mfg. 10 - 2	24.00	24.79	25.66	2.47	3.26	4.13
3b	Mfg. 10 - 3	23.96	24.59	25.27	2.43	3.06	3.74
4b	Mfg. 9 - 1	23.67	24.25	24.93	2.14	2.73	3.40
5b	Mfg. 9 - 2	23.75	24.36	25.10	2.22	2.84	3.58
6b	Mfg. 9 - 3	23.79	24.37	25.03	2.26	2.84	3.50
7b	circuit breaker	23.69	24.36	25.21	2.16	2.84	3.69
8b	line wire	25.34	26.37	27.40	3.81	4.84	5.88
9b	line wire splicing device	24.37	25.54	26.91	2.84	4.01	5.38
10b	load wire	23.38	24.06	24.84	1.86	2.54	3.32
11b	load wire splicing device	28.62	30.57	32.60	7.09	9.05	11.07
12b	room ambient	21.54	21.54	21.50			
13b	current (amps)	19.99	19.99	19.99			

Test 4b - thru Mfg. 2 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		13	14	15			
time (MM:SS) →		0:00	:09	:15			
	Breaker trip time	:21					
1b	Mfg. 10 - 1	21.91	23.26	24.56	0.52	1.87	3.16
2b	Mfg. 10 - 2	21.93	24.79	26.37	0.54	3.40	4.97
3b	Mfg. 10 - 3	21.91	23.93	25.26	0.52	2.54	3.87
4b	Mfg. 9 - 1	21.95	24.22	25.49	0.56	2.83	4.10
5b	Mfg. 9 - 2	21.93	24.57	25.87	0.54	3.18	4.48
6b	Mfg. 9 - 3	21.90	24.12	25.30	0.51	2.73	3.90
7b	circuit breaker	22.03	23.68	24.72	0.64	2.28	3.33
8b	line wire	22.07	23.08	24.22	0.68	1.69	2.83
9b	line wire splicing device	21.89	24.14	26.27	0.50	2.75	4.87
10b	load wire	21.93	24.17	25.69	0.54	2.78	4.30
11b	load wire splicing device	21.95	26.40	28.99	0.56	5.01	7.60
12b	room ambient	21.40	21.38	21.40			
13b	current (amps)	30.03	29.98	29.94			

Test 4c - thru Mfg. 3 10-amp breaker at 200% current (10A * 200% = 20A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		33	34	35			
time (MM:SS) →		:56	1:03	1:10			
	Breaker trip time	1:17					
1c	Mfg. 10 - 1	28.89	29.56	30.22	7.33	8.01	8.67
2c	Mfg. 10 - 2	29.13	29.80	30.47	7.57	8.25	8.92
3c	Mfg. 10 - 3	28.24	28.82	29.43	6.69	7.27	7.87
4c	Mfg. 9 - 1	27.96	28.54	29.11	6.41	6.98	7.56
5c	Mfg. 9 - 2	27.95	28.55	29.13	6.40	6.99	7.58
6c	Mfg. 9 - 3	27.87	28.37	28.89	6.31	6.82	7.34
7c	circuit breaker	30.46	31.20	31.96	8.91	9.65	10.41
8c	line wire	31.76	32.54	33.32	10.20	10.99	11.77
9c	line wire splicing device	30.32	31.15	31.96	8.77	9.60	10.41
10c	load wire	32.17	32.94	33.69	10.62	11.39	12.14
11c	load wire splicing device	39.40	40.57	41.66	17.85	19.02	20.11
12c	room ambient	21.59	21.54	21.53			
13c	current (amps)	20.00	20.00	20.00			

Test 4c - thru Mfg. 3 15-amp breaker at 200% current (15A * 200% = 30A); max temps, reading every 7s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		16	17	18			
time (MM:SS) →		:21	:28	:35			
	Breaker trip time	:42					
1c	Mfg. 10 - 1	24.57	25.84	27.05	3.19	4.45	5.67
2c	Mfg. 10 - 2	28.42	30.54	32.56	7.04	9.16	11.18
3c	Mfg. 10 - 3	33.47	35.78	37.86	12.09	14.40	16.48
4c	Mfg. 9 - 1	24.87	26.08	27.27	3.49	4.70	5.89
5c	Mfg. 9 - 2	27.04	28.63	30.11	5.66	7.25	8.73
6c	Mfg. 9 - 3	26.95	28.35	29.72	5.57	6.97	8.34
7c	circuit breaker	25.75	27.15	28.60	4.37	5.77	7.22
8c	line wire	24.57	25.65	26.68	3.19	4.27	5.30
9c	line wire splicing device	27.76	29.81	31.74	6.38	8.43	10.35
10c	load wire	26.52	28.22	29.72	5.14	6.84	8.34
11c	load wire splicing device	27.66	29.85	31.88	6.28	8.47	10.49
12c	room ambient	21.40	21.37	21.36			
13c	current (amps)	29.34	29.29	30.17			

Test 1b - thru Mfg. 2 10-amp breaker at 100% current (10A * 100% = 10A); max temps, reading every 60s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		67	72	77			
time (HH:MM:SS) →		1:04:00	1:09:00	1:14:00			
1b	Mfg. 10 - 1	33.66	33.62	33.48	12.17	12.13	11.99
2b	Mfg. 10 - 2	30.46	30.56	30.61	8.97	9.07	9.12
3b	Mfg. 10 - 3	28.97	29.03	28.87	7.48	7.54	7.38
4b	Mfg. 9 - 1	28.59	28.61	28.68	7.10	7.12	7.19
5b	Mfg. 9 - 2	29.99	29.94	29.81	8.50	8.45	8.32
6b	Mfg. 9 - 3	28.44	28.40	28.15	6.95	6.91	6.66
7b	circuit breaker	41.26	41.48	41.60	19.77	19.99	20.11
8b	line wire	31.15	30.97	30.89	9.66	9.48	9.40
9b	line wire splicing device	28.63	28.27	28.01	7.14	6.78	6.52
10b	load wire	28.45	28.20	28.09	6.96	6.71	6.60
11b	load wire splicing device	30.47	29.94	29.87	8.98	8.45	8.38
12b	room ambient	22.46	22.07	21.66			
13b	current (amps)	10.01	10.01	10.01			

Test 2b - thru Mfg. 2 10-amp breaker at 135% current (10A * 135% = 13.5A); max temps, reading every 20s

data logger CH #	Location	Recorded Temperatures (°C)			Calculated Temperature Rise (°C)		
scan # →		202	203	204			
time (MM:SS) →		66:20	66:40	67:00			
	Breaker trip time	> 67 mins. (no trip)					
1b	Mfg. 10 - 1	40.89	40.89	40.88	18.96	18.97	18.96
2b	Mfg. 10 - 2	37.03	37.03	37.04	15.11	15.11	15.12
3b	Mfg. 10 - 3	34.24	34.26	34.21	12.31	12.34	12.29
4b	Mfg. 9 - 1	33.52	33.50	33.53	11.60	11.58	11.61
5b	Mfg. 9 - 2	35.79	35.78	35.75	13.87	13.86	13.83
6b	Mfg. 9 - 3	33.44	33.45	33.39	11.52	11.53	11.47
7b	circuit breaker	56.60	56.56	56.59	34.68	34.64	34.67
8b	line wire	38.73	38.68	38.65	16.81	16.76	16.72
9b	line wire splicing device	33.69	33.57	33.57	11.76	11.65	11.65
10b	load wire	33.57	33.50	33.50	11.65	11.57	11.58
11b	load wire splicing device	37.08	36.99	37.04	15.16	15.07	15.12
12b	room ambient	22.10	22.03	21.97			
13b	current (amps)	13.49	13.49	13.49			

Appendix D Flexing Tests

Conductor Flexing tests on 14-2 AWG copper-clad aluminum NMB cable:

test #	wire connection method	pass / fail (10x flexion)	comments
6-1	wrap around terminal screw	pass	ends of hot and neutral wires broke when removing them from their terminals after the test
6-2	single compression	pass	
6-3	double compression	pass	
6-1-1	wrap around terminal screw	failed	retest of 6-1; hot wire (black) broke on 8th flexion
6-1-2	wrap around terminal screw	pass	retest of 6-1 using copper wire
6-1-3	wrap around terminal screw	pass	retest of 6-1

NOTE: One Legrand receptacle was used for all 3 tests above and 9in/lbs was applied to all three terminal screws.

PACIFIC TEST AND MEASUREMENT

PO Box 2363, Clackamas, OR 97015
15648 114th Ave. Suite 109, Clackamas OR 97015
Phone: 503-406-4373 Fax: 503 905 0457
www.pacifictestandmeasurement.com

Certificate of Conformance

Issued to:	CDCMello Consulting LLC PO Box 872317 Vancouver, WA 98687
Customer PO:	Verbal Chuck Mello
Model:	UL3055
Lot Number:	952103-019
Report:	JK202006300-003
Description:	Type J, 30 Gauge FEP/FEP Teflon, Special Limits of Error Tolerance, 15 feet length, Thermocouple

Pacific Test and Measurement Inc certifies that the order of thermocouples meets all applicable instructions, specifications, and in accordance with DAP UL 00-OP-C0037 version 10.0. The preferred method of welding to produce a single point weld or bead using ThermX model 258B welder has been used to assemble the thermocouple junction which has been proven as reliable and repeatable through validation. The finish products were assembled from UL4047, a spool of described wire calibrated to accredited standards as described in the calibration report.

Certified by: _____ Date: ___7-10-2020_____
(Quality Department)

ACCREDITED
CERT #2496.01

Report of Calibration

Eustis Co.,Inc./Pyrocom Calibration lab
12407-B Mukilteo Speedway #200
Lynnwood, wa 98087

Model: UL4047 Serial: 952103-019 Description: TYPE J, 30AWG, FEP/FEP	Customer: . . CDCMello Consulting LLC PO Box 872317 Vancouver, WA 98687
Calibration Range: Limited Received Condition: New Current: N/A Procedure: ECP 339/341	

The unit under test (UUT) on this certificate has been calibrated by comparison method as covered by ASTM E220-13, and calibrated against standards traceable to the National Institute of Standards and Technology (NIST). Eustis Co., Inc./Pyrocom Calibration Lab meets the requirements of ANSI/NCSL Z540-1-1994 and ISO/IEC 17025 and is accredited by A2LA via Certificate Number 2496.01 for calibrations within the scope to which it applies. The uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2. All results contained within this certificate relate only to the item calibrated. Any number of factors may cause the calibrated item to drift out of calibration.

Nominal Value (Set-point) (C)	Actual Value (Reference) (C)	UUT (Test Sensor) (C)	Error (C)	Measurement Uncertainty (C)	Method of Realization
21.00	21.41	21.38	-0.03	+/- 0.31	COMP
40.00	40.08	40.02	-0.06	+/- 0.40	COMP
95.00	95.02	94.97	-0.05	+/- 0.40	COMP
150.00	150.02	150.10	0.08	+/- 0.50	COMP
200.00	200.01	200.23	0.22	+/- 0.50	COMP

Test Equipment

Manufacturer	Model	Description	Serial Number	Recall Date
Hart Scientific	1560	"Black Stack" Base Unit	96539	NCR
Hart Scientific	2560	SPRT Module	A25631	3/24/2021
Fluke	5628	4 Wire SPRT	4303	3/26/2021
Fluke	2566	Thermocouple Scanner	B7A380	3/24/2021
Fluke	9173	Metrology Well, 700 C	B47975	NCR
Fluke	7380	Bath, Ultra Low-Temperature	B2A527	NCR

Calibration Date: 6/18/2020
Temperature: 23.0 C
Humidity: 47%
Customer Order: 74523

Technician: Julia Kulin

Approved By: Walter Paulson
QA Manager

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Report of Calibration

Notes: The thermocouple wire meets or exceeds the criteria established for type "J" SPECIAL LIMITS OF ERROR per ASTM E230/E230M-17 table 1 & ISA-MC96.1-1982 Par. 2.5 Table 8 +/- 1.1°C OR +/- .4% whichever is greater. Lot calibration data supplied for your reference.
Calibrated item meets special limits of error for all results given according to the comparison of "error" reading to the specifications found in ASTM E230/E230M-17 table 1 & MC96.1-1982 table 8; acceptance determination is ultimately the responsibility of the customer, taking into account all uncertainties and other factors. The closer the results are to the specification limits, the greater the risk that the unit under test will be out of tolerance.

Report issue date: JUN 1 9 2020

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Certification Number CK198-33105-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Data Acquisition Unit
Make	Keysight
Model	34972A
Serial Number	MY49002695
Identification	EM7054
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 57.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-006 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
Root Difference Square guardbanding method used.						
UUT IDENTIFICATION						
Serial Number: MY49002695 Firmware Level: 1.11-1.12-02-01						
INPUT MODULE CHARACTERISTICS						
Model: 34901A Firmware Level: 2.3						
SELF TEST				Pass	Pass	

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
INTERNAL DMM VERIFICATION						
ZERO OFFSET VERIFICATION						
DC CURRENT						
10 mA Range						
0.00000 mA	0.00000	-0.00200	0.00200	0.00003	0.00003	0.000007
100 mA Range						
0.0000 mA	0.0000	-0.0050	0.0050	0.0000	0.0000	0.00006
1 A Range						
0.000000 A	0.000000	-0.000100	0.000100	0.000001	0.000001	0.0000006
DC VOLTS						
100 mV Range						
0.0000 mV	0.0000	-0.0040	0.0040	0.0004	0.0004	0.00007
1 V Range						
0.000000 V	0.000000	-0.000007	0.000007	0.000001	0.000001	0.0000007
10 V Range						
0.00000 V	0.00000	-0.00005	0.00005	0.00000	0.00000	0.000007
100 V Range						
0.0000 V	0.0000	-0.0006	0.0006	0.0000	0.0000	0.00006
300 V Range						
0.000 V	0.000	-0.009	0.009	0.000	0.000	0.0006
2 WIRE						
100 Range						
0.0000 Ohm	0.0000	-4.0040	4.0040	0.0626	0.0626	0.00007
1 k Range						
0.000000 kOhm	0.000000	-0.004010	0.004010	0.000065	0.000065	0.0000006
10 k Range						
0.00000 kOhm	0.00000	-0.00410	0.00410	0.00008	0.00008	0.000006
100 k Range						
0.0000 kOhm	0.0000	-0.0050	0.0050	0.0002	0.0002	0.00007
1 M Range						
0.000000 MOhm	0.000000	-0.000014	0.000014	0.000000	0.000000	0.0000007
10 M Range						

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
0.00000 MOhm	0.00000	-0.00010	0.00010	0.00000	0.00000	0.000007
100 M? Range						
0.0000 MOhm	0.0000	-0.0100	0.0100	0.0000	0.0000	0.00006
4 WIRE						
100 Range						
0.0000 Ohm	0.0000	-0.0040	0.0040	-0.0023	-0.0023	0.00006
1 k Range						
0.000000 kOhm	0.000000	-0.000010	0.000010	0.000000	0.000000	0.0000006
10 k Range						
0.00000 kOhm	0.00000	-0.00010	0.00010	0.00000	0.00000	0.000007
100 k Range						
0.0000 kOhm	0.0000	-0.0010	0.0010	0.0000	0.0000	0.00007
1 M Range						
0.000000 MOhm	0.000000	-0.000010	0.000010	0.000000	0.000000	0.0000006
10 M Range						
0.00000 MOhm	0.00000	-0.00010	0.00010	0.00000	0.00000	0.000006
100 M Range						
0.0000 MOhm	0.0000	-0.0100	0.0100	0.0000	0.0000	0.00007
GAIN VERIFICATION						
DC VOLTS						
100 mV Range						
100.0000 mV	100.0000	99.9910	100.0090	100.0000	100.0000	0.00006
-100.0000 mV	-100.0000	-100.0090	-99.9910	-99.9987	-99.9987	0.00007
1 V Range						
1.000000 V	1.000000	0.999953	1.000047	0.999993	0.999993	0.0000007
-1.000000 V	-1.000000	-1.000047	-0.999953	-0.999989	-0.999989	0.0000007
10 V Range						
10.00000 V	10.00000	9.99960	10.00040	9.99994	9.99994	0.000006
-10.00000 V	-10.00000	-10.00040	-9.99960	-9.99992	-9.99992	0.000006
100 V Range						
100.0000 V	100.0000	99.9949	100.0051	99.9996	99.9996	0.00007
-100.0000 V	-100.0000	-100.0051	-99.9949	-99.9993	-99.9993	0.00007
300 V Range						
300.000 V	300.000	299.978	300.022	299.998	299.998	0.0006

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
2 WIRE						
100 Range						
100.0000 Ohm	100.0000	95.9860	104.0140	100.0067	100.0067	0.00007
1 k Range						
1.000000 kOhm	1.000000	0.995890	1.004110	1.000032	1.000032	0.0000006
10 k Range						
10.00000 kOhm	10.00000	9.99490	10.00510	10.00035	10.00035	0.000007
100 k Range						
100.0000 kOhm	100.0000	99.9850	100.0150	100.0029	100.0029	0.00006
1 M Range						
1.000000 MOhm	1.000000	0.999886	1.000114	1.000016	1.000016	0.0000006
10 M Range						
10.00000 MOhm	10.00000	9.99590	10.00410	9.99768	9.99768	0.000006
100 M Range						
100.0000 MOhm	100.0000	99.1900	100.8100	100.3688	100.3688	0.00007
4 WIRE						
100 Range						
100.0000 Ohm	100.0000	99.9860	100.0140	100.0039	100.0039	0.00006
1 k Range						
1.000000 kOhm	1.000000	0.999890	1.000110	1.000030	1.000030	0.0000007
10 k Range						
10.00000 kOhm	10.00000	9.99890	10.00110	10.00032	10.00032	0.000006
100 k Range						
100.0000 kOhm	100.0000	99.9890	100.0110	100.0021	100.0021	0.00007
1 M Range						
1.000000 MOhm	1.000000	0.999890	1.000110	0.999970	0.999970	0.0000007
10 M Range						
10.00000 MOhm	10.00000	9.99590	10.00410	9.99595	9.99595	0.000006
100 M Range						
100.0000 MOhm	100.0000	99.1900	100.8100	99.8275	99.8275	0.00006
DC CURRENT						
10 mA Range						
10.00000 mA	10.00000	9.99300	10.00700	9.99898	9.99898	0.000007
-10.00000 mA	-10.00000	-10.00700	-9.99300	-9.99887	-9.99887	0.000007

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
100 mA Range						
100.0000 mA	100.0000	99.9450	100.0550	99.9882	99.9882	0.00006
-100.0000 mA	-100.0000	-100.0550	-99.9450	-99.9879	-99.9879	0.00006
1 A Range						
1.000000 A	1.000000	0.998900	1.001100	0.999534	0.999534	0.0000006
-1.000000 A	-1.000000	-1.001100	-0.998900	-0.999537	-0.999537	0.0000006
AC VOLTS						
100 mV Range						
10.0000 mV @ 1 kHz	10.0000	9.9540	10.0460	9.9997	9.9997	0.00006
100.0000 mV @ 1 kHz	100.0000	99.9000	100.1000	99.9912	99.9912	0.00006
100.0000 mV @ 50 kHz	100.0000	99.8300	100.1700	99.9383	99.9383	0.00006
1 V Range						
1.000000 V @ 20 Hz	1.000000	0.999000	1.001000	0.999803	0.999803	0.0000006
1.000000 V @ 1 kHz	1.000000	0.999000	1.001000	0.999950	0.999950	0.0000006
1.000000 V @ 20 kHz	1.000000	0.999000	1.001000	0.999888	0.999888	0.0000006
1.000000 V @ 50 kHz	1.000000	0.998300	1.001700	0.999504	0.999504	0.0000007
1.000000 V @ 100 kHz	1.000000	0.993200	1.006800	0.998811	0.998811	0.0000006
1.000000 V @ 200 kHz	1.000000	0.955000	1.045000	0.999068	0.999068	0.0000006
1.000000 V @ 250 kHz	1.000000	0.955000	1.045000	0.999202	0.999202	0.0000007
1.000000 V @ 300 kHz	1.000000	0.955000	1.045000	0.998797	0.998797	0.0000006
10 V Range						
0.10000 V @ 1 kHz	0.10000	0.08594	0.11406	0.10086	0.10086	0.000006
1.00000 V @ 1 kHz	1.00000	0.99540	1.00460	0.99992	0.99992	0.000006
10.00000 V @ 10 Hz	10.00000	9.99000	10.01000	9.99743	9.99743	0.000007
10.00000 V @ 1 kHz	10.00000	9.99000	10.01000	9.99855	9.99855	0.000006
10.00000 V @ 50 kHz	10.00000	9.98300	10.01700	9.99499	9.99499	0.000006
100 V Range						
100.0000 V @ 1 kHz	100.0000	99.9000	100.1000	99.9653	99.9653	0.00006
100.0000 V @ 50 kHz	100.0000	99.8300	100.1700	99.8943	99.8943	0.00006

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
300 V Range						
300.000 V @ 1 kHz	300.000	299.580	300.420	299.884	299.884	0.0006
200.000 V @ 50 kHz	200.000	199.400	200.600	199.750	199.750	0.0007
AC CURRENT						
10 mA Range						
10.00000 mA @ 1 kHz	10.00000	9.98600	10.01400	9.99766	9.99766	0.000007
100 mA Range						
100.0000 mA @ 1 kHz	100.0000	99.4000	100.6000	99.9484	99.9484	0.00007
1 A Range						
0.010000 A @ 1 kHz	0.010000	0.008590	0.011410	0.009960	0.009960	0.0000007
1.000000 A @ 1 kHz	1.000000	0.998600	1.001400	0.999502	0.999502	0.0000006
FREQUENCY						
100 Hz Range						
100.0000 Hz	100.0000	99.9000	100.1000	100.0056	100.0056	0.00007
100 kHz Range						
100.0000 kHz	100.0000	99.9900	100.0100	100.0001	100.0001	0.00007

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY

Certificate No. ACT-1272

Certification Number CK198-39504-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Multimeter Digital Multimeter
Make	Fluke
Model	179
Serial Number	77840008
Identification	EM4437
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	68.3°F, 20.2°C, 56.2%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-001 rev. 2

This certificate shall not be altered in any form or reproduced, except in full, without prior written approval from originating lab. These results relate only to the item(s) calibrated.
Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in base units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
600 mV Range						
300.0 mV @ 45 Hz	300.0	296.7	303.3	299.2	299.2	0.07
6 V Range						
5.000 V @ 500 Hz	5.000	4.947	5.053	4.987	4.987	0.0007
5.000 V @ 1 kHz	5.000	4.897	5.103	4.949	4.949	0.0007
60 V Range						
50.00 V @ 45 Hz	50.00	49.47	50.53	49.98	49.98	0.007
50.00 V @ 1 kHz	50.00	48.97	51.03	50.02	50.02	0.007
600 V Range						
300.0 V @ 45 Hz	300.0	296.7	303.3	299.9	299.9	0.07
500.0 V @ 500 Hz	500.0	494.7	505.3	500.5	500.5	0.06
500.0 V @ 1 kHz	500.0	489.7	510.3	500.5	500.5	0.06
1000 V Range						
1000 V @ 45 Hz	1000	987	1013	1002	1002	0.7

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CERTIFICATE OF CALIBRATION

Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
FREQUENCY						
45.00 Hz @ 1 V	45.00	44.95	45.06	45.01	45.01	0.007
50.00 kHz @ 5 V	50.00	49.94	50.06	50.00	50.00	0.006
DC VOLTAGE						
6 V Range						
5.000 V	5.000	4.994	5.007	4.997	4.997	0.0006
600 V Range						
300.0 V	300.0	299.5	300.5	299.8	299.8	0.06
1000 V Range						
1000 V	1000	997	1004	999	999	0.6
-1000 V	-1000	-1004	-997	-1000	-1000	0.7
DC VOLTS						
FREQUENCY						
45.00 Hz @ 3 V	45.00	44.95	45.06	45.01	45.01	0.007
50.00 kHz @ 30 V	50.00	49.94	50.06	50.00	50.00	0.007
DC MILLIVOLTS						
30.0 mV	30.0	29.8	30.2	30.0	30.0	0.06
-300.0 mV	-300.0	-300.5	-299.5	-299.9	-299.9	0.06
600.0 mV	600.0	599.3	600.7	599.7	599.7	0.07
TEMPERATURE						
0.0 °C	0.0	-1.0	1.0	1.0	1.0	0.06
-40.0 °C	-40.0	-41.4	-38.6	-39.0	-39.0	0.07
400.0 °C	400.0	395.0	405.0	400.9	400.9	0.06
OHMS						
600 Ohm Range						
19.0 Ohm	19.0	18.6	19.4	19.3	19.3	0.07
50 MOhm Range						
19.00 MOhm	19.00	18.68	19.32	19.00	19.00	0.006
CAPACITANCE						
1000 nF Range						
900 nF	900	887	913	899	899	0.6
CONTINUITY						
0 Ohms: Beeper On				Pass	Pass	
190 Ohms: Beeper Off				Pass	Pass	
DIODE TEST						

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
2.000 V	2.000	1.978	2.022	2.000	2.000	0.0007
AC MILLIAMPS						
60 mA Range						
3.00 mA @ 45 Hz	3.00	2.92	3.08	3.00	3.00	0.007
50.00 mA @ 1 kHz	50.00	49.22	50.78	50.06	50.06	0.006
400 mA Range						
400.0 mA @ 1 kHz	400.0	393.7	406.3	400.4	400.4	0.07
AC AMPS						
6 A Range						
4.000 A @ 45 Hz	4.000	3.937	4.063	4.005	4.005	0.0007
10A Range						
9.00 A @ 1 kHz	9.00	8.84	9.16	9.04	9.04	0.007
DC MILLIAMPS						
60 mA Range						
3.00 mA	3.00	2.94	3.06	3.00	3.00	0.006
50.00 mA	50.00	49.47	50.53	49.92	49.92	0.007
400 mA Range						
-400.0 mA	-400.0	-404.3	-395.7	-399.8	-399.8	0.07
DC AMPS						
6 A Range						
4.000 A	4.000	3.957	4.043	3.999	3.999	0.0007
10 A Range						
-9.00 A	-9.00	-9.12	-8.88	-9.01	-9.01	0.006

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CERTIFICATE OF CALIBRATION

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Certificate No. ACT-1272

Certification Number CK198-38060-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Multimeter Digital Multimeter
Make	Fluke
Model	175
Serial Number	13700492
Identification	EM7014
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	68.2°F, 20.1°C, 56.6%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-001 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in base units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
600 mV Range						
300.0 mV @ 45 Hz	300.0	296.7	303.3	299.9	299.9	0.07
6 V Range						
5.000 V @ 500 Hz	5.000	4.947	5.053	4.994	4.994	0.0007
5.000 V @ 1 kHz	5.000	4.897	5.103	4.955	4.955	0.0006
60 V Range						
50.00 V @ 45 Hz	50.00	49.47	50.53	49.94	49.94	0.007
50.00 V @ 1 kHz	50.00	48.97	51.03	50.06	50.06	0.006
600 V Range						
300.0 V @ 45 Hz	300.0	296.7	303.3	299.8	299.8	0.07
500.0 V @ 500 Hz	500.0	494.7	505.3	500.4	500.4	0.07
500.0 V @ 1 kHz	500.0	489.7	510.3	500.4	500.4	0.06
1000 V Range						
1000 V @ 45 Hz	1000	987	1013	996	996	0.6

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
FREQUENCY						
45.00 Hz @ 1 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 5 V	50.00	49.94	50.06	50.00	50.00	0.007
DC VOLTAGE						
6 V Range						
5.000 V	5.000	4.990	5.010	5.000	5.000	0.0007
600 V Range						
300.0 V	300.0	299.4	300.6	300.0	300.0	0.06
1000 V Range						
1000 V	1000	997	1004	1000	1000	0.7
-1000 V	-1000	-1004	-997	-1000	-1000	0.7
DC VOLTS						
FREQUENCY						
45.00 Hz @ 3 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 30 V	50.00	49.94	50.06	50.00	50.00	0.007
DC MILLIVOLTS						
30.0 mV	30.0	29.8	30.2	30.0	30.0	0.07
-300.0 mV	-300.0	-300.6	-299.4	-299.9	-299.9	0.06
600.0 mV	600.0	598.9	601.1	599.9	599.9	0.06
OHMS						
600 Ohm Range						
19.0 Ohm	19.0	18.6	19.4	19.0	19.0	0.07
50 MOhm Range						
19.00 MOhm	19.00	18.68	19.32	18.99	18.99	0.006
CAPACITANCE						
1000 nF Range						
900 nF	900	887	913	900	900	0.7
CONTINUITY						
0 Ohms: Beeper On				Pass	Pass	
190 Ohms: Beeper Off				Pass	Pass	
DIODE TEST						
2.000 V	2.000	1.978	2.022	2.001	2.001	0.0006
AC MILLIAMPS						
60 mA Range						

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
3.00 mA @ 45 Hz	3.00	2.92	3.08	3.01	3.01	0.007
50.00 mA @ 1 kHz	50.00	49.22	50.78	49.96	49.96	0.007
400 mA Range						
400.0 mA @ 1 kHz	400.0	393.7	406.3	399.4	399.4	0.06
AC AMPS						
6 A Range						
4.000 A @ 45 Hz	4.000	3.937	4.063	3.997	3.997	0.0007
10A Range						
9.00 A @ 1 kHz	9.00	8.84	9.16	9.00	9.00	0.007
DC MILLIAMPS						
60 mA Range						
3.00 mA	3.00	2.94	3.06	3.02	3.02	0.006
50.00 mA	50.00	49.47	50.53	49.99	49.99	0.006
400 mA Range						
-400.0 mA	-400.0	-404.3	-395.7	-400.0	-400.0	0.07
DC AMPS						
6 A Range						
4.000 A	4.000	3.957	4.043	3.999	3.999	0.0007
10 A Range						
-9.00 A	-9.00	-9.12	-8.88	-9.00	-9.00	0.007

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CERTIFICATE OF CALIBRATION

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Certificate No. ACT-1272

Certification Number CK198-38779-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Multimeter Digital Multimeter
Make	Fluke
Model	179
Serial Number	14370601
Identification	EM7024
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	68.2°F, 20.1°C, 56.6%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-000 rev. 2
FVE-001 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
600 mV Range						
300.0 mV @ 45 Hz	300.0	296.7	303.3	300.0	300.0	0.06
6 V Range						
5.000 V @ 500 Hz	5.000	4.947	5.053	4.997	4.997	0.0006
5.000 V @ 1 kHz	5.000	4.897	5.103	4.961	4.961	0.0006
60 V Range						
50.00 V @ 45 Hz	50.00	49.47	50.53	49.97	49.97	0.006
50.00 V @ 1 kHz	50.00	48.97	51.03	50.10	50.10	0.007
600 V Range						
300.0 V @ 45 Hz	300.0	296.7	303.3	300.0	300.0	0.07
500.0 V @ 500 Hz	500.0	494.7	505.3	500.9	500.9	0.06
500.0 V @ 1 kHz	500.0	489.7	510.3	500.8	500.8	0.06
1000 V Range						
1000 V @ 45 Hz	1000	987	1013	997	997	0.7

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
AC VOLTS						
FREQUENCY						
45.00 Hz @ 1 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 5 V	50.00	49.94	50.06	50.00	50.00	0.006
DC VOLTAGE						
6 V Range						
5.000 V	5.000	4.994	5.007	5.000	5.000	0.0006
600 V Range						
300.0 V	300.0	299.5	300.5	299.9	299.9	0.06
1000 V Range						
1000 V	1000	997	1004	1000	1000	0.7
-1000 V	-1000	-1004	-997	-1000	-1000	0.7
DC VOLTS						
FREQUENCY						
45.00 Hz @ 3 V	45.00	44.95	45.06	45.00	45.00	0.007
50.00 kHz @ 30 V	50.00	49.94	50.06	50.00	50.00	0.006
DC MILLIVOLTS						
30.0 mV	30.0	29.8	30.2	30.0	30.0	0.06
-300.0 mV	-300.0	-300.5	-299.5	-299.9	-299.9	0.06
600.0 mV	600.0	599.3	600.7	599.8	599.8	0.06
TEMPERATURE						
0.0 °C	0.0	-1.0	1.0	0.5	0.5	0.06
-40.0 °C	-40.0	-41.4	-38.6	-39.3	-39.3	0.06
400.0 °C	400.0	395.0	405.0	400.4	400.4	0.06
OHMS						
600 Ohm Range						
19.0 Ohm	19.0	18.6	19.4	19.0	19.0	0.06
50 MOhm Range						
19.00 MOhm	19.00	18.68	19.32	18.98	18.98	0.006
CAPACITANCE						
1000 nF Range						
900 nF	900	887	913	900	900	0.6
CONTINUITY						
0 Ohms: Beeper On				Pass	Pass	
190 Ohms: Beeper Off				Pass	Pass	
DIODE TEST						

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
2.000 V	2.000	1.978	2.022	2.001	2.001	0.0007
AC MILLIAMPS						
60 mA Range						
3.00 mA @ 45 Hz	3.00	2.92	3.08	3.02	3.02	0.006
50.00 mA @ 1 kHz	50.00	49.22	50.78	50.03	50.03	0.006
400 mA Range						
400.0 mA @ 1 kHz	400.0	393.7	406.3	399.9	399.9	0.06
AC AMPS						
6 A Range						
4.000 A @ 45 Hz	4.000	3.937	4.063	4.004	4.004	0.0006
10A Range						
9.00 A @ 1 kHz	9.00	8.84	9.16	9.01	9.01	0.007
DC MILLIAMPS						
60 mA Range						
3.00 mA	3.00	2.94	3.06	3.01	3.01	0.007
50.00 mA	50.00	49.47	50.53	49.99	49.99	0.007
400 mA Range						
-400.0 mA	-400.0	-404.3	-395.7	-399.9	-399.9	0.06
DC AMPS						
6 A Range						
4.000 A	4.000	3.957	4.043	3.998	3.998	0.0006
10 A Range						
-9.00 A	-9.00	-9.12	-8.88	-9.00	-9.00	0.007

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK198-41226-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Clamp Meter
Make	AEMC
Model	SR759
Serial Number	224137GKDV
Identification	EM6996
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 56.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-007 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-546	24560221	CK093-41519-573	04/30/2021
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
1A Range; 1000mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 mA	10.0	8.7	11.3	10.1	10.1	0.07
100 mA	100.0	96.0	104.0	101.3	101.3	0.06
500 mA	500.0	495.5	504.5	504.5	504.5	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
1 A	1.000	0.992	1.008	1.008	1.008	0.0006
10A Range; 100mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
100 mA	10.0	9.7	10.3	10.0	10.0	0.07
1 A	100.0	99.3	100.7	100.4	100.4	0.07
5 A	500.0	497.5	502.5	501.8	501.8	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
10 A	1.000	0.995	1.005	1.004	1.004	0.0007
100A Range; 10mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
1 A	10.0	9.7	10.3	10.0	10.0	0.07
10 A	100.0	99.3	100.7	100.1	100.1	0.06

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Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0 (V AC)	498.5 (V AC)	501.5 (V AC)	500.3 (V AC)	500.3 (V AC)	0.06 (V AC)
100 A	1.000	0.998	1.002	1.001	1.001	0.0006
1000A Range; 1mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 A	10.0	9.7	10.3	10.0	10.0	0.06
100 A	100.0	99.3	100.7	100.1	100.1	0.07
500 A	500.0	499.0	501.0	500.5	500.5	0.07
900 A	900.0	898.0	902.0	901.2	901.2	0.07

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY

Certificate No. ACT-1272

Certification Number CK198-40179-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Clamp Meter
Make	AEMC
Model	SR759
Serial Number	224139GKDV
Identification	EM6997
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 56.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-007 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-546	24560221	CK093-41519-573	04/30/2021
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
1A Range; 1000mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 mA	10.0	8.7	11.3	10.1	10.1	0.06
100 mA	100.0	96.0	104.0	101.1	101.1	0.06
500 mA	500.0	495.5	504.5	504.5	504.5	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
1 A	1.000	0.992	1.008	1.008	1.008	0.0006
10A Range; 100mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
100 mA	10.0	9.7	10.3	10.0	10.0	0.07
1 A	100.0	99.3	100.7	100.2	100.2	0.06
5 A	500.0	497.5	502.5	500.9	500.9	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
10 A	1.000	0.995	1.005	1.002	1.002	0.0006
100A Range; 10mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
1 A	10.0	9.7	10.3	10.0	10.0	0.06
10 A	100.0	99.3	100.7	100.1	100.1	0.07

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0 (V AC)	498.5 (V AC)	501.5 (V AC)	500.1 (V AC)	500.1 (V AC)	0.06 (V AC)
100 A	1.000	0.998	1.002	1.001	1.001	0.0006
1000A Range; 1mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 A	10.0	9.7	10.3	10.0	10.0	0.07
100 A	100.0	99.3	100.7	100.1	100.1	0.06
500 A	500.0	499.0	501.0	500.3	500.3	0.06
900 A	900.0	898.0	902.0	901.4	901.4	0.06

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK198-41583-466

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Clamp Meter
Make	AEMC
Model	SR759
Serial Number	239584HKDV
Identification	EM8032
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Alex Paulsen
Technical Review By	Tim Bending
Calibration Location	FVM
Calibration Conditions	67.8°F, 19.9°C, 56.3%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVE-007 rev. 2

This certificate shall not be altered in any form or reproduced, except in full, without prior written approval from originating lab. These results relate only to the item(s) calibrated.
Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-275A	RY11838	CJ191-70508-513	07/28/2020
FVS-546	24560221	CK093-41519-573	04/30/2021
FVS-737	4542903	CK041-57440-531	02/28/2021

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
1A Range; 1000mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 mA	10.0	8.7	11.3	10.2	10.2	0.07
100 mA	100.0	96.0	104.0	101.1	101.1	0.07
500 mA	500.0	495.5	504.5	504.3	504.3	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
1 A	1.000	0.992	1.008	1.007	1.007	0.0007
10A Range; 100mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
100 mA	10.0	9.7	10.3	10.0	10.0	0.07
1 A	100.0	99.3	100.7	100.2	100.2	0.07
5 A	500.0	497.5	502.5	500.7	500.7	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)
10 A	1.000	0.995	1.005	1.002	1.002	0.0006
100A Range; 10mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
1 A	10.0	9.7	10.3	10.0	10.0	0.07
10 A	100.0	99.3	100.7	100.0	100.0	0.07

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Certificate No. ACT-1272

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0 (V AC)	498.5 (V AC)	501.5 (V AC)	500.0 (V AC)	500.0 (V AC)	0.07 (V AC)
100 A	1.000	0.998	1.002	1.000	1.000	0.0007
1000A Range; 1mV/A @60 Hz	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)	(mV AC)
10 A	10.0	9.7	10.3	10.0	10.0	0.07
100 A	100.0	99.3	100.7	100.0	100.0	0.06
500 A	500.0	499.0	501.0	500.3	500.3	0.07
900 A	900.0	898.0	902.0	900.6	900.6	0.07

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK196-72143-379

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Torque Wrench
Make	CDI
Model	1502LDIN (3%)
Serial Number	0312910937
Identification	EM8363
Customer Location	ICD
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Jim Peterson
Technical Review By	Kevin Dehne
Calibration Location	FVM
Calibration Conditions	69.0°F, 20.6°C, 54.2%RH
Calibration Date	07/14/2020
Recalibration Due	07/14/2021

Procedures Followed
FVE-014 rev. 2

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVS-093	03111	CK191-31886-628	10/31/2020
FVS-275A	RY11838	CJ191-70508-513	07/28/2020

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
Clockwise	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)
	30.00	29.10	30.90	29.89	29.89	0.091
	90.00	87.30	92.70	90.23	90.23	0.271
	150.00	145.50	154.50	152.00	152.00	0.450
Counter Clockwise	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)	(in lb)
	30.00	29.10	30.90	30.31	30.31	0.091
	90.00	87.30	92.70	89.53	89.53	0.271
	150.00	145.50	154.50	148.58	148.58	0.450

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CERTIFICATE OF CALIBRATION

ACCREDITED ISO/IEC 17025 CALIBRATION AND TESTING LABORATORY
Certificate No. ACT-1272

Certification Number CK198-49542-348

For Eaton Corporation - ICD
W126 N7250 Flint Drive
Menomonee Falls, WI 53051

Purchase Order #	4044-671109
Test Instrument	Tape Measure
Make	Stanley
Model	30-824
Serial Number	
Identification	EM6927
Customer Location	ICD
	Tony
Condition Received	In Tolerance
Condition Returned	In Tolerance
Calibrated By	Matthew Roughen
Technical Review By	Laura Fuhrmann
Calibration Location	FVM
Calibration Conditions	69.5°F, 20.8°C, 34.8%RH
Calibration Date	07/16/2020
Recalibration Due	07/16/2021

Procedures Followed
FVM-042 rev. 1

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Form Revision 6: 02/04/2012

Standards Used

Instrument	Serial Number	Trace Number	Next Cal
FVM-044	C404R	CH121-20770-384	05/28/2022
FVM-079A	RY11924	CJ191-72229-513	07/28/2020

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. (This is considered "shared responsibility.") Uncertainties expressed in nominal units.

All instruments have been calibrated against standards traceable to NIST. Calibration was completed in accordance with ISO/IEC 17025:2017, ANSI/NCSL Z540-1-1994 and ANSI/NCSL Z540.3-2006. Other standards listed upon request.

Calibration Results

* denotes "Out of Tolerance"

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
Length	(in)	(in)	(in)	(in)	(in)	
	12.000	11.969	12.031	11.995	11.995	0.0006
	24.000	23.938	24.062	23.995	23.995	0.0007
	48.000	47.938	48.062	47.995	47.995	0.0007
	72.000	71.938	72.062	71.995	71.995	0.0007
	144.000	143.938	144.062	143.995	143.995	0.0006
	216.000	215.938	216.062	215.995	215.995	0.0006
	312.000	311.938	312.062	311.995	311.995	0.0007
Length	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
	500.00	499.00	501.00	499.87	499.87	0.007
	1000.00	999.00	1001.00	999.87	999.87	0.006
	5000.00	4999.00	5001.00	4999.87	4999.87	0.008
	8000.00	7999.00	8001.00	7999.87	7999.87	0.012

Public Input No. 2642-NFPA 70-2020 [Article 311]

Article 311 Medium Voltage Conductors, Cable, Cable Joints and Cable Terminations

Part I. General

311.1 Scope.

This article covers the use, installation, construction specifications, and ampacities for Type MV medium voltage conductors, cable, cable joints, and cable terminations .

311.2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Cable Joint, Type MV.

A connection, consisting of an insulation system and a connector, where two (or more) cables are joined together, in a way which is to be chemically, mechanically and electrically stable.

Informational Note: Cable joints are often referred to as splices. However, the term splice includes many other applications not included in the definition of a cable joint. Refer to the industry standard IEEE-404, *IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5kV to 500kV* , for more information on cable joints.

Cable Termination, Type MV.

A connection, consisting of an insulation system and a connector, installed on a type MV cable, to connect from a cable to a device, such as equipment, in a way which is to be chemically, mechanically and electrically stable.

Informational Note No.1: Type MV Cable Terminations include terminations used to connect directly to equipment or insulators. Refer to the industry standard IEEE-48, *IEEE Standard for Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV* , for information on terminations.

Informational Note No.2: Type MV Cable Terminations also include separable insulated connectors, which are a type of pluggable cable termination and may be used for connection to equipment such as, switchgear or transformers. A separable connector has a matching interface that the separable connector plugs into on the equipment such as, switchgear or transformers. Separable connectors may also be ganged together to form a distribution junction using specialized junction brackets. Refer to the industry standard IEEE-386, *IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Rated 2.5kV through 35 kV* , and IEEE-1215, *IEEE Guide for the Application of Separable Insulated Connectors* , for more information on separable insulated connectors.

Electrical Ducts.

Electrical conduits, or other raceways round in cross section, that are suitable for use underground or embedded in concrete.

Medium Voltage Cable, Type MV.

A single or multiconductor solid dielectric insulated cable rated 2001 volts up to and including 35,000 volts, nominal.

Thermal Resistivity.

As used in this *Code*, the heat transfer capability through a substance by conduction.

Informational Note: Thermal resistivity is the reciprocal of thermal conductivity and is designated Rho, which is expressed in the units °C-cm/W.

311.6 Listing Requirements.

Type MV cables, type MV cable joints, type MV cable terminations, connectors and associated fittings shall be listed.

Part II. Construction Specifications

311.10 Constructions and Applications.

Type MV cables shall comply with the applicable provisions in 311.10(A) through (C).

(A) Conductor Application and Insulation.

Conductor application and insulation shall comply with Table 311.10(A).

(B) Thickness of Insulation and Jacket for Nonshielded Insulated Conductors.

Thickness of insulation and jacket for nonshielded solid dielectric insulated conductors rated 2001 volts to 5000 volts shall comply with Table 311.10(B).

(C) Thickness of Insulation for Shielded Insulated Conductors.

Thickness of insulation for shielded solid dielectric insulated conductors rated 2001 volts to 35,000 volts shall comply with Table 311.10(C) and 311.10(C)(1) through (C)(3).

(1) 100 Percent Insulation Level.

Cables shall be permitted to be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible but, in any case, within 1 minute. These cables are applicable to cable installations that are on grounded systems and shall be permitted to be used on other systems provided the above clearing requirements are met in completely de-energizing the faulted section.

(2) 133 Percent Insulation Level.

Cables shall be permitted to be applied in situations where the clearing time requirements of the 100 percent level category cannot be met and the faulted section will be de-energized in a time not exceeding 1 hour. Cable shall be permitted to be used in 100 percent insulation level applications where the installation requires additional insulation.

(3) 173 Percent Insulation Level.

Cables shall be permitted to be applied under all of the following conditions:

(1) In industrial establishments where the conditions of maintenance and supervision ensure only qualified persons service the installation

(2) Where the fault clearing time requirements of the 133 percent level category cannot be met

(3) Where an orderly shutdown is required to protect equipment and personnel

(4) Where the faulted section will be de-energized in an orderly shutdown

Cables shall be permitted to be used in 100 percent or 133 percent insulation level applications where the installation requires additional insulation.

Table 311.10(A) Conductor Application and Insulation Rated 2001 Volts and Higher

Trade Name	Type Letter	Maximum Operating Temperature	Application Provision	Insulation	Outer Covering
Medium voltage solid dielectric	MV-90	90°C	Dry or wet locations	Thermoplastic or thermosetting	Jacket, sheath, or armor
	MV-105*	105°C			

*Where design conditions require maximum conductor temperatures above 90°C.

Table 311.10(B) Thickness of Insulation and Jacket for Nonshielded Solid Dielectric Insulated Conductors Rated 2001 Volts to 5000 Volts

Conductor Size (AWG or kcmil)	Dry Locations, Single Conductor						Wet or Dry Locations						Multicondu Insulatic
	Without Jacket Insulation		With Jacket				Single Conductor						
			Insulation		Jacket		Insulation		Jacket				
	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils			
8	2.79	110	2.29	90	0.76	30	3.18	125	2.03	80			
6	2.79	110	2.29	90	0.76	30	3.18	125	2.03	80			
4–2	2.79	110	2.29	90	1.14	45	3.18	125	2.03	80			
1–2/0	2.79	110	2.29	90	1.14	45	3.18	125	2.03	80			
3/0–4/0	2.79	110	2.29	90	1.65	65	3.18	125	2.41	95			
213–500	3.05	120	2.29	90	1.65	65	3.56	140	2.79	110			
501–750	3.30	130	2.29	90	1.65	65	3.94	155	3.18	125			
751–1000	3.30	130	2.29	90	1.65	65	3.94	155	3.18	125			
1001–1250	3.56	140	2.92	115	1.65	65	4.32	170	3.56	140			
1251–1500	3.56	140	2.92	115	2.03	80	4.32	170	3.56	140			
1501–2000	3.56	140	2.92	115	2.03	80	4.32	170	3.94	155			

*Under a common overall covering such as a jacket, sheath, or armor.

Table 311.10(C) Thickness of Insulation for Shielded Solid Dielectric Insulated Conductors Rated 2001 Volts to 35,000 Volts

	2001–5000 Volts	5001–8000 Volts			8001–15,000	
Conductor Size	100 Percent	100 Percent	133 Percent	173 Percent	100 Percent	

(AWG or kcmil)	Insulation Level mm	mils	Insulation Level mm	mils	Insulation Level mm	mils	Insulation Level mm	mils	Insulation Level mm	mils	In m
8	2.29	90	—	—	—	—	—	—	—	—	–
6–4	2.29	90	2.92	115	3.56	140	4.45	175	—	—	–
2	2.29	90	2.92	115	3.56	140	4.45	175	4.45	175	5.5
1	2.29	90	2.92	115	3.56	140	4.45	175	4.45	175	5.5
1/0–2000	2.29	90	2.92	115	3.56	140	4.45	175	4.45	175	5.5

Conductor Size (AWG or kcmil)	25,001–28,000 Volts 100 Percent Insulation Level mm	mils	133 Percent Insulation Level mm	mils	173 Percent Insulation Level mm	mils	28,001–35,000 Volts 100 Percent Insulation Level mm	mils	133 Percent Insulation Level mm	mils	F In m
1	7.11	280	8.76	345	11.30	445	—	—	—	—	–
1/0–2000	7.11	280	8.76	345	11.30	445	8.76	345	10.67	420	14

311.12 Conductors.

(A) Minimum Size of Conductors.

The minimum size of conductors shall be as shown in Table 311.12(A), except as permitted elsewhere in this *Code*.

Table 311.12(A) Minimum Size of Conductors

Conductor Voltage Rating (Volts)	Minimum Conductor Size (AWG) Copper, Aluminum, or Copper-Clad Aluminum
2001–5000	8
5001–8000	6
8001–15,000	2
15,001–28,000	1
28,001–35,000	1/0

(B) Conductor Material.

Conductors shall be of aluminum, copper-clad aluminum, or copper unless otherwise specified.

(C) Stranded Conductors.

Where installed in raceways, conductors not specifically permitted or required elsewhere in this Code to be solid shall be stranded.

311.14 Conductor Identification.

Conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from grounded and grounding conductors. Distinguishing markings shall not conflict in any manner with the surface markings required by 311.16(B)(1). Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C). Feeders shall be identified in accordance with 215.12.

311.16 Marking for Type MV Cables and Conductors .

(A) Required Information **for Type MV Cables and Conductors** .

All conductors and cables shall be marked to indicate the following information, using the applicable method described in 311.16(B):

(1) The maximum rated voltage

(2) The proper type letter or letters for the type of wire or cable as specified elsewhere in this *Code*

(3) The manufacturer's name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified

(4) The AWG size or circular mil area

Informational Note: See Chapter 9, Table 8, Conductor Properties, for conductor area expressed in SI units for conductor sizes specified in AWG or circular mil area.

(B) Method of Marking for **Type MV Cables and Conductors** .

One or more of the methods in 311.16(B)(1) through (B)(4) shall be used for marking of cable.

(1) Surface Marking.

Cables shall be durably marked on the surface. The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).

(2) Marker Tape.

Metal-covered multiconductor cables shall employ a marker tape located within the cable and along its complete length.

(3) Tag Marking.

Metal-covered, single-conductor cables shall be marked by means of a printed tag attached to the reel.

(4) Optional Marking of Wire Size.

The information required in 311.16(A)(4) shall be permitted to be marked on the surface of the individual insulated conductors for multiconductor Type MC cable.

(C) Optional Markings.

Cables shall be permitted to be marked to indicate special characteristics of the cable materials, such as limited smoke and sunlight resistance.

311.17 Marking for Type MV Cable Joints and Terminations.

(A) Required Information for Type MV Cable Joints, Terminations and Connectors. All type MV cable joints, cable terminations and connectors shall be marked to indicate the following information, using one or more of the methods described in 311.17 (B) (1) or (B) (2) and may be optionally marked as described in 311.17 (D):

(1) The maximum rated voltage.

(2) The proper type letter or letters for the type of wire or cable as specified elsewhere in this *Code* that the cable joint or cable terminations is listed for use with.

(3) The manufacturers name, trademark, or other distinctive marking by which the organizations responsible for the product can be readily identified.

(4) The condutor AWG size or cirular mil area size, or range of sizes, that the cable joint or cable terminations is listed for use with.

(5) The cable outer diameter size, or size range, that the cable joint or cable termination is listed for use with.

(6) Connectors shall be marked with the following information; the marking shall aslo be on the unit container (the smallest container in which the connector is packaged):

(a) The manufacturers name, trademark, or other distinctive marking by which the organization responsible for the product can be redily identified.

(b) The manufacturers catalog number.

(c) The conductor AWG size or circular mil use range, and die number, if applicable.

(d) The type of conductor material(s) the connector is for use with.

(B) Method of Marking for Type MV Cable Joints, Terminations and Connectors.

One or both of the methods in 311.17 (B)(1) or (B)(2) shall be used for the marking of cable joints, terminations or connectors.

(1) Surface Marking.

Type MV cable joints, terminations or connectors shall be durably marked on the surface

(2) Tag Marking.

Type MV Cable joints, terminations or connectors shall be marked by means of a durably printed tag or label attached to joint or termination.

(D) Optional Markings.

Type MV cable joints and cable terminations shall be permitted to be marked to indicate special characteristics, such as limited smoke and sunlight resistance.

Part III. Installation

311.30 Installation.

~~Type~~ Qualified persons with documented training and experience in the installation and testing of type MV cable shall ~~be installed, terminated, and tested by qualified persons.~~ perform the installation and testing of type MV cable.Qualified persons with documented training and experience in the installation of type MV cable joints shall perform the installation of type MV cable joints. Qualified persons with documented training and experience in the installation of type MV cable terminations shall perform the installation of type MV cable terminations.

Informational Note No. 1: Information about accepted industry practices and installation procedures for medium-voltage cable are described in ANSI/NECA/NCSCB 600, *Standard for Installing and Maintaining Medium-Voltage Cable*, and in IEEE 576, *Recommended Practice for Installation, Termination, and Testing of Insulated Power Cables as Used in Industrial and Commercial Applications*.

Informational Note No. 2: Where medium-voltage cable is used for dc circuits, low frequency polarization can create hazardous voltages. When handling the cable these voltages may be present or may develop on dc stressed cable while the circuit is energized. Solidly grounding the cable prior to contacting, cutting or disconnecting cables in dc circuits is a method to discharge these voltages.

311.32 Uses Permitted.

(A) Type MV cable . shall be permitted for use on power systems rated up to and including 35,~~000 volts~~ 000 Volts , nominal, as follows:

(1) In wet or dry locations.

(2) In raceways.

(3) In cable trays, where identified for the use, in accordance with 392.10, 392.20(B), (C), and (D), 392.22(C), 392.30(B)(1), 392.46, 392.56, and 392.60. Type MV cable that has an overall metallic sheath or armor, complies with the requirements for Type MC cable, and is identified as “MV or MC” shall be permitted to be installed in cable trays in accordance with 392.10(B)(2).

(4) In messenger-supported wiring in accordance with Part II of Article 396.

(5) As exposed runs in accordance with 300.37. Type MV cable that has an overall metallic sheath or armor, complies with the requirements for Type MC cable, and is identified as “MV or MC” shall be permitted to be installed as exposed runs of metal-clad cable in accordance with 300.37.

(6) Corrosive conditions where exposed to oils, greases, vapors, gases, fumes, liquids, or other substances having a deleterious effect on the conductor or insulation shall be of a type suitable for the application.

(7) Conductors in parallel in accordance with 310.10(G).

(8) Type MV cable used where exposed to direct sunlight shall be identified for the use.

Informational Note: The “uses permitted” is not an all-inclusive list.

(B) Type MV cable Joints and Terminations. shall be permitted for use on power systems rated up to and including 35,000 Volts, nominal, as follows:

(1) Type MV cable joints and terminations, used where exposed to direct sunlight, shall be identified for the use.

(2) Direct Buried.

(3) Where used intermittently or continuously submerged in water at a depth not exceeding 7m (23 ft) type MV cable joints and terminations shall be identified for the use.

(4) The environmental operating temperature range shall be identified.

(5) Where used in one or more of the following conditions type MV cable joints and terminations shall be identified for the use:

a. Underground Chambers,

b. Tunnels,

c. Conduits,

d. Manholes,

e. Vaults

(6) Corrosive conditions where exposed to oils, greases, vapors, gases, fumes, liquids, or other substances having a deleterious effect on the joint or termination shall be of a type suitable for the application.

(7) In cable trays, where identified for use, in accordance with 392.10, 392.20(B), (C) and (D), 392.22 (C), 392.30(B)(1), 392.46, 392.56 and 392.60.

Informational Note: The “uses permitted” is not an all-inclusive list.

311.36 Direct-Burial Conductors.

Type MV conductors and cables used for direct burial applications shall be shielded, identified for such use, and installed in accordance with 300.50.

Exception No. 1: Nonshielded multiconductor cables rated 2001 volts to 2400 volts shall be permitted if the cable has an overall metallic sheath or armor.

The metallic shield, sheath, or armor shall be connected to a grounding electrode conductor, a grounding busbar, or a grounding electrode.

Exception No. 2: Airfield lighting cable used in series circuits that are rated up to 5000 volts and are powered by regulators shall be permitted to be nonshielded.

Informational Note to Exception No. 2: Federal Aviation Administration (FAA) Advisory Circulars (ACs) provide additional practices and methods for airport lighting.

311.40 Support.

Type MV cable terminated in equipment or installed in pull boxes or vaults shall be secured and supported by metallic or nonmetallic supports suitable to withstand the weight by cable ties listed and identified for securement and support, or other approved means, at intervals not exceeding 1.5 m (5 ft) from terminations or a maximum of 1.8 m (6 ft) between supports.

311.44 Shielding.

Nonshielded, ozone-resistant insulated conductors with a maximum phase-to-phase voltage of 5000 volts shall be permitted in Type MC cables in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation. For other establishments, solid dielectric insulated conductors operated above 2000 volts in permanent installations shall have ozone-resistant insulation and shall be shielded. All metallic insulation shields shall be connected to a grounding electrode conductor, a grounding busbar, an equipment grounding conductor, or a grounding electrode.

Informational Note: The primary purposes of shielding are to confine the voltage stresses to the insulation, dissipate insulation leakage current, drain off the capacitive charging current, and carry ground-fault current to facilitate operation of ground-fault protective devices in the event of an electrical cable fault.

Exception No. 1: Nonshielded insulated conductors listed by a qualified testing laboratory shall be permitted for use up to 2400 volts under the following conditions:

(1) Conductors shall have insulation resistant to electric discharge and surface tracking, or the insulated conductor(s) shall be covered with a material resistant to ozone, electric discharge, and surface tracking.

(2) Where used in wet locations, the insulated conductor(s) shall have an overall nonmetallic jacket or a continuous metallic sheath.

(3) Insulation and jacket thicknesses shall be in accordance with Table 311.10(B).

Exception No. 2: Nonshielded insulated conductors listed by a qualified testing laboratory shall be permitted for use up to 5000 volts to replace existing nonshielded conductors, on existing equipment in industrial establishments only, under the following conditions:

(1) Where the condition of maintenance and supervision ensures that only qualified personnel install and service the installation.

(2) Conductors shall have insulation resistant to electric discharge and surface tracking, or the insulated conductor(s) shall be covered with a material resistant to ozone, electric discharge, and surface tracking.

(3) Where used in wet locations, the insulated conductor(s) shall have an overall nonmetallic jacket or a continuous metallic sheath.

(4) Insulation and jacket thicknesses shall be in accordance with Table 311.10(B).

Informational Note: Relocation or replacement of equipment may not comply with the term existing as related to this exception.

Exception No. 3: Where permitted in 311.36, Exception No. 2.

311.45 Shielding at Type MV Cable Joints and Terminations.

Type MV cable joints and terminations shall be provided with means to connect the metallic insulation shield to ground if required.

Part IV. Ampacities

311.60 Ampacities of Conductors.

(A) General.

(1) Tables or Engineering Supervision.

Ampacities for solid dielectric-insulated conductors shall be permitted to be determined by tables or under engineering supervision, as provided in 311.60(B) and (C).

The ampacity of Type MV cable installed in cable tray shall be determined in accordance with 392.80(B).

(2) Selection of Ampacity.

Where more than one calculated or tabulated ampacity could apply for a given circuit length, the lowest value shall be used.

Exception: Where different ampacities apply to portions of a circuit, the higher ampacity shall be permitted to be used if the total portion(s) of the circuit with the lower ampacity does not exceed the lesser of 3.0 m (10 ft) or 10 percent of the total circuit.

Informational Note: See 110.40 for conductor temperature limitations due to termination provisions.

(B) Engineering Supervision.

Under engineering supervision, conductor ampacities shall be permitted to be calculated by using the following general equation:

$$I = \sqrt{\frac{T_c - (T_a + \Delta T_d)}{R_{dc}(1 + Y_c)R_{ca}}} \times 10^3 \text{ amperes} \qquad \textbf{[311.60(B)]}$$

where:

T_C = conductor temperature (°C)

T_a = ambient temperature (°C)

ΔT_d = dielectric loss temperature rise

R_{dc} = dc resistance of conductor at temperature, T_C

Y_C = component ac resistance resulting from skin effect and proximity effect

R_{ca} = effective thermal resistance between conductor and surrounding ambient

Informational Note: The dielectric loss temperature rise (ΔT_d) is negligible for single circuit extruded dielectric cables rated below 46 kilovolts.

(C) Tables.

Ampacities for conductors rated 2001 volts to 35,000 volts shall be as specified in Table 311.60(C)(67) through Table 311.60(C)(86). Ampacities for ambient temperatures other than those specified in the ampacity tables shall be corrected in accordance with 311.60(D)(4).

Informational Note No. 1: For ampacities calculated in accordance with 311.60(A), reference IEEE 835, *Standard Power Cable Ampacity Tables*, and the references therein for availability of all factors and constants.

Informational Note No. 2: Ampacities provided by this section do not take voltage drop into consideration. See 210.19(A), Informational Note No. 4, for branch circuits and 215.2(A), Informational Note No. 2, for feeders.

Table 311.60(C)(67) Ampacities of Insulated Single Copper Conductor Cables Triplexed in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	65	74	—	—
6	90	99	100	110
4	120	130	130	140
2	160	175	170	195
1	185	205	195	225
1/0	215	240	225	255
2/0	250	275	260	295
3/0	290	320	300	340
4/0	335	375	345	390
250	375	415	380	430
350	465	515	470	525
500	580	645	580	650
750	750	835	730	820
1000	880	980	850	950

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(68) Ampacities of Insulated Single Aluminum Conductor Cables Triplexed in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	50	57	—	—
6	70	77	75	84
4	90	100	100	110
2	125	135	130	150
1	145	160	150	175
1/0	170	185	175	200

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
2/0	195	215	200	230
3/0	225	250	230	265
4/0	265	290	270	305
250	295	325	300	335
350	365	405	370	415
500	460	510	460	515
750	600	665	590	660
1000	715	800	700	780

Note: Refer to 311.60(E) for basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(69) Ampacities of Insulated Single Copper Conductor Isolated in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor					
	2001–5000 Volts Ampacity		5001–15,000 Volts Ampacity		15,001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	83	93	—	—	—	—
6	110	120	110	125	—	—
4	145	160	150	165	—	—
2	190	215	195	215	—	—
1	225	250	225	250	225	250
1/0	260	290	260	290	260	290
2/0	300	330	300	335	300	330
3/0	345	385	345	385	345	380
4/0	400	445	400	445	395	445
250	445	495	445	495	440	490
350	550	615	550	610	545	605
500	695	775	685	765	680	755
750	900	1000	885	990	870	970
1000	1075	1200	1060	1185	1040	1160
1250	1230	1370	1210	1350	1185	1320
1500	1365	1525	1345	1500	1315	1465
1750	1495	1665	1470	1640	1430	1595
2000	1605	1790	1575	1755	1535	1710

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(70) Ampacities of Insulated Single Aluminum Conductor Isolated in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor							
	2001–5000 Volts Ampacity		5001–15,000 Volts Ampacity		15,001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	64	71	—	—	—	—
6	85	95	87	97	—	—
4	115	125	115	130	—	—
2	150	165	150	170	—	—
1	175	195	175	195	175	195
1/0	200	225	200	225	200	225
2/0	230	260	235	260	230	260
3/0	270	300	270	300	270	300
4/0	310	350	310	350	310	345
250	345	385	345	385	345	380
350	430	480	430	480	430	475
500	545	605	535	600	530	590
750	710	790	700	780	685	765
1000	855	950	840	940	825	920
1250	980	1095	970	1080	950	1055
1500	1105	1230	1085	1215	1060	1180
1750	1215	1355	1195	1335	1165	1300
2000	1320	1475	1295	1445	1265	1410

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(71) Ampacities of an Insulated

Three-Conductor Copper Cable Isolated in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	59	66	—	—
6	79	88	93	105
4	105	115	120	135
2	140	154	165	185
1	160	180	185	210
1/0	185	205	215	240
2/0	215	240	245	275

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
3/0	250	280	285	315
4/0	285	320	325	360
250	320	355	360	400
350	395	440	435	490
500	485	545	535	600
750	615	685	670	745
1000	705	790	770	860

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(72) Ampacities of an Insulated

Three-Conductor Aluminum Cable Isolated in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	46	51	—	—
6	61	68	72	80
4	81	90	95	105
2	110	120	125	145
1	125	140	145	165
1/0	145	160	170	185
2/0	170	185	190	215
3/0	195	215	220	245
4/0	225	250	255	285
250	250	280	280	315
350	310	345	345	385
500	385	430	425	475
750	495	550	540	600
1000	585	650	635	705

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(73) Ampacities of an Insulated Triplexed or Three Single-Conductor Copper Cables in Isolated Conduit in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	55	61	—	—
6	75	84	83	93
4	97	110	110	120
2	130	145	150	165
1	155	175	170	190
1/0	180	200	195	215
2/0	205	225	225	255
3/0	240	270	260	290
4/0	280	305	295	330
250	315	355	330	365
350	385	430	395	440
500	475	530	480	535
750	600	665	585	655
1000	690	770	675	755

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(74) Ampacities of an Insulated Triplexed or Three Single-Conductor Aluminum Cables in Isolated Conduit in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	43	48	—	—
6	58	65	65	72
4	76	85	84	94
2	100	115	115	130
1	120	135	130	150
1/0	140	155	150	170
2/0	160	175	175	200
3/0	190	210	200	225
4/0	215	240	230	260
250	250	280	255	290
350	305	340	310	350
500	380	425	385	430
750	490	545	485	540
1000	580	645	565	640

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum

operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(75) Ampacities of an Insulated

Three-Conductor Copper Cable in Isolated Conduit in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	52	58	—	—
6	69	77	83	92
4	91	100	105	120
2	125	135	145	165
1	140	155	165	185
1/0	165	185	195	215
2/0	190	210	220	245
3/0	220	245	250	280
4/0	255	285	290	320
250	280	315	315	350
350	350	390	385	430
500	425	475	470	525
750	525	585	570	635
1000	590	660	650	725

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(76) Ampacities of an Insulated

Three-Conductor Aluminum Cable in Isolated Conduit in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	41	46	—	—
6	53	59	64	71
4	71	79	84	94
2	96	105	115	125
1	110	125	130	145
1/0	130	145	150	170
2/0	150	165	170	190

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
3/0	170	190	195	220
4/0	200	225	225	255
250	220	245	250	280
350	275	305	305	340
500	340	380	380	425
750	430	480	470	520
1000	505	560	550	615

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(77) Ampacities of Three Single-Insulated Copper Conductors in Underground Electrical Ducts

(Three Conductors per Electrical Duct)

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]				
8	64	69	—	—
6	85	92	90	97
4	110	120	115	125
2	145	155	155	165
1	170	180	175	185
1/0	195	210	200	215
2/0	220	235	230	245
3/0	250	270	260	275
4/0	290	310	295	315
250	320	345	325	345
350	385	415	390	415
500	470	505	465	500
750	585	630	565	610
1000	670	720	640	690
Three Circuits [See Figure 311.60(D)(3), Detail 2.]				
8	56	60	—	—

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
6	73	79	77	83
4	95	100	99	105
2	125	130	130	135
1	140	150	145	155
1/0	160	175	165	175
2/0	185	195	185	200
3/0	210	225	210	225
4/0	235	255	240	255
250	260	280	260	280
350	315	335	310	330
500	375	405	370	395
750	460	495	440	475
1000	525	565	495	535
Six Circuits [See Figure 311.60(D)(3), Detail 3.]				
8	48	52	—	—
6	62	67	64	68
4	80	86	82	88
2	105	110	105	115
1	115	125	120	125
1/0	135	145	135	145
2/0	150	160	150	165
3/0	170	185	170	185
4/0	195	210	190	205
250	210	225	210	225
350	250	270	245	265
500	300	325	290	310
750	365	395	350	375
1000	410	445	390	415

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(78) Ampacities of Three Single-Insulated Aluminum Conductors in Underground Electrical Ducts

(Three Conductors per Electrical Duct)

Conductor Size	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	5001–35,000 Volts Ampacity

(AWG or kcmil)	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105		90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]					
8	50	54		—	—
6	66	71		70	75
4	86	93		91	98
2	115	125		120	130
1	130	140		135	145
1/0	150	160		155	165
2/0	170	185		175	190
3/0	195	210		200	215
4/0	225	245		230	245
250	250	270		250	270
350	305	325		305	330
500	370	400		370	400
750	470	505		455	490
1000	545	590		525	565
Three Circuits [See Figure 311.60(D)(3), Detail 2.]					
8	44	47		—	—
6	57	61		60	65
4	74	80		77	83
2	96	105		100	105
1	110	120		110	120
1/0	125	135		125	140
2/0	145	155		145	155
3/0	160	175		165	175
4/0	185	200		185	200
250	205	220		200	220
350	245	265		245	260
500	295	320		290	315
750	370	395		355	385
1000	425	460		405	440
Six Circuits [See Figure 311.60(D)(3), Detail 3.]					
8	38	41		—	—
6	48	52		50	54
4	62	67		64	69
2	80	86		80	88
1	91	98		90	99
1/0	105	110		105	110
2/0	115	125		115	125
3/0	135	145		130	145

4/0	150	165	-	150	160
250	165	180	-	165	175
350	195	210	-	195	210
500	240	255	-	230	250
750	290	315	-	280	305
1000	335	360	-	320	345

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(79) Ampacities of Three Insulated Copper Conductors Cabled Within an Overall Covering

(Three-Conductor Cable) in Underground Electrical Ducts (One Cable per Electrical Duct)

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor				
	2001–5000 Volts Ampacity		-	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	-	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]					
8	59	64	-	—	—
6	78	84	-	88	95
4	100	110	-	115	125
2	135	145	-	150	160
1	155	165	-	170	185
1/0	175	190	-	195	210
2/0	200	220	-	220	235
3/0	230	250	-	250	270
4/0	265	285	-	285	305
250	290	315	-	310	335
350	355	380	-	375	400
500	430	460	-	450	485
750	530	570	-	545	585
1000	600	645	-	615	660
Three Circuits [See Figure 311.60(D)(3), Detail 2.]					
8	53	57	-	—	—
6	69	74	-	75	81
4	89	96	-	97	105
2	115	125	-	125	135
1	135	145	-	140	155
1/0	150	165	-	160	175
2/0	170	185	-	185	195
3/0	195	210	-	205	220
4/0	225	240	-	230	250

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
250	245	265	255	270
350	295	315	305	325
500	355	380	360	385
750	430	465	430	465
1000	485	520	485	515
Six Circuits [See Figure 311.60(D)(3), Detail 3.]				
8	46	50	—	—
6	60	65	63	68
4	77	83	81	87
2	98	105	105	110
1	110	120	115	125
1/0	125	135	130	145
2/0	145	155	150	160
3/0	165	175	170	180
4/0	185	200	190	200
250	200	220	205	220
350	240	270	245	275
500	290	310	290	305
750	350	375	340	365
1000	390	420	380	405

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(80) Ampacities of Three Insulated Aluminum Conductors Cabled Within an Overall Covering

(Three-Conductor Cable) in Underground Electrical Ducts (One Cable per Electrical Duct)

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]				
8	46	50	—	—
6	61	66	69	74
4	80	86	89	96
2	105	110	115	125

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
1	120	130	135	145
1/0	140	150	150	165
2/0	160	170	170	185
3/0	180	195	195	210
4/0	205	220	220	240
250	230	245	245	265
350	280	310	295	315
500	340	365	355	385
750	425	460	440	475
1000	495	535	510	545
Three Circuits [See Figure 311.60(D)(3), Detail 2.]				
8	41	44	—	—
6	54	58	59	64
4	70	75	75	81
2	90	97	100	105
1	105	110	110	120
1/0	120	125	125	135
2/0	135	145	140	155
3/0	155	165	160	175
4/0	175	185	180	195
250	190	205	200	215
350	230	250	240	255
500	280	300	285	305
750	345	375	350	375
1000	400	430	400	430
Six Circuits [See Figure 311.60(D)(3), Detail 3.]				
8	36	39	—	—
6	46	50	49	53
4	60	65	63	68
2	77	83	80	86
1	87	94	90	98
1/0	99	105	105	110
2/0	110	120	115	125
3/0	130	140	130	140
4/0	145	155	150	160
250	160	170	160	170
350	190	205	190	205

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
500	230	245	230	245
750	280	305	275	295
1000	320	345	315	335

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(81) Ampacities of Single Insulated Copper Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 9.]				
8	110	115	—	—
6	140	150	130	140
4	180	195	170	180
2	230	250	210	225
1	260	280	240	260
1/0	295	320	275	295
2/0	335	365	310	335
3/0	385	415	355	380
4/0	435	465	405	435
250	470	510	440	475
350	570	615	535	575
500	690	745	650	700
750	845	910	805	865
1000	980	1055	930	1005
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 10.]				
8	100	110	—	—
6	130	140	120	130
4	165	180	160	170
2	215	230	195	210
1	240	260	225	240
1/0	275	295	255	275
2/0	310	335	290	315
3/0	355	380	330	355

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
4/0	400	430	375	405
250	435	470	410	440
350	520	560	495	530
500	630	680	600	645
750	775	835	740	795
1000	890	960	855	920

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(82) Ampacities of Single Insulated Aluminum Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 9.]				
8	85	90	—	—
6	110	115	100	110
4	140	150	130	140
2	180	195	165	175
1	205	220	185	200
1/0	230	250	215	230
2/0	265	285	245	260
3/0	300	320	275	295
4/0	340	365	315	340
250	370	395	345	370
350	445	480	415	450
500	540	580	510	545
750	665	720	635	680
1000	780	840	740	795
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 10.]				
8	80	85	—	—
6	100	110	95	100
4	130	140	125	130
2	165	180	155	165

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
1	190	200	175	190
1/0	215	230	200	215
2/0	245	260	225	245
3/0	275	295	255	275
4/0	310	335	290	315
250	340	365	320	345
350	410	440	385	415
500	495	530	470	505
750	610	655	580	625
1000	710	765	680	730

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(83) Ampacities of Three Insulated Copper Conductors Cabled Within an Overall Covering

(Three-Conductor Cable), Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 5.]				
8	85	89	—	—
6	105	115	115	120
4	135	150	145	155
2	180	190	185	200
1	200	215	210	225
1/0	230	245	240	255
2/0	260	280	270	290
3/0	295	320	305	330
4/0	335	360	350	375
250	365	395	380	410
350	440	475	460	495
500	530	570	550	590
750	650	700	665	720
1000	730	785	750	810
Two Circuits [See Figure 311.60(D)(3), Detail 6.]				

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	80	84	—	—
6	100	105	105	115
4	130	140	135	145
2	165	180	170	185
1	185	200	195	210
1/0	215	230	220	235
2/0	240	260	250	270
3/0	275	295	280	305
4/0	310	335	320	345
250	340	365	350	375
350	410	440	420	450
500	490	525	500	535
750	595	640	605	650
1000	665	715	675	730

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(84) Ampacities of Three Insulated Aluminum Conductors Cabled Within an Overall Covering

(Three-Conductor Cable), Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 5.]				
8	65	70	—	—
6	80	88	90	95
4	105	115	115	125
2	140	150	145	155
1	155	170	165	175
1/0	180	190	185	200
2/0	205	220	210	225
3/0	230	250	240	260
4/0	260	280	270	295
250	285	310	300	320
350	345	375	360	390

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
500	420	450	435	470
750	520	560	540	580
1000	600	650	620	665
Two Circuits [See Figure 311.60(D)(3), Detail 6.]				
8	60	66	—	—
6	75	83	80	95
4	100	110	105	115
2	130	140	135	145
1	145	155	150	165
1/0	165	180	170	185
2/0	190	205	195	210
3/0	215	230	220	240
4/0	245	260	250	270
250	265	285	275	295
350	320	345	330	355
500	385	415	395	425
750	480	515	485	525
1000	550	590	560	600

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(85) Ampacities of Three Triplexed Single Insulated Copper Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 7.]				
8	90	95	—	—
6	120	130	115	120
4	150	165	150	160
2	195	205	190	205
1	225	240	215	230
1/0	255	270	245	260
2/0	290	310	275	295

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
3/0	330	360	315	340
4/0	375	405	360	385
250	410	445	390	410
350	490	580	470	505
500	590	635	565	605
750	725	780	685	740
1000	825	885	770	830
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 8.]				
8	85	90	—	—
6	110	115	105	115
4	140	150	140	150
2	180	195	175	190
1	205	220	200	215
1/0	235	250	225	240
2/0	265	285	255	275
3/0	300	320	290	315
4/0	340	365	325	350
250	370	395	355	380
350	445	480	425	455
500	535	575	510	545
750	650	700	615	660
1000	740	795	690	745

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(86) Ampacities of Three Triplexed Single Insulated Aluminum Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 7.]				
8	70	75	—	—
6	90	100	90	95

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor			
	2001–5000 Volts Ampacity		5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
4	120	130	115	125
2	155	165	145	155
1	175	190	165	175
1/0	200	210	190	205
2/0	225	240	215	230
3/0	255	275	245	265
4/0	290	310	280	305
250	320	350	305	325
350	385	420	370	400
500	465	500	445	480
750	580	625	550	590
1000	670	725	635	680
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 8.]				
8	65	70	—	—
6	85	95	85	90
4	110	120	105	115
2	140	150	135	145
1	160	170	155	170
1/0	180	195	175	190
2/0	205	220	200	215
3/0	235	250	225	245
4/0	265	285	255	275
250	290	310	280	300
350	350	375	335	360
500	420	455	405	435
750	520	560	485	525
1000	600	645	565	605

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

(D) Ampacity Adjustment.

(1) Grounded Shields.

Ampacities shown in Table 311.60(C)(69), Table 311.60(C)(70), Table 311.60(C)(81), and Table 311.60(C)(82) shall apply for cables with shields grounded at one point only. Where shields for these cables are grounded at more than one point, ampacities shall be adjusted to take into consideration the heating due to shield currents.

Informational Note: Tables other than those listed contain the ampacity of cables with shields grounded at multiple points.

(2) Burial Depth.

Where the burial depth of direct burial or electrical duct bank circuits is modified from the values shown in a figure or table, ampacities shall be permitted to be modified as indicated in 311.60(D)(2)(a) and (D)(2)(b). No ampacity adjustments shall be required where the burial depth is decreased.

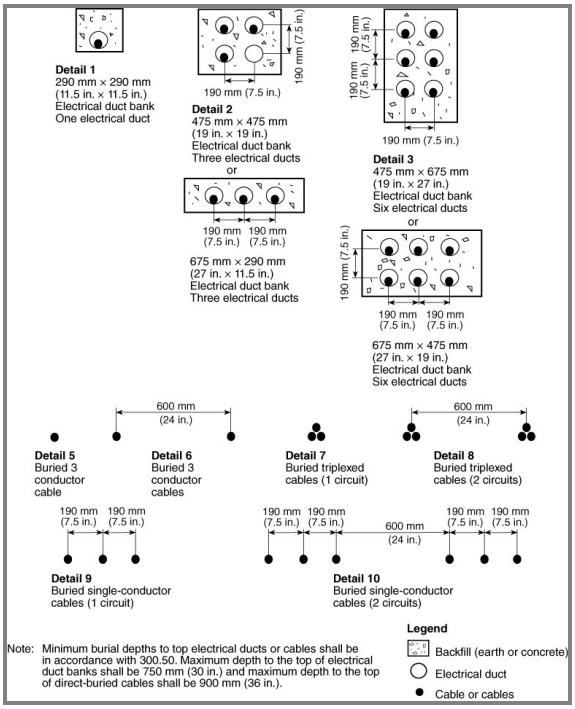
(a) Where burial depths are increased in part(s) of an electrical duct run, a decrease in ampacity of the conductors shall not be required, provided the total length of parts of the duct run increased in depth is less than 25 percent of the total run length.

(b) Where burial depths are deeper than shown in a specific underground ampacity table or figure, an ampacity derating factor of 6 percent per 300 mm (1 ft) increase in depth for all values of rho shall be permitted.

(3) Electrical Ducts Entering Equipment Enclosures.

At locations where electrical ducts enter equipment enclosures from underground, spacing between such ducts, as shown in Figure 311.60(D)(3), shall be permitted to be reduced without requiring the ampacity of conductors therein to be reduced.

Figure 311.60(D)(3) Cable Installation Dimensions for Use with Table 311.60(C)(77) Through Table 311.60(C)(86).



(4) Ambient Temperature Correction.

Ampacities for ambient temperatures other than those specified in the ampacity tables shall be corrected in accordance with Table 311.60(D)(4) or shall be permitted to be calculated using the following equation:

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}}$$ **[311.60(D)(4**

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the table for T_C and T_a

T_C = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

Table 311.60(D)(4) Ambient Temperature Correction Factors

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor		Ambient Temperature (°F)
	90°C	105°C	
10 or less	1.26	1.21	50 or less
11–15	1.22	1.18	51–59
16–20	1.18	1.14	60–68
21–25	1.14	1.11	69–77
26–30	1.10	1.07	78–86
31–35	1.05	1.04	87–95
36–40	1.00	1.00	96–104
41–45	0.95	0.96	105–113
46–50	0.89	0.92	114–122
51–55	0.84	0.88	123–131
56–60	0.77	0.83	132–140
61–65	0.71	0.78	141–149
66–70	0.63	0.73	150–158
71–75	0.55	0.68	159–167
76–80	0.45	0.62	168–176
81–85	0.32	0.55	177–185
86–90	—	0.48	186–194
91–95	—	0.39	195–203
96–100	—	0.28	204–212

(E) Ampacity in Air.

Ampacities for conductors and cables in air shall be as specified in Table 311.60(C)(67) through Table 311.60(C)(76). Ampacities shall be based on the following:

(1) Conductor temperatures of 90°C (194°F) and 105°C (221°F)

(2) Ambient air temperature of 40°C (104°F)

Informational Note: See 311.60(D)(4) where the ambient air temperature is other than 40°C (104°F).

(F) Ampacity in Underground Electrical Ducts and Direct Buried in Earth.

Ampacities for conductors and cables in underground electrical ducts and direct buried in earth shall be as specified in Table 311.60(C)(77) through Table 311.60(C)(86). Ampacities shall be based on the following:

(1) Ambient earth temperature of 20°C (68°F)

(2) Arrangement in accordance with Figure 311.60(D)(3)

(3) 100 percent load factor

(4) Thermal resistance (Rho) of 90

(5) Conductor temperatures 90°C (194°F) and 105°C (221°F)

(6) Minimum burial depths to the top electrical ducts or cables shall be in accordance with 300.50.

(7) Maximum depth to the top of electrical duct banks shall be 750 mm (30 in.), and maximum depth to the top of direct-buried cables shall be 900 mm (36 in.).

Additional Proposed Changes

File Name	Description	Approved
PI_For_Article_311_-For_Submission.docx	Word document containing the PI and companion PI's	

Statement of Problem and Substantiation for Public Input

Under the 2020 edition of the NEC, Medium Voltage, Type MV cable and “associated fittings” are required to be listed per 311.6. However, it is not clear that listing is required for the additional MV Cable system components, such as connectors, cable joints and cable terminations. These components are a part of an MV Cable system, but they are manufactured, and purchased separate of the Type MV cable itself. They are not conductors, so, by Article 100 definitions, they are “devices”, not “fittings”, as they carry electrical energy as their principle function. These devices play a critical role in a MV cable system and the article has been revised to clearly include the requirements for these components of the system. The article as currently written does acknowledge that terminations should be installed by qualified personnel illustrating the importance of them in the system but says little else related to their use. The addition of Type MV cable Joints and Terminations is being proposed as part of article 311, this is a departure from other parts of the code where similar components would be addressed separately in different articles. The requirements for these components of an MV cable system have been intentionally included in article 311. Joints and terminations, while often purchased and installed by separate responsible installers and user’s, medium voltage cable, joints and terminations make up a complete system. The type MV cable joints and terminations are an equally important part to the cable of a medium voltage cable system and the proposed changes seek to address their uses and importance in the overall Medium Voltage cable system. Because there are currently no listed Type MV Cable Joints or terminations the recommended effective date of the proposed changes is 2026 to allow time for installers and users to work through existing stock and for manufacturers to obtain listing of the components.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2654-NFPA 70-2020 [Section No. 250.184(C)]	Companion
Public Input No. 2655-NFPA 70-2020 [Section No. 300.50(B)]	Companion
Public Input No. 2656-NFPA 70-2020 [Section No. 300.50(D)]	Companion
Public Input No. 2657-NFPA 70-2020 [Section No. 392.56]	Companion
Public Input No. 2658-NFPA 70-2020 [Definition:]	Companion
Public Input No. 2654-NFPA 70-2020 [Section No. 250.184(C)]	
Public Input No. 2655-NFPA 70-2020 [Section No. 300.50(B)]	
Public Input No. 2656-NFPA 70-2020 [Section No. 300.50(D)]	
Public Input No. 2657-NFPA 70-2020 [Section No. 392.56]	
Public Input No. 2658-NFPA 70-2020 [Definition:]	

Submitter Information Verification

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Submittal Date: Wed Aug 26 13:58:15 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8616-NFPA 70-2021

Statement: Terminations, MV cable joints and MV cable connectors are being added to provide for complete system installation. The listing requirement in 311/315.6 was expanded to include these additional items with a future effective date to allow the industry time to exhaust inventory of unlisted inventory and to comply with the listing requirement. New section 311/315.17 was added detailing the application of these connectors and markings. Section 311/315.30 was revised to require qualified personnel to complete the installation including cable joints and terminations. Other revisions were made dealing with the installation of these connectors. Code Making Panel 6 refers to the Correlating Committee for review of the modification to the Title of Article 311/315 to include the words Cable, Cable Joints and Terminations.

The Direct Current Voltage rating is being limited to 2500 Volts due to industry experience. Higher voltages are being investigated for their effect on extruded insulation materials. This change is being referred to the Correlating Committee which has purview over Scopes of Articles.

The most current edition of the standard was updated to 2020 in 311/315.30 information note.

Correcting an oversight in 311/315.32 when Article 311 was created out of Article 328 and 310.

The shielding for cables is not suitable for clearing ground fault events unless sized properly.

The note in 311/315.60(D)4 gives users guidance on conductor ampacities and considering terminations.

Information notes were added to refer to industry standards.

PI For Article 311 and Companion PI's

Substantiation for Proposal - Under the 2020 edition of the NEC, Medium Voltage, Type MV cable and "associated fittings" are required to be listed per 311.6. However, it is not clear that listing is required for the additional MV Cable system components, such as connectors, cable joints and cable terminations. These components are a part of an MV Cable system, but they are manufactured, and purchased separate of the Type MV cable itself. They are not conductors, so, by Article 100 definitions, they are "devices", not "fittings", as they carry electrical energy as their principle function. These devices play a critical role in a MV cable system and the article has been revised to clearly include the requirements for these components of the system. The article as currently written does acknowledge that terminations should be installed by qualified personnel illustrating the importance of them in the system but says little else related to their use. The addition of Type MV cable Joints and Terminations is being proposed as part of article 311, this is a departure from other parts of the code where similar components would be addressed separately in different articles. The requirements for these components of an MV cable system have been intentionally included in article 311. Joints and termination, while often purchased and installed by separate responsible installers and user's, medium voltage cable, joints and terminations make up a complete system. The type MV cable joints and terminations are an equally important part to the cable of a medium voltage cable system and the proposed changes seek to address their uses and importance in the overall Medium Voltage cable system. Because there are currently no listed Type MV Cable Joints or terminations the recommended effective date of the proposed changes is 2026 to allow time for installers and users to work through existing stock and for manufacturers to obtain listing of the components.

ARTICLE 311

Medium Voltage Conductors, Cable, Cable Joints, and Cable Terminations

Part I. General

311.1 Scope. This article covers the use, installation, construction specifications, and ampacities for Type MV medium voltage conductors, cable, cable joints, and cable terminations.

311.2 Definitions. The definitions in this section shall apply only within this article.

Cable Joint, Type MV. A connection, consisting of an insulation system and a connector, where two (or more) cables are spliced or joined together, in a way which is to be chemically, mechanically and electrically stable.

Informational Note: Cable Joints are often referred to as splices. However, the term splice includes many other applications not included in the definition of cable joint. Refer to the industry standard IEEE-404 for more information on cable joints.

Termination, Type MV. A connection, consisting of an insulation system and a connector, installed on a cable, to connect from a cable to a device, such as equipment, in a way which is to be chemically, mechanically and electrically stable.

Informational Note No. 1: MV Cable Terminations include terminations used to connect directly to equipment or insulators. Refer to the industry standard IEEE-48, *IEEE Standard for Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV*, for information on terminations.

Informational Note No. 2: MV Cable Terminations also include Separable insulated connectors, which are a type of pluggable cable termination and may be used for connection to equipment, such as switchgear or transformers. A separable connector has a matching interface that the separable connector plugs into on the switchgear or transformer. Separable connectors may also be ganged together to form a distribution junction using specialized junction brackets. Refer to the industry standard IEEE-386, *IEEE Standard for Seperable Insulated Connector Systems for Power Distribution Systems Rated 2.5kV through 35 kV*, and IEEE-1215, *IEEE Guide for the Application of Separable Insulated Connectors*, for more information on separable insulated connectors

Electrical Ducts. Electrical conduits, or other raceways round in cross section, that are suitable for use underground or embedded in concrete.

Medium Voltage Cable, Type MV. A single or multiconductor solid dielectric insulated cable rated 2001 volts up to and including 35,000 volts, nominal.

Thermal Resistivity. As used in this Code, the heat transfer capability through a substance by conduction.

Informational Note: Thermal resistivity is the reciprocal of thermal conductivity and is designated Rho, which is expressed in the units °C-cm/W.

311.6 Listing Requirements. Type MV cables, Type MV cable joints, Type MV cable terminations, connectors and associated fittings shall be listed.

311.16 Marking for Type MV Cables and Conductors.

(A) Required Information. All Conductors and cables shall be marked to indicate the following information, using the applicable method described in 311.16 (B):

(1) The maximum rated voltage.

(2) The proper type letter or letters for the type of wire or cable as specified elsewhere in this *Code.*

(3) The manufacturers name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified.

(4) The AWG size or circular mill area.

Informational Note: See Chapter 9, Table 8, Conductor Properties, for conductor area expressed in SI units for conductor sizes specified in AWG or circular mil area.

(B) Method of Marking <u>for Type MV Cables</u>. One or more of the methods in 311.16 (B) (1) through (B) (3) shall be used for marking of cable.

(1) Surface Marking. Cables shall be durably marked on the surface. The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other cable markings shall be repeated at intervals not exceeding 1.0 m (40 in).

(2) Marker Tape. Metal-Covered multiconductor cables shall employ a marker tape located within the cable and along it's complete length.

(3) Tag Marking. Metal Covered, single-conductor cables shall be marked by means of a printed tag attached to the reel.

(4) Optional Marking of Wire Size. The information required in 311.16 (A) (4) shall be permitted to be marked on the surface of the individual insulated conductors for multi conductor Type MC Cable.

(C) Optional Markings. Cables shall be permitted to be marked to indicate special characteristics of the cable materials, such as limited smoke and sunlight resistance.

<u>311.17 Marking for Type MV Cable Joints and Terminations.</u> <u>One or both of the methods in 311.17 (B) (1) or (B) (2) shall be used for marking of Type MV cable joints, terminations and connectors.</u>

<u>(A) Required Information for Cable Joints, Terminations and Connectors</u><u>. All type MV cable joints and cable terminations and their included connector shall be marked to indicate the following information, using one or more of the methods described in 311.117 (B) (1) or (B) (2) and may be optionally marked as described in 311.16 (D):</u>

<u>(1) The maximum rated voltage.</u>

<u>(2) The proper type letter or letters for the type of wire or cable as specified elsewhere in this *Code* that the cable joint or cable termination is listed for use with.</u>

<u>(3) The manufacturers name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified.</u>

<u>(4) The conductor AWG size or circular mil area size, or range of sizes, that the cable joint or cable termination is listed for use with.</u>

<u>(5) The cable outer diameter size, or size range, that the cable joint or cable termination is listed for use with.</u>

<u>(6) Connectors shall be marked with the following information; the marking shall also be on the unit container (the smallest container in which the connector is packaged):</u>

(a) The manufacturers name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified.

(b) The manufacturers catalog number.

(c) The conductor AWG size or circular mil use range, and die number, if applicable.

(d) The type of conductor material(s) the connector is intended for use with

(B) Method of Marking for Type MV Joints, Terminations and Connectors. One or more of the methods in 311.17 (B) (1) or (B) (2) shall be used for marking of cable.

(1) Surface Marking. Type MV cable joints, cable terminations or connectors shall be durably marked on the surface.

(2) Tag Marking. Type MV cable joints or cable terminations shall be marked by means of a printed tag or label attached to the joint or termination.

(D) Optional Markings. Type MV cable joints and cable terminations shall be permitted to be marked to indicate special characteristics, such as limited smoke and sunlight resistance.

Part III. Installation

311.30 Installation. ~~Type MV cable shall be installed, terminated, and tested by qualified persons.~~ Qualified persons with documented training and experience in the installation and testing of Type MV cable shall perform the installation and testing of the cable. Qualified persons with documented training and experience in the installation of type MV cable joints shall perform the installation of the type MV cable joints. Qualified persons with documented training and experience in the installation of type MV cable termination shall perform the installation of type MV cable terminations.

311.32 Uses Permitted.

(A)Type MV cable. shall be permitted for use on power systems rated up to and including 35,000 volts, nominal, as follows:

(1) In wet or dry locations.

(2) In raceways.

(3) In cable trays, where identified for the use, in accordance with 392.10, 392.20(B), (C), and (D), 392.22(C), 392.30(B)(1), 392.46, 392.56, and 392.60. Type MV cable that has an overall metallic sheath or armor, complies with the requirements for Type MC cable, and is identified as “MV or MC” shall be permitted to be installed in cable trays in accordance with 392.10(B)(2).

(4) In messenger-supported wiring in accordance with Part II of Article 396.

(5) As exposed runs in accordance with 300.37. Type MV cable that has an overall metallic sheath or armor, complies with the requirements for Type MC cable, and is identified as “MV or MC” shall be permitted to be installed as exposed runs of metal-clad cable in accordance with 300.37.

(6) Corrosive conditions where exposed to oils, greases, vapors, gases, fumes, liquids, or other substances having a deleterious effect on the conductor or insulation shall be of a type suitable for the application.

(7) Conductors in parallel in accordance with 310.10(G).

(8) Type MV cable used where exposed to direct sunlight shall be identified for the use.

(B) **Type MV cable Joints and Terminations.** shall be permitted for use on power systems rated up to and including 35,000 volts, nominal, as follows:

Informational Note: The "uses permitted" is not an all-inclusive list.

(1) Type MV cable joints and terminations, used where exposed to direct sunlight, shall be identified for the use.

(2) Direct Buried

(3) Where used intermittently or continuously submerged in water at a depth not exceeding 7 m (23 ft) type MV cable joints and terminations shall be identified for the use.

(4) Environmental operating temperature range shall be identified

(5) Where used in one or more of the following conditions type MV cable joints and terminations shall be identified for the use:

A. Underground chambers,
B. Tunnels,
C. Conduits,
D. Manholes,
E. Vaults

(6) Corrosive conditions where exposed to oils, greases, vapors, gases, fumes, liquids, or other substances having a deleterious effect on the conductor or insulation shall be of a type suitable for the application.

(7) In cable trays, where identified for the use, in accordance with 392.10, 392.20(B), (C), and (D), 392.22(C), 392.30(B)(1), 392.46, 392.56, and 392.60.

311.45 Shielding at Type MV Cable Joints and Terminations. Type MV cable joints and terminations shall be provided with means to connect the metallic insulation shield to ground if required.

ARTICLE 250

250.184 Solidly Grounded Neutral Systems

(C) Multigrounded Neutral Systems

(5) In a multigrounded shielded cable system, the shielding shall be grounded at each type MV cable joint and type MV termination that is exposed to personnel contact.

Commented [KP1]: Look at current 250.184 and see if termination should be added or is already addressed.

ARTICLE 300

300.50(B) Wet Locations.

The interior of enclosures or raceways installed underground shall be considered to be a wet location. Insulated conductors and cables installed in these enclosures or raceways in underground installations shall be listed for use in wet locations and shall comply with 310.10(C). Any connections, splices, or type MV cable joints in an underground installation shall be approved for wet locations.

300.50(D) Splices and Type MV Cable Joints.

Direct burial cables shall be permitted to be spliced, jointed, or tapped without the use of splice boxes, provided they are installed using materials suitable for the application. The taps, splices, and type MV cable joints shall be watertight and protected from mechanical damage. Where cables are shielded, the shielding shall be continuous across the splice, tap or type MV cable joint.

392.56 Cable Splices.

Cable splices and type MV Cable joints, made and insulated by approved methods shall be permitted to be located within a cable tray, provided they are accessible. Splices and type MV Cable joints shall be permitted to project above the side rails where not subject to physical damage.

Informative Annex A Product Safety Standards

Article	Standard Number	Standard Title
~~328~~ 311	UL 1072	Medium-Voltage Power Cables
	ANSI C119.4	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
	IEEE 48	IEEE Standard for test Procedures and requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5kV through 500 kV

IEEE 386	IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems rated 2.5kV through 35kV
IEEE 404	IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV

Public Input No. 3911-NFPA 70-2020 [Section No. 311.1]

311.1 Scope.

This article covers the use, installation, construction specifications, and ampacities for Type MV medium voltage conductors and cable. This article does not cover cables used above 2500 Volts for direct-current (dc) circuits.

Additional Proposed Changes

File Name	Description	Approved
311_Proposals_for_MV_DC.docx	Word document with the PI and substantiation.	

Statement of Problem and Substantiation for Public Input

This public input is being submitted to address the potential use of MV cables in direct current applications based on the following reasoning. 1) There is currently industry experience that cables used with dc voltages below 2500V applications have been used with no reported problems and research to suggest above this voltage there may be issues with space charge formation in extruded cables that are not properly designed and tested for use with direct currents. 2) Materials and performance testing for listed cables type MV-90 and MV-105 are based on proving suitability of use for alternating current circuits, no specific performance tests are called out in the standard UL 1072 to prove suitability for use in direct current circuits. 4) Other sections of the code, such as 425.28 (a), 410.134 and 408.3 (E) (2) currently make distinctions for certain apparatus dependent on if the intended use is for alternating or direct current.

Submitter Information Verification

Submitter Full Name: Paul Knapp
Organization: UL LLC
Street Address:
City:
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Zip:
Submittal Date: Wed Sep 09 15:23:41 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8616-NFPA 70-2021

Statement: Terminations, MV cable joints and MV cable connectors are being added to provide for complete system installation. The listing requirement in 311/315.6 was expanded to include these additional items with a future effective date to allow the industry time to exhaust inventory of unlisted inventory and to comply with the listing requirement. New section 311/315.17 was added detailing the application of these connectors and markings. Section 311/315.30 was revised to require qualified personnel to complete the installation including cable joints and terminations. Other revisions were made dealing with the installation of these connectors. Code Making Panel 6 refers to the Correlating Committee for review of the modification to the Title of Article 311/315 to include the words Cable, Cable Joints and Terminations.

The Direct Current Voltage rating is being limited to 2500 Volts due to industry experience. Higher voltages are being investigated for their effect on extruded insulation materials. This change is being referred to the Correlating Committee which has purview over Scopes of Articles.

The most current edition of the standard was updated to 2020 in 311/315.30 information note.

Correcting an oversight in 311/315.32 when Article 311 was created out of Article 328 and 310.

The shielding for cables is not suitable for clearing ground fault events unless sized properly.

The note in 311/315.60(D)4 gives users guidance on conductor ampacities and considering terminations.

Information notes were added to refer to industry standards.

311 Proposals for MV DC

Substantiation for the proposal: 1) There is currently industry experience that cables used with dc voltages below 2500V applications have been used with no reported problems and research to suggest above this voltage there are issues with space charge formation in extruded cables that are not properly designed and tested for use with direct currents. 2) Materials and performance testing for listed cables type MV-90 and MV-105 are based on proving suitability of use for alternating current circuits, no specific performance tests are called out in the standard to prove suitability for use in direct current circuits. 4) Other sections of the code, such as 425.28 (a), 410.134 and 408.3 (E) (2) currently make distinctions for certain apparatus dependent on if the intended use is for alternating or direct current. This suggests that the code acknowledges that there are differences in apparatus use and construction depending on the type of current they are intended to be used with.

311.1 Scope.
This article covers the use, installation, construction specifications, and ampacities for Type MV medium voltage conductors and cable. This article does not cover cables used above 2500 V for direct-current (dc) circuits.

Public Input No. 3524-NFPA 70-2020 [Section No. 311.2]

(Relocate all definitions in the 311. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

311. 2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Electrical Ducts.

Electrical conduits, or other raceways round in cross section, that are suitable for use underground or embedded in concrete.

Medium Voltage Cable, Type MV.

A single or multiconductor solid dielectric insulated cable rated 2001 volts up to and including 35,000 volts, nominal.

Thermal Resistivity.

As used in this *Code*, the heat transfer capability through a substance by conduction.

Informational Note: Thermal resistivity is the reciprocal of thermal conductivity and is designated Rho, which is expressed in the units °C-cm/W.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:15:23 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 987-NFPA 70-2020 [Section No. 311.10(B)]

(B) Thickness of Insulation and Jacket for Nonshielded Insulated Conductors.

Thickness of insulation and jacket for nonshielded solid dielectric insulated conductors rated 2001 volts to 5000 volts shall comply with Table 311.10(B).

Exception No. 1:
FAA L-824 airfield lighting cable shall be permitted in wet or dry locations with 90 mil insulation +30 mil jacket or 110 mil insulation.

or

FAA L-824 airfield lighting cable shall be permitted in wet or dry applications.

or

FAA L-824 airfield lighting cable listed in AC 150/5345-53 manufactured to the Table 311.10(B) requirements for dry locations shall be permitted in wet or dry applications.

Informational Note to Exception No. 1: Federal Aviation Administration (FAA) Advisory Circulars (ACs) provide additional practices and methods for airport lighting.

Additional Proposed Changes

File Name	Description	Approved
150-5345-7F_Spec_for_L-824_UG_Elect_Cable_for_Airport_Lgt_Ckt.pdf	FAA cable specification	
150-5345-7F_Spec_for_L-824_UG_Elect_Cable_for_Airport_Lgt_Ckt.pdf	FAA Certification listing	
300C_IND_FAA_COLORABLE_FAA-L-824_TYPE_C_CBL_01-19.pdf	Cable manufacturer's data sheet #1	
300C_IND_FAA_FAA-L-824_TYPE_B_AIRPT_LGT_PWR_CBL_EPRCPE_01-19_0.pdf	Cable manufacturer's data sheet #2	
300C_IND_FAA_TRIPLE_RATED_MV-90_FAA_TYPE_C_CSA_TYPE_ASLC_01-19.pdf	Cable manufacturer's data sheet #3	

Statement of Problem and Substantiation for Public Input

FAA L-824 cables are suitable for use at 90°C wet or dry in conduit, duct, aerial and direct burial installations, however the FAA specified insulation and jacket thickness does not comply with Table 311.10(B) requirements.
FAA L-824 cables are used extensively in underground applications with an excellent performance record.

Submitter Information Verification

Submitter Full Name: Carl Johnson II
Organization: AVCON, Inc.

Affiliation: none
Street Address:
City:
State:
Zip:
Submittal Date: Wed May 06 17:45:14 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FAA L-824 Cable is not recognized by the NEC in general. Therefore, there must be product recognition that is in line with NEC standards.

U.S. Department
of Transportation

Federal Aviation
Administration

Advisory Circular

Subject: Specification for L-824 Underground Electrical Cable for Airport Lighting Circuits	**Date:** 8/19/2013	**AC No:** 150/5345-7F
	Initiated by: AAS-100	**Change:**

1. Purpose. This advisory circular (AC) comprises the Federal Aviation Administration (FAA) specifications for L-824 underground electrical cable for airport lighting circuits.

2. Effective Date. Effective 6 months after the issue date of this AC, only cable qualified with the specifications herein will be listed in AC 150/5345-53, Airport Lighting Equipment Certification Program.

3. Cancellation. AC 150/5345-7E, Specification for L-824 Underground Electrical Cable for Airport Lighting Circuits, dated August 2, 2001, is canceled.

4. Application. The FAA recommends the specifications contained in this AC for the development of airport lighting circuits using L-824 underground electrical cable. The use of these specifications is mandatory for airport projects receiving FAA-administered Federal funds under such programs as the Airport Improvement Program or the Passenger Facility Charge Program.

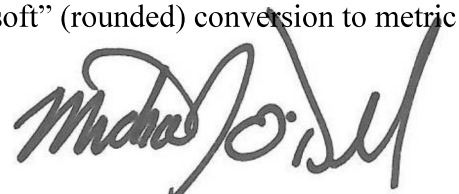
5. Principal Changes. The following principal changes have been incorporated:

a. Updated all references to latest revisions.

b. Updated all internet links for obtaining publications.

c. Deleted FAA-STD-013, Quality Control Program Requirements. Replaced with ANSI/ISO 9001, Quality Management Systems – Requirements.

6. Metric Units. Throughout this AC, customary English units are used followed with "soft" (rounded) conversion to metric units. The English units govern.



Michael J. O'Donnell
Director of Airport Safety and Standards

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SPECIFICATION FOR L-824 UNDERGROUND ELECTRICAL CABLE FOR AIRPORT LIGHTING CIRCUITS

1. Scope and Classification.

1.1 Scope. This specification covers requirements for underground electrical cable intended for use in airport lighting circuits.

Type B Single and multiple conductor cables rated 600 volts and 5,000 volts having ethylene propylene insulation and an overall jacket.

Type C Single and multiple conductor cables rated 600 volts and 5,000 volts having cross-linked polyethylene insulation. Multiple conductor cables and shielded cable must have an overall jacket.

This specification does not apply to wire or cable used to manufacture Class A connectors per AC 150/5345-26, FAA Specification for L-823 Plug and Receptacle, Cable Connectors, or for the manufacture of the transformer leads per AC 150/5345-47, Specification for Series to Series Isolation Transformers for Airport Lighting Systems.

See AC 150/5340-30, Design and Installation Details for Airport Visual Aids, for additional information about acceptable wire insulation types and installation guidelines. See also AC 150/5370-10, Standards for Specifying Construction of Airports, for additional information about wire insulation types.

2. Applicable Documents.

2.1 General. The following documents in effect on the date of request for approval form a part of this specification to the extent specified herein. In the event of conflict, this specification must govern.

2.1.1 American National Standards Institute (ANSI)/International Organization for Standardization (ISO):

ISO 9001:2008	Quality Management Systems - Requirements

2.1.2 Insulated Cable Engineers Association, Inc. (ICEA)/ National Electrical Manufacturers Association (NEMA) Publications:

ANSI/ICEA S-95-658 / NEMA WC70 – 2009	Power Cables Rated 2000 V or Less for Use in the Distribution of Electrical Energy
ANSI/ICEA S-96-659 / NEMA WC71 – 1999	Standard for Non-Shielded Cables Rated 2001-5000 V for Use in the Distribution of Electrical Energy

ICEA S-93-639 / NEMA WC74 – 2000	5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electrical Energy
ANSI/ICEA T-26-465 / NEMA WC54 – 2008	Guide for Frequency of Sampling Extruded Dielectric Power, Control, Instrumentation and Portable Cables for Test

FAA ACs are available for download on the FAA Airports Web site: http://www.faa.gov/airports/resources/advisory_circulars/.

Copies of ICEA/NEMA publications may be purchased from the International Cable Engineer's Association, Inc. (ICEA) website: www.icea.net/Public_Pages/Documents/NewPowerDocumentsPage.html.

3. Requirements.

3.1 General. The cable must be suitable for the intended application and must be manufactured consistent with the best commercial practices.

3.1.1 Detail Requirements. The cable type must be manufactured per the requirements and options (where applicable) in Table 1.

3.2 Marking. The cable must be durably marked with the manufacturer's name or trademark, cable trade name or catalog number, conductor size, and voltage rating. The markings must be repeated at regular intervals not exceeding 24 inches (0.6 meters (m)). The markings must not decrease the jacket or insulation thickness to less than the specified value.

4. Quality Assurance Provisions.

4.1 Qualification Requirements.

4.1.1 Qualification Request. Procedures for obtaining qualification approval are in the latest edition of AC 150/5345-53, Airport Lighting Equipment Certification Program.

4.1.2 Qualification Testing. All cable intended for qualification to this AC must comply with the requirements in paragraph 4.2.

4.1.3 Quality Control Provisions. The manufacturer must provide and maintain a quality control program per ANSI/ISO 9001 (an onsite FAA Quality and Reliability Officer (QRO) is not required) or equivalent Department of Defense quality standards (example: MIL-Q-9858A).

4.1.4 Guarantee. The manufacturer must provide the following minimum guarantee for each cable: that the cable has been manufactured and will perform per this specification and that any defect in material or workmanship that may occur during proper and normal use during a period

of 1 year from the date of installation or a maximum of 2 years from date of shipment will be corrected or replaced by the manufacturer.

4.2 Qualification Testing. Qualification testing must be performed on each insulation type and voltage rating of cable, per Table 1.

4.3 Production Testing. Production sample tests must be performed at the frequency per ICEA T-26-465/ NEMA WC54. Where no frequency is specified, testing frequency must be determined by the product certification organization. At a minimum, production testing must include the High Voltage Spark and Insulation Resistance.

4.4 Production Test Records. At any time after approval has been granted under this specification, a certified copy of factory test reports on the most recent runs of any type of cable meeting this specification must be made available by the manufacturer upon written request by the FAA. Production testing records must be maintained for a period of 3 years and made available for review by the third-party certifier's quality inspection personnel.

Table 1. Cable Requirements

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	600	5000	600	5000
1. CONDUCTOR				
a. Material: Coated and uncoated copper	x	x	x	x
b. General Requirements:				
ICEA S-95-658, Section 2	x	--	x	--
ICEA S-96-659, Section 2, non-shielded	--	x	--	x
ICEA S-93-639, Section 2, shielded	--	x	--	x
c. Stranding: 7-wire Class B strand or	x	x	x	x
19-wire Class C strand	x	x	x	x
d. Size: AWG	12-4	8-4	12-4	8-4
e. Conductor stress control (conductor shield)				
ICEA S-96-659, Section 3, non-shielded	--	optional	--	optional
ICEA S-93-639, Section 3, shielded	--	x	--	x
2. INSULATION				
a. Material:				
Ethylene Propylene Rubber				
ICEA S-95-658, Class E-1 or E-2	x	--	--	--
ICEA S-96-659, Class E-1 or E-2 or E-4, non-shielded	--	x	--	--
ICEA S-93-639, Class I, II, or IV, shielded	--	x	--	--
Cross-linked Polyethylene				
ICEA S-95-658, Class X-1 or X-2 or X-3	--	--	x	--
ICEA S-96-659, Class X-1 or X-2, non-shielded	--	--	--	x
ICEA S-93-639, Class XLPE, shielded	--	--	--	x
b. Thickness:				
ICEA S-95-658, Table 3-4, column B	x	--	--	--
ICEA S-95-658, Table 3-4, column A (single cond.)	--	--	x	--
ICEA S-95-658, Table 3-4, column B (multi-cond.)	--	--	x	--
ICEA S-96-659, Table 4-2 (single cond.), non-shielded	--	x	--	x
ICEA S-96-659, Table 4-3 (multi-cond.), non-shielded	--	--	--	x
ICEA S-93-639, Table 4-3, shielded	--	x	--	x
3. SHIELDING				
Nonmetallic covering and metallic tape:				
ICEA S-93-639, Section 5 & 6	--	optional	--	optional

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	600	5000	600	5000
4. MULTIPLE CONDUCTOR CABLE				
Cable assembly:				
ICEA S-95-658, Section 5	x	--	x	--
ICEA S-96-659, Section 6, non-shielded	--	x	--	x
ICEA S-93-639, Section 8, shielded	--	x	--	x
5. JACKET				
a. Material:				
Heavy-Duty Neoprene				
ICEA S-95-658, Par. 4.1.3	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.3, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.2, shielded	--	x	--	x
Heavy-Duty Chlorosulfonated Polyethylene				
ICEA S-95-658, Par. 4.1.11	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.11, nonshielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.10, shielded	--	x	--	x
Polyvinyl Chloride				
ICEA S-95-658, Par. 4.1.5	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.5, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.4, shielded	--	x	--	x
Polyethylene				
ICEA S-95-658, Par. 4.1.6	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.6, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.5, shielded	--	x	--	x
Chlorinated Polyethylene, Thermoplastic				
ICEA S-95-658, Par. 4.1.12	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.12, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.11, shielded	--	x	--	x
Chlorinated Polyethylene, Cross-Linked, Heavy Duty				
ICEA S-95-658, Par. 4.1.13	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.13, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.12, shielded	--	x	--	x
b. Thickness				
(1) Single conductor, non-shielded				
ICEA S-95-658, Table 4-2	x	--	--	--
ICEA S-96-659, Table 4-2	--	x	--	optional

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	600	5000	600	5000
5. JACKET (continued)				
(2) Single conductor, shielded				
ICEA S-93-639, Table 7-3	--	x	--	x
(3) Multiple conductor				
ICEA S-95-658, Table 4-4	x	--	x	--
ICEA S-96-659, Table 5-3, non-shielded	--	x	--	x
ICEA S-93-639, Table 7-3, shielded	--	x	--	x
6. COMPONENT TESTS				
Conductor, Conductor stress control layer, Insulation, Insulation shield and Jacket:				
ICEA S-95-658, Section 6	x	--	x	--
ICEA S-96-659, Section 7	--	no shield	--	no shield
ICEA S-93-639, Section 9	--	shielded	--	shielded
7. HIGH VOLTAGE TESTS				
Test methods must be per—				
ICEA S-95-658, Section 6	x	--	x	--
ICEA S-96-659, Section 7	--	no shield	--	no shield
ICEA S-93-639, Section 9	--	shielded	--	shielded
Test voltages must be per a, b, c, or d				
a. High voltage – ac				
ICEA S-95-658, Table 3-4	x	--	x	--
ICEA S-96-659, Table 4-2	--	no shield	--	no shield
ICEA S-93-639, Table 4-1	--	shielded	--	shielded
b. High voltage - dc (alternate to ac)				
ICEA S-95-658, Table 3-4	x	--	x	--
ICEA S-96-659, Table 4-2	--	no shield	--	no shield
ICEA S-93-639, Table D-1	--	shielded	--	shielded
c. High voltage spark test - ac				
ICEA S-95-658, Table 3-4	x	--	x	--
d. High voltage spark test - dc (alternate to ac)				
ICEA S-95-658, Table 3-4	x	--	x	--

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	**600**	**5000**	**600**	**5000**
8. DISCHARGE RESISTANCE TESTS				
Single conductor, non-shielded only				
ICEA S-96-659, Table 4-5, no jacket	--	--	--	x
ICEA S-96-659, Table 5-1, with jacket	--	x	--	x
ICEA S-96-659, E-4 Insulation, Tables 4-5 & 7-1		x		
9. INSULATION RESISTANCE				
ICEA S-95-658, Par. 6.10.2	x	--	x	--
ICEA S-96-659, Par. 7.11.2	--	no shield	--	no shield
ICEA S-93-639, Par. 9.12.3	--	shielded	--	shielded
10. PARTIAL DISCHARGE				
ICEA S-93-639, Par. 9.12.2, shielded	--	x	--	x

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U.S. Department
of Transportation

Federal Aviation
Administration

Advisory Circular

Subject: Specification for L-824 Underground Electrical Cable for Airport Lighting Circuits	**Date:** 8/19/2013	**AC No:** 150/5345-7F
	Initiated by: AAS-100	**Change:**

1. Purpose. This advisory circular (AC) comprises the Federal Aviation Administration (FAA) specifications for L-824 underground electrical cable for airport lighting circuits.

2. Effective Date. Effective 6 months after the issue date of this AC, only cable qualified with the specifications herein will be listed in AC 150/5345-53, Airport Lighting Equipment Certification Program.

3. Cancellation. AC 150/5345-7E, Specification for L-824 Underground Electrical Cable for Airport Lighting Circuits, dated August 2, 2001, is canceled.

4. Application. The FAA recommends the specifications contained in this AC for the development of airport lighting circuits using L-824 underground electrical cable. The use of these specifications is mandatory for airport projects receiving FAA-administered Federal funds under such programs as the Airport Improvement Program or the Passenger Facility Charge Program.

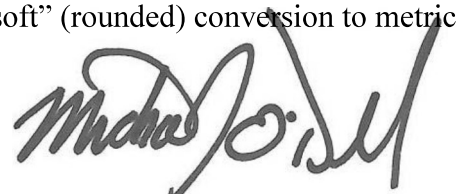
5. Principal Changes. The following principal changes have been incorporated:

a. Updated all references to latest revisions.

b. Updated all internet links for obtaining publications.

c. Deleted FAA-STD-013, Quality Control Program Requirements. Replaced with ANSI/ISO 9001, Quality Management Systems – Requirements.

6. Metric Units. Throughout this AC, customary English units are used followed with "soft" (rounded) conversion to metric units. The English units govern.



Michael J. O'Donnell
Director of Airport Safety and Standards

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SPECIFICATION FOR L-824 UNDERGROUND ELECTRICAL CABLE FOR AIRPORT LIGHTING CIRCUITS

1. Scope and Classification.

1.1 Scope. This specification covers requirements for underground electrical cable intended for use in airport lighting circuits.

Type B Single and multiple conductor cables rated 600 volts and 5,000 volts having ethylene propylene insulation and an overall jacket.

Type C Single and multiple conductor cables rated 600 volts and 5,000 volts having cross-linked polyethylene insulation. Multiple conductor cables and shielded cable must have an overall jacket.

This specification does not apply to wire or cable used to manufacture Class A connectors per AC 150/5345-26, FAA Specification for L-823 Plug and Receptacle, Cable Connectors, or for the manufacture of the transformer leads per AC 150/5345-47, Specification for Series to Series Isolation Transformers for Airport Lighting Systems.

See AC 150/5340-30, Design and Installation Details for Airport Visual Aids, for additional information about acceptable wire insulation types and installation guidelines. See also AC 150/5370-10, Standards for Specifying Construction of Airports, for additional information about wire insulation types.

2. Applicable Documents.

2.1 General. The following documents in effect on the date of request for approval form a part of this specification to the extent specified herein. In the event of conflict, this specification must govern.

2.1.1 American National Standards Institute (ANSI)/International Organization for Standardization (ISO):

ISO 9001:2008	Quality Management Systems - Requirements

2.1.2 Insulated Cable Engineers Association, Inc. (ICEA)/ National Electrical Manufacturers Association (NEMA) Publications:

ANSI/ICEA S-95-658 / NEMA WC70 – 2009	Power Cables Rated 2000 V or Less for Use in the Distribution of Electrical Energy
ANSI/ICEA S-96-659 / NEMA WC71 – 1999	Standard for Non-Shielded Cables Rated 2001-5000 V for Use in the Distribution of Electrical Energy

ICEA S-93-639 / NEMA WC74 – 2000	5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electrical Energy
ANSI/ICEA T-26-465 / NEMA WC54 – 2008	Guide for Frequency of Sampling Extruded Dielectric Power, Control, Instrumentation and Portable Cables for Test

FAA ACs are available for download on the FAA Airports Web site: http://www.faa.gov/airports/resources/advisory_circulars/.

Copies of ICEA/NEMA publications may be purchased from the International Cable Engineer's Association, Inc. (ICEA) website: www.icea.net/Public_Pages/Documents/NewPowerDocumentsPage.html.

3. Requirements.

3.1 General. The cable must be suitable for the intended application and must be manufactured consistent with the best commercial practices.

3.1.1 Detail Requirements. The cable type must be manufactured per the requirements and options (where applicable) in Table 1.

3.2 Marking. The cable must be durably marked with the manufacturer's name or trademark, cable trade name or catalog number, conductor size, and voltage rating. The markings must be repeated at regular intervals not exceeding 24 inches (0.6 meters (m)). The markings must not decrease the jacket or insulation thickness to less than the specified value.

4. Quality Assurance Provisions.

4.1 Qualification Requirements.

4.1.1 Qualification Request. Procedures for obtaining qualification approval are in the latest edition of AC 150/5345-53, Airport Lighting Equipment Certification Program.

4.1.2 Qualification Testing. All cable intended for qualification to this AC must comply with the requirements in paragraph 4.2.

4.1.3 Quality Control Provisions. The manufacturer must provide and maintain a quality control program per ANSI/ISO 9001 (an onsite FAA Quality and Reliability Officer (QRO) is not required) or equivalent Department of Defense quality standards (example: MIL-Q-9858A).

4.1.4 Guarantee. The manufacturer must provide the following minimum guarantee for each cable: that the cable has been manufactured and will perform per this specification and that any defect in material or workmanship that may occur during proper and normal use during a period

of 1 year from the date of installation or a maximum of 2 years from date of shipment will be corrected or replaced by the manufacturer.

4.2 Qualification Testing. Qualification testing must be performed on each insulation type and voltage rating of cable, per Table 1.

4.3 Production Testing. Production sample tests must be performed at the frequency per ICEA T-26-465/ NEMA WC54. Where no frequency is specified, testing frequency must be determined by the product certification organization. At a minimum, production testing must include the High Voltage Spark and Insulation Resistance.

4.4 Production Test Records. At any time after approval has been granted under this specification, a certified copy of factory test reports on the most recent runs of any type of cable meeting this specification must be made available by the manufacturer upon written request by the FAA. Production testing records must be maintained for a period of 3 years and made available for review by the third-party certifier's quality inspection personnel.

Table 1. Cable Requirements

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	600	5000	600	5000
1. CONDUCTOR				
a. Material: Coated and uncoated copper	x	x	x	x
b. General Requirements:				
ICEA S-95-658, Section 2	x	--	x	--
ICEA S-96-659, Section 2, non-shielded	--	x	--	x
ICEA S-93-639, Section 2, shielded	--	x	--	x
c. Stranding: 7-wire Class B strand or	x	x	x	x
19-wire Class C strand	x	x	x	x
d. Size: AWG	12-4	8-4	12-4	8-4
e. Conductor stress control (conductor shield)				
ICEA S-96-659, Section 3, non-shielded	--	optional	--	optional
ICEA S-93-639, Section 3, shielded	--	x	--	x
2. INSULATION				
a. Material:				
Ethylene Propylene Rubber				
ICEA S-95-658, Class E-1 or E-2	x	--	--	--
ICEA S-96-659, Class E-1 or E-2 or E-4, non-shielded	--	x	--	--
ICEA S-93-639, Class I, II, or IV, shielded	--	x	--	--
Cross-linked Polyethylene				
ICEA S-95-658, Class X-1 or X-2 or X-3	--	--	x	--
ICEA S-96-659, Class X-1 or X-2, non-shielded	--	--	--	x
ICEA S-93-639, Class XLPE, shielded	--	--	--	x
b. Thickness:				
ICEA S-95-658, Table 3-4, column B	x	--	--	--
ICEA S-95-658, Table 3-4, column A (single cond.)	--	--	x	--
ICEA S-95-658, Table 3-4, column B (multi-cond.)	--	--	x	--
ICEA S-96-659, Table 4-2 (single cond.), non-shielded	--	x	--	x
ICEA S-96-659, Table 4-3 (multi-cond.), non-shielded	--	--	--	x
ICEA S-93-639, Table 4-3, shielded	--	x	--	x
3. SHIELDING				
Nonmetallic covering and metallic tape:				
ICEA S-93-639, Section 5 & 6	--	optional	--	optional

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	600	5000	600	5000
4. MULTIPLE CONDUCTOR CABLE				
Cable assembly:				
ICEA S-95-658, Section 5	x	--	x	--
ICEA S-96-659, Section 6, non-shielded	--	x	--	x
ICEA S-93-639, Section 8, shielded	--	x	--	x
5. JACKET				
a. Material:				
Heavy-Duty Neoprene				
ICEA S-95-658, Par. 4.1.3	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.3, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.2, shielded	--	x	--	x
Heavy-Duty Chlorosulfonated Polyethylene				
ICEA S-95-658, Par. 4.1.11	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.11, nonshielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.10, shielded	--	x	--	x
Polyvinyl Chloride				
ICEA S-95-658, Par. 4.1.5	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.5, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.4, shielded	--	x	--	x
Polyethylene				
ICEA S-95-658, Par. 4.1.6	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.6, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.5, shielded	--	x	--	x
Chlorinated Polyethylene, Thermoplastic				
ICEA S-95-658, Par. 4.1.12	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.12, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.11, shielded	--	x	--	x
Chlorinated Polyethylene, Cross-Linked, Heavy Duty				
ICEA S-95-658, Par. 4.1.13	x	--	multi-cond.	--
ICEA S-96-659, Par. 5.1.13, non-shielded	--	x	--	optional
ICEA S-93-639, Par. 7.1.12, shielded	--	x	--	x
b. Thickness				
(1) Single conductor, non-shielded				
ICEA S-95-658, Table 4-2	x	--	--	--
ICEA S-96-659, Table 4-2	--	x	--	optional

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	600	5000	600	5000
5. JACKET (continued)				
(2) Single conductor, shielded				
ICEA S-93-639, Table 7-3	--	x	--	x
(3) Multiple conductor				
ICEA S-95-658, Table 4-4	x	--	x	--
ICEA S-96-659, Table 5-3, non-shielded	--	x	--	x
ICEA S-93-639, Table 7-3, shielded	--	x	--	x
6. COMPONENT TESTS				
Conductor, Conductor stress control layer, Insulation, Insulation shield and Jacket:				
ICEA S-95-658, Section 6	x	--	x	--
ICEA S-96-659, Section 7	--	no shield	--	no shield
ICEA S-93-639, Section 9	--	shielded	--	shielded
7. HIGH VOLTAGE TESTS				
Test methods must be per—				
ICEA S-95-658, Section 6	x	--	x	--
ICEA S-96-659, Section 7	--	no shield	--	no shield
ICEA S-93-639, Section 9	--	shielded	--	shielded
Test voltages must be per a, b, c, or d				
a. High voltage – ac				
ICEA S-95-658, Table 3-4	x	--	x	--
ICEA S-96-659, Table 4-2	--	no shield	--	no shield
ICEA S-93-639, Table 4-1	--	shielded	--	shielded
b. High voltage - dc (alternate to ac)				
ICEA S-95-658, Table 3-4	x	--	x	--
ICEA S-96-659, Table 4-2	--	no shield	--	no shield
ICEA S-93-639, Table D-1	--	shielded	--	shielded
c. High voltage spark test - ac				
ICEA S-95-658, Table 3-4	x	--	x	--
d. High voltage spark test - dc (alternate to ac)				
ICEA S-95-658, Table 3-4	x	--	x	--

CABLE TYPE	B		C	
VOLTAGE RATING, VOLTS	**600**	**5000**	**600**	**5000**
8. DISCHARGE RESISTANCE TESTS				
Single conductor, non-shielded only				
ICEA S-96-659, Table 4-5, no jacket	--	--	--	x
ICEA S-96-659, Table 5-1, with jacket	--	x	--	x
ICEA S-96-659, E-4 Insulation, Tables 4-5 & 7-1		x		
9. INSULATION RESISTANCE				
ICEA S-95-658, Par. 6.10.2	x	--	x	--
ICEA S-96-659, Par. 7.11.2	--	no shield	--	no shield
ICEA S-93-639, Par. 9.12.3	--	shielded	--	shielded
10. PARTIAL DISCHARGE				
ICEA S-93-639, Par. 9.12.2, shielded	--	x	--	x

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Draka

A brand of the Prysmian Group

Colorable FAA-L-824 Type C Cable

Single conductor for airport lighting / 8, 6 & 4 AWG / XLPE insulation / 5KV



Applications

These are single conductor 5000 volt non shielded power cables suitable for L-824 underground installation for lighting at airports per FAA L-824 Type C and AC 150/5345-53 Appendix 3. FAA L-824 cables are suitable for use at 90°C wet or dry in conduit, duct, aerial and direct burial installations.

This cable is available in solid colors for permanent circuit identification: black, blue, green, grey, orange, red, terra cotta, yellow, white, and purple.

Specifications and Ratings

- FAA Advisory Circular 150/5345-7F
- Equipment Certification Program AC150/5345-53 appendix 3 in accordance with Underground Electrical Cable for Airport Lighting Circuits per spec L-824 and ICEA S-96-659 (NEMA WC71).
- Draka's airport lighting cables have been certified as 100% Buy American by the FAA.
  https://www.faa.gov/airports/aip/

Design Parameters

CONDUCTORS: Soft drawn stranded bare copper per ASTM B3 and ASTM B8.

INSULATION: Crosslinked polyethylene (XLPE) 110 mil thick in accordance with ICEA S-96-659. An optional separator tape under the insulation eases stripping. Available in ten colors (see chart on page 2).

Available Colors:

- Black
- Blue
- Green
- Grey
- Orange
- Red
- Terra Cotta
- Yellow
- White
- Purple

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300C_IND_FAA_COLORABLE_FAA-L-824_TYPE_C_CBL_01-19

Draka

A brand of the Prysmian Group

Colorable FAA-L-824 Type C Cable

Single conductor for airport lighting / 8, 6 & 4 AWG / XLPE insulation / 5KV

Part Number	Insulation Color	Conductor Size	Stranding	Insulation Thickness in (mm)	Nominal Cable O.D. in (mm)	Cable Weight Lbs/Mft (Kg/Km)
389171	Black	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393000	Blue	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393001	Green	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393002	Grey	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393003	Orange	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393004	Red	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393005	Terra Cotta	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393006	Yellow	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393007	White	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
393010	Purple	8 AWG	7 x .0486	.110 (2.8)	0.375 (9.53)	92 (137)
389172	Black	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
393018	Blue	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
393012	Grey	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
393013	Orange	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
393014	Red	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
393015	Terra cotta	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
393016	Yellow	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
393017	White	6 AWG	7 x .0612	.110 (2.8)	0.410 (10.4)	129 (192)
389181	Black	4 AWG	7 x .0772	.110 (2.8)	0.460 (11.7)	185 (276)
393020	Blue	4 AWG	7 x .0772	.110 (2.8)	0.460 (11.7)	185 (276)
393021	Green	4 AWG	7 x .0772	.110 (2.8)	0.460 (11.7)	185 (276)

a. 8AWG Minimum Bending Radius - Training: 1.6in (4.1cm), Pulling: 2.4in (6.1cm)
b. 6AWG Minimum Bending Radius - Training: 1.7in (4.3cm), Pulling: 2.6in (6.6cm)
c. 4AWG Minimum Bending Radius - Training: 1.9in (4.8cm), Pulling: 2.9in (7.4cm)

The data herein is approximate and subject to normal manufacturing tolerances.

Information is subject to change without notice. Consult factory for a variety of alternate constructions for specific applications.

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300C_IND_FAA_COLORABLE_FAA-L-824_TYPE_C_CBL_01-19

Draka

A brand of the Prysmian Group

FAA-L-824 Type B Airport Lighting Power Cable

Single conductor / 8, 6 and 4 AWG / 5000 volt / EPR insulation / CPE jacket



Applications

These are single conductor 5000 volt nonshielded power cables suitable for underground installation for use as airport lighting circuits per FAA L-824 Type B and listed in the FAA AC 150/5345-53 Appendix 3. They are rated for use at 90°C in dry conditions.

FAA L-824 cables are suitable for use in conduit, duct, aerial and direct burial installations up to 5000 volts. The CPE jacket offers additional protection from de-icing fluids.

Draka's airport lighting cables have been certified as 100% "Buy American" by the FAA.

https://www.faa.gov/airports/aip/

Specifications and Ratings

- FAA Advisory Circular 150/5345-7F
- Airport Lighting Equipment Certification Program AC150/5345-53 appendix 3 in accordance with Underground Electrical Cable for Airport Lighting Circuits per spec L-824.
- ICEA S-96-659 / NEMA WC71

Design Parameters

CONDUCTOR: Class C, soft drawn tinned copper stranded to ASTM B3 & B8. Class B and Bare copper options also available.

INSULATION: Ethylene propylene rubber (EPR) compound in accordance with the requirements of ICEA S-96-659/NEMA WC 71. Cable jacket available in solid colors.

JACKET: Chlorinated PolyEthylene (CPE) compound in accordance with ICEA S-96-659 / NEMA WC71.

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300C_IND_FAA_FAA-L-824_TYPE_B_AIRPT_LGT_PWR CBL_EPR/CPE_01-19

Draka

A brand of the Prysmian Group

FAA-L-824 Type B Airport Lighting Power Cable

Single conductor / 8, 6 and 4 AWG / 5000 volt / EPR insulation / CPE jacket

Part Number	Conductor Size	Stranding	Insulation Thickness mils (mm)	Jacket Thickness mils (mm)	Approximate Cable O.D. in (mm)	Cable Weight Lbs/Mft (Kg/Km)
388278	8 AWG	19	90 (2.3)	30 (0.76)	0.420 (10.7)	117 (174)
388785	6 AWG	19	90 (2.3)	30 (0.76)	0.460 (11.7)	157 (234)
388287	4 AWG	19	90 (2.3)	30 (0.76)	0.505 (12.8)	217 (323)

Optional features include jacketed constructions: Ethylene propylene rubber (EPR) insulation with a PVC jacket.

AWG Minimum Bending Radius- Training 1.7in (4.3cm), Pulling 2.6in (6.6cm); 6AWG Minimum Bending Radius- Training 1.9in (4.8cm), Pulling 2.9in (7.4cm); 4AWG Minimum Bending Radius- Training 2.1in (5.3cm), Pulling 3.2in (8.1cm)

The data herein is approximate and subject to normal manufacturing tolerances.

Information is subject to change without notice. Consult factory for a variety of alternate constructions for specific applications.

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300C_IND_FAA_FAA-L-824_TYPE_B_AIRPT_LGT_PWR CBL_EPR/CPE_01-19

Draka

A brand of the Prysmian Group

Triple Rated MV-90, FAA Type C & CSA Type ASLC

Single conductor / 8, 6, and 4 AWG / XLPE insulation



Applications

FAA MV-90 CABLES are for medium voltage power transmission of up to 5000 volts. All Draka MV-90 cables are UL listed as intended for use in accordance with NEC Article 310-6 in dry locations up to 90°C. They may also be used as rugged cables in ducted lighting circuits (600 volt to 2400 volt).

The 4, 6 and 8 AWG conductor cables are FAA approved for airport lighting circuits in accordance with the FAA advisory circular 150/5345-7F.

Draka's airport lighting cables have been reviewed and confirmed to meet the FAA guidance for using US manufactured products.

Airport series lighting cables are suitable for use above and below ground in dry or wet locations in accordance with the Canadian Electrical Code, Part I, Section 74.

Design Parameters

CONDUCTOR: Soft drawn stranded bare copper per ASTM B3 and ASTM B8.

STRAND SHIELD: Extruded layer of semiconducting material.

INSULATION: Cross linked polyethylene (XLPE) compound in accordance with the requirements of UL 1072 and the National Electric Code.

Specifications and Ratings

- UL 1072 MV-90 DRY; 2,400 V
- ICEA S-96-659
- NEMA WC71
- FAA L-824 TYPE C; 5,000 V
- FAA (for 4, 6 & 8 AWG conductor cables)
- FAA Advisory Circular 150/5345-7F
- CSA C22.2 No. 179, Type ASLC; 5,000 V
- Low Temperature Rating: -35°C Cold Bend
- Sunlight Resistant

Part Number	Conductor Size and Stranding	Conductor Stranding	Average Insulation Thickness In (mm)	Nominal Cable O.D. In (mm)	Approximate Cable Weight Lbs/Mft (Kg/Km)
389431	8 AWG	7	.110 (2.8)	.400 (10.2)	97 (144)
389432	6 AWG	7	.110 (2.8)	.440 (11.2)	132 (196)
389433	4 AWG	7	.110 (2.8)	.480 (12.2)	189 (281)

The data herein is approximate and subject to normal manufacturing tolerances.
Information is subject to change without notice. Consult factory for a variety of alternate constructions for specific applications.

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300C_IND_FAA_TRIPLE_RATED_MV-90_FAA_TYPE_C_CSA_TYPE_ASLC_01-19

Public Input No. 4122-NFPA 70-2020 [Section No. 311.16(A)]

(A) Required Information.

All conductors and cables shall be marked to indicate the following information, using the applicable method described in 311.16(B):

(1) The maximum rated voltage

(2) The proper type letter or letters for the type of wire or cable as specified elsewhere in this *Code*

(3) The manufacturer's name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified

(4) The AWG size or circular mil area

(5) Color of the conductor's primary insulation's color, as either a full word or as an abbreviation.

FPN 1: Tracer colors are not covered by this item.

FPN 2: Below are examples of possible color labels, including the full name and a possible abbreviation:

WHITE, [WHT]

BLACK, [BLK]

RED, [BLK]

BLUE, [BLU]

* GREEN, [GRN]

* GRAY, [GRY]

* BROWN, [BRN]

ORANGE, [ORG]

YELLOW, [YEL]

ORANGE, [ORG]

PURPLE, [PUR]

PINK, [PNK]

TAN, [TAN]

Informational Note: See Chapter 9, Table 8, Conductor Properties, for conductor area expressed in SI units for conductor sizes specified in AWG or circular mil area.

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Statement of Problem and Substantiation for Public Input

This change is being recommended to cut down on the number of hazards that have been introduced in the field due to misidentification of the color embedded into the conductors' insulation.

Depending upon the source, it has been stated that men have rates as few as 1 in 12 (~8.33%), 8-10% and as many as many as one-in-six (~16.67%) of some sort of Color Vision Deficiency. (It's a less catchy phrase than "color blind", but more accurate.) Because the condition is hereditary by way of the X-chromasome, only 1 in 200 (~0.50%) or 0.4-1.0% of women have the same condition(s).
* Trichromacy is when all three vision cones, S, M & L are working correctly together (91.3% men & 99.6% women).

* The most common form of color vision deficiency is Anomalous Trichromacy when one of the cones is impaired:
* Deuteranomaly: The "M" cone is responsible for medium wavelength colors (Greens); Deuteranopia is when the "M"s sensitivity is shifted right to the L's band lengths (5.0% men & 0.35% women).
* Protanomaly: The "L" cone is responsible for the higher wavelength colors (Red); Protanopia is when the "L"s sensitivity is shifted left to the N's bond lengths (1.3% men & 0.02% women).
* Tritanomaly involves the "S" cone (regarding Blues and Yellows) is extremely rare at 0.0001% men and 0.0001% women
* Monochromacy, or total "color blindness" is very rare at rates of 0.0001% or 1 in 40,000 (~0.0025%) for male and female.

The above numbers add up to circa 330,000 people (~5%) world wide; some of these people are electricians.

Comment:
Non Color Vision Deficient people may not understand how someone can enter into the electrical field with said color deficiency. It actually IS possible to either be ignorant of such a situation or to not realize that one's situation is advanced enough to cause problems until one is well within a career.

It does not take Color Vision Deficiency ("Color Blindness") in order to misidentify a conductor's insulation color. Anecdotal evidence indicates numerous manufacturers have made colors that are not easy even for the most visually acure people to identify. Over time the colors in some conductor's insulation has been known to fade or discolor. Add into these situations problems with poor lighting, dust and any other number of conditions, and one can see that the color misidentification can cause serious safety problems. (Try identifying a green, gray and brown conductor, in a dusty, shady environment, when the manufacturer has not added sufficient pigment to the insulation.)

* In the event that Code Making Panel 6 should reject the main substantiation, strictly on safety argument(s), then here is an alternate argument: As per any ADA (American with Disabilities Act) rights I may have at my use, I hereby request this change as an ADA workplace reasonable accommodation for ONLY the colors of Green, Gray and Brown. I hope CMP6 will agree that this is not a preferred solution, the NFPA-70 should require labeling all of the primary insulation colors.

Submitter Information Verification

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Submittal Date: Wed Sep 09 21:24:48 EDT 2020

Committee: NEC-P06

Committee Statement

Resolution: The NEC currently provides direction for identifying current carrying conductors, grounded conductors and grounding conductors. There's no substantiation for justifying the range of colors.

Public Input No. 895-NFPA 70-2020 [Section No. 311.30]

311.30 Installation.

Type MV cable shall be installed, terminated, and tested by qualified persons.

Informational Note No. 1: Information about accepted industry practices and installation procedures for medium-voltage cable are described in ANSI/NECA/NCSCB 600-2020 , *Standard for Installing and Maintaining Medium-Voltage Cable*, and in IEEE 576, *Recommended Practice for Installation, Termination, and Testing of Insulated Power Cables as Used in Industrial and Commercial Applications*.

Informational Note No. 2: Where medium-voltage cable is used for dc circuits, low frequency polarization can create hazardous voltages. When handling the cable these voltages may be present or may develop on dc stressed cable while the circuit is energized. Solidly grounding the cable prior to contacting, cutting or disconnecting cables in dc circuits is a method to discharge these voltages.

Statement of Problem and Substantiation for Public Input

The latest edition of this National Electrical Installation Standard (NEIS) NECA/NCSCB 600 is 2020.

Submitter Information Verification

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Submittal Date: Tue Apr 21 13:07:37 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8616-NFPA 70-2021

Statement: Terminations, MV cable joints and MV cable connectors are being added to provide for complete system installation. The listing requirement in 311/315.6 was expanded to include these additional items with a future effective date to allow the industry time to exhaust inventory of unlisted inventory and to comply with the listing requirement. New section 311/315.17 was added detailing the application of these connectors and markings. Section 311/315.30 was revised to require qualified personnel to complete the installation including cable joints and terminations. Other revisions were made dealing with the installation of these connectors. Code Making Panel 6 refers to the Correlating Committee for review of the modification to the Title of Article 311/315 to include the words Cable, Cable Joints and Terminations.

The Direct Current Voltage rating is being limited to 2500 Volts due to industry experience. Higher voltages are being investigated for their effect on extruded insulation materials. This change is being referred to the Correlating Committee which has purview over Scopes of Articles.

The most current edition of the standard was updated to 2020 in 311/315.30 information note.

Correcting an oversight in 311/315.32 when Article 311 was created out of Article 328 and 310.

The shielding for cables is not suitable for clearing ground fault events unless sized properly.

The note in 311/315.60(D)4 gives users guidance on conductor ampacities and considering terminations.

Information notes were added to refer to industry standards.

Public Input No. 1162-NFPA 70-2020 [Section No. 311.32]

311.32 Uses Permitted.

Type MV cable shall be permitted for use on power systems rated up to and including 35,000 volts, nominal, as follows:

(1) In wet or dry locations.

(2) In raceways.

(3) In cable trays, where identified for the use, in accordance with 392.10, 392.20(B), (C), and (D), 392.22(C), 392.30(B)(1), 392.46, 392.56, and 392.60. Type MV cable that has an overall metallic sheath or armor, complies with the requirements for Type MC cable, and is identified as “MV or MC” shall be permitted to be installed in cable trays in accordance with 392.10(B)(2).

(4) Direct buried in accordance with 300.50.

(5) In messenger-supported wiring in accordance with Part II of Article 396.

(6) As exposed runs in accordance with 300.37. Type MV cable that has an overall metallic sheath or armor, complies with the requirements for Type MC cable, and is identified as “MV or MC” shall be permitted to be installed as exposed runs of metal-clad cable in accordance with 300.37.

(7) Corrosive conditions where exposed to oils, greases, vapors, gases, fumes, liquids, or other substances having a deleterious effect on the conductor or insulation shall be of a type suitable for the application.

(8) Conductors in parallel in accordance with 310.10(G).

(9) Type MV cable used where exposed to direct sunlight shall be identified for the use.

Informational Note: The “uses permitted” is not an all-inclusive list.

Statement of Problem and Substantiation for Public Input

Direct earth burial of MV conductors and cables is permitted by the NEC and cable listings.
Direct earth burial was included in the 2017 NEC 328.10 uses permitted list.
Direct earth burial is specifically addressed in 2010 NEC 311.36.
While the informational note states that the "uses permitted" is not all-inclusive, direct earth burial is as prevalent a method as an installation in raceway or wet and dry locations.

Submitter Information Verification

Submitter Full Name: Carl Johnson II
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Submittal Date: Tue May 19 17:03:29 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8616-NFPA 70-2021

Statement: Terminations, MV cable joints and MV cable connectors are being added to provide for complete system installation. The listing requirement in 311/315.6 was expanded to include these additional items with a future effective date to allow the industry time to exhaust inventory of unlisted inventory and to comply with the listing requirement. New section 311/315.17 was added detailing the application of these connectors and markings. Section 311/315.30 was revised to require qualified personnel to complete the installation including cable joints and terminations. Other revisions were made dealing with the installation of these connectors. Code Making Panel 6 refers to the Correlating Committee for review of the modification to the Title of Article 311/315 to include the words Cable, Cable Joints and Terminations.

The Direct Current Voltage rating is being limited to 2500 Volts due to industry experience. Higher voltages are being investigated for their effect on extruded insulation materials. This change is being referred to the Correlating Committee which has purview over Scopes of Articles.

The most current edition of the standard was updated to 2020 in 311/315.30 information note.

Correcting an oversight in 311/315.32 when Article 311 was created out of Article 328 and 310.

The shielding for cables is not suitable for clearing ground fault events unless sized properly.

The note in 311/315.60(D)4 gives users guidance on conductor ampacities and considering terminations.

Information notes were added to refer to industry standards.

Public Input No. 958-NFPA 70-2020 [Section No. 311.36]

311.36 Direct-Burial Conductors.

Type MV conductors and cables used for direct burial applications shall be shielded, identified for such use, and installed in accordance with 300.50.

Exception No. 1: Nonshielded multiconductor cables rated 2001 volts to 2400 volts shall be permitted if the cable has an overall metallic sheath or armor.

The metallic shield, sheath, or armor shall be connected to a grounding electrode conductor, a grounding busbar, or a grounding electrode.

Exception No. 2:- - L-824 Airfield lighting cable used in series circuits that are rated up to 5000 volts and are powered by constant current regulators shall be permitted to be nonshielded.

Informational Note to Exception No. 2: Federal Aviation Administration (FAA) Advisory Circulars (ACs) provide additional practices and methods for airport lighting.

Statement of Problem and Substantiation for Public Input

L-824 is the Federal Aviation Administrations (FAA) designation for airfield lighting cable.
The term "regulator" is used in several places in NFPA 70. Art 392.10 uses "constant current regulator", Art 490.23 applies to a "voltage regulator". For this specific application the correct term would be "constant current regulator".

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 957-NFPA 70-2020 [Section No. 300.37]	
Public Input No. 957-NFPA 70-2020 [Section No. 300.37]	

Submitter Information Verification

Submitter Full Name: Carl Johnson II
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Submittal Date: Tue May 05 17:27:21 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FAA L-824 Cable is not recognized by the NEC in general. There is no substantiation to limit the regulators to constant current.

Public Input No. 3325-NFPA 70-2020 [Section No. 311.44]

311.44 Shielding.

Nonshielded, ozone-resistant insulated conductors with a maximum phase-to-phase voltage of 5000 volts shall be permitted in Type MC cables in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation. For other establishments, solid dielectric insulated conductors operated above 2000 volts in permanent installations shall have ozone-resistant insulation and shall be shielded. All metallic insulation shields shall be connected to a grounding electrode conductor, a grounding busbar, an equipment grounding conductor, or a grounding electrode. Equipment grounding conductors installed with circuits using medium voltage cables shall be sized according to 250.190(C).

Informational Note: The primary purposes of shielding are to confine the voltage stresses to the insulation, dissipate insulation leakage current, and drain off the capacitive charging current~~, and carry ground-fault current to facilitate operation of ground-fault protective devices in the event of an electrical cable fault~~ .

Exception No. 1: Nonshielded insulated conductors listed by a qualified testing laboratory shall be permitted for use up to 2400 volts under the following conditions:

(1) Conductors shall have insulation resistant to electric discharge and surface tracking, or the insulated conductor(s) shall be covered with a material resistant to ozone, electric discharge, and surface tracking.

(2) Where used in wet locations, the insulated conductor(s) shall have an overall nonmetallic jacket or a continuous metallic sheath.

(3) Insulation and jacket thicknesses shall be in accordance with Table 311.10(B).

Exception No. 2: Nonshielded insulated conductors listed by a qualified testing laboratory shall be permitted for use up to 5000 volts to replace existing nonshielded conductors, on existing equipment in industrial establishments only, under the following conditions:

(1) Where the condition of maintenance and supervision ensures that only qualified personnel install and service the installation.

(2) Conductors shall have insulation resistant to electric discharge and surface tracking, or the insulated conductor(s) shall be covered with a material resistant to ozone, electric discharge, and surface tracking.

(3) Where used in wet locations, the insulated conductor(s) shall have an overall nonmetallic jacket or a continuous metallic sheath.

(4) Insulation and jacket thicknesses shall be in accordance with Table 311.10(B).

Informational Note: Relocation or replacement of equipment may not comply with the term existing as related to this exception.

Exception No. 3: Where permitted in 311.36, Exception No. 2.

Statement of Problem and Substantiation for Public Input

The shielding for cables is not suitable for clearing ground fault events unless sized properly. See 250.190(C). This section should be revised to refer to Section 250.190 for equipment grounding conductor requirements, which more appropriately addresses minimum sizing requirements in 250.190(C)(2) and (3). Currently the text in this Informational Note is misleading and causing confusion in the field and could result in undersized equipment grounding conductors or lack of required

minimum sized equipment grounding conductors with circuits installed using medium voltage cables. Here is another problem contained within this IN, the rule (311.44) says shields can be connected to a grounding electrode conductor, which could be as small as a 6 AWG copper conductor which in many cases would be too small for a feeder installation that consists of shielded MV cables. The tape type shielding is often significantly smaller that concentric stranded shielding. Not to mention if cables are used in a parallel feeder arrangement, they would be severely undersized with respect to what would be required as a minimum size equipment grounding conductor.

Submitter Information Verification

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Submittal Date: Tue Sep 08 05:46:09 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8616-NFPA 70-2021

Statement: Terminations, MV cable joints and MV cable connectors are being added to provide for complete system installation. The listing requirement in 311/315.6 was expanded to include these additional items with a future effective date to allow the industry time to exhaust inventory of unlisted inventory and to comply with the listing requirement. New section 311/315.17 was added detailing the application of these connectors and markings. Section 311/315.30 was revised to require qualified personnel to complete the installation including cable joints and terminations. Other revisions were made dealing with the installation of these connectors. Code Making Panel 6 refers to the Correlating Committee for review of the modification to the Title of Article 311/315 to include the words Cable, Cable Joints and Terminations.

The Direct Current Voltage rating is being limited to 2500 Volts due to industry experience. Higher voltages are being investigated for their effect on extruded insulation materials. This change is being referred to the Correlating Committee which has purview over Scopes of Articles.

The most current edition of the standard was updated to 2020 in 311/315.30 information note.

Correcting an oversight in 311/315.32 when Article 311 was created out of Article 328 and 310.

The shielding for cables is not suitable for clearing ground fault events unless sized properly.

The note in 311/315.60(D)4 gives users guidance on conductor ampacities and considering terminations.

Information notes were added to refer to industry standards.

Public Input No. 959-NFPA 70-2020 [Section No. 311.44]

311.44 Shielding.

Nonshielded, ozone-resistant insulated conductors with a maximum phase-to-phase voltage of 5000 volts shall be permitted in Type MC cables in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation. For other establishments, solid dielectric insulated conductors operated above 2000 volts in permanent installations shall have ozone-resistant insulation and shall be shielded. All metallic insulation shields shall be connected to a grounding electrode conductor, a grounding busbar, an equipment grounding conductor, or a grounding electrode.

Informational Note: The primary purposes of shielding are to confine the voltage stresses to the insulation, dissipate insulation leakage current, drain off the capacitive charging current, and carry ground-fault current to facilitate operation of ground-fault protective devices in the event of an electrical cable fault.

Exception No. 1: Nonshielded insulated conductors listed by a qualified testing laboratory shall be permitted for use up to 2400 volts under the following conditions:

(1) Conductors shall have insulation resistant to electric discharge and surface tracking, or the insulated conductor(s) shall be covered with a material resistant to ozone, electric discharge, and surface tracking.

(2) Where used in wet locations, the insulated conductor(s) shall have an overall nonmetallic jacket or a continuous metallic sheath.

(3) Insulation and jacket thicknesses shall be in accordance with Table 311.10(B).

Exception No. 2: Nonshielded insulated conductors listed by a qualified testing laboratory shall be permitted for use up to 5000 volts to replace existing nonshielded conductors, on existing equipment in industrial establishments only, under the following conditions:

(1) Where the condition of maintenance and supervision ensures that only qualified personnel install and service the installation.

(2) Conductors shall have insulation resistant to electric discharge and surface tracking, or the insulated conductor(s) shall be covered with a material resistant to ozone, electric discharge, and surface tracking.

(3) Where used in wet locations, the insulated conductor(s) shall have an overall nonmetallic jacket or a continuous metallic sheath.

(4) Insulation and jacket thicknesses shall be in accordance with Table 311.10(B).

Informational Note: Relocation or replacement of equipment may not comply with the term existing as related to this exception.

Exception No. 3: ~~Where permitted in 311.36 , Exception No. 2~~
L-824 Airfield lighting cable used in series circuits that are rated up to 5000 volts and are powered by constant current regulators shall be permitted to be nonshielded.

Informational Note to Exception No. 3: Federal Aviation Administration (FAA) Advisory Circulars (ACs) provide additional practices and methods for airport lighting .

Statement of Problem and Substantiation for Public Input

Typically it is better to have common information in a single location, thus simplifying updates, changes, etc.
However, in this case it is necessary to include the full text in this second location. In today's electronic

world, this exception would not be found using a search function. While some L-824 5,000 volt cable is still direct buried, the majority is installed in conduit. The full text of the exception should be contained in this part to provide clarity and intent.

Submitter Information Verification

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Submittal Date: Tue May 05 17:40:12 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FAA L-824 Cable is not recognized by the NEC in general. Therefore, there must be product recognition that is in line with NEC standards.

Public Input No. 97-NFPA 70-2019 [Section No. 311.60(D)(4)]

(4) Ambient Temperature Correction.

Ampacities for ambient temperatures other than those specified in the ampacity tables shall be corrected in accordance with Table 311.60(D)(4) or shall be permitted to be calculated using the following equation:

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}}$$ **[311.60(D)(4**

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the table for T_C and T_a

T_C = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

Informational Note: See 110.40 for ambient temperature adjustments for terminals.

Table 311.60(D)(4) Ambient Temperature Correction Factors

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor		Ambient Temperature (°F)
	90°C	105°C	
10 or less	1.26	1.21	50 or less
11–15	1.22	1.18	51–59
16–20	1.18	1.14	60–68
21–25	1.14	1.11	69–77
26–30	1.10	1.07	78–86
31–35	1.05	1.04	87–95
36–40	1.00	1.00	96–104
41–45	0.95	0.96	105–113
46–50	0.89	0.92	114–122
51–55	0.84	0.88	123–131
56–60	0.77	0.83	132–140
61–65	0.71	0.78	141–149
66–70	0.63	0.73	150–158
71–75	0.55	0.68	159–167
76–80	0.45	0.62	168–176
81–85	0.32	0.55	177–185
86–90	—	0.48	186–194
91–95	—	0.39	195–203
96–100	—	0.28	204–212

Statement of Problem and Substantiation for Public Input

This is a companion proposal for the revision of 110.40. It is editorial in nature to provide guidance for

the user of this section. Please see substantiation for proposed revision to 110.40.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 95-NFPA 70-2019 [Section No. 110.40]	Ambient temperature correction factors for terminals

Submitter Information Verification

Submitter Full Name: Paul Guidry
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Submittal Date: Tue Nov 12 15:57:37 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8616-NFPA 70-2021

Statement: Terminations, MV cable joints and MV cable connectors are being added to provide for complete system installation. The listing requirement in 311/315.6 was expanded to include these additional items with a future effective date to allow the industry time to exhaust inventory of unlisted inventory and to comply with the listing requirement. New section 311/315.17 was added detailing the application of these connectors and markings. Section 311/315.30 was revised to require qualified personnel to complete the installation including cable joints and terminations. Other revisions were made dealing with the installation of these connectors. Code Making Panel 6 refers to the Correlating Committee for review of the modification to the Title of Article 311/315 to include the words Cable, Cable Joints and Terminations.

The Direct Current Voltage rating is being limited to 2500 Volts due to industry experience. Higher voltages are being investigated for their effect on extruded insulation materials. This change is being referred to the Correlating Committee which has purview over Scopes of Articles.

The most current edition of the standard was updated to 2020 in 311/315.30 information note.

Correcting an oversight in 311/315.32 when Article 311 was created out of Article 328 and 310.

The shielding for cables is not suitable for clearing ground fault events unless sized properly.

The note in 311/315.60(D)4 gives users guidance on conductor ampacities and considering terminations.

Information notes were added to refer to industry standards.

Public Input No. 906-NFPA 70-2020 [New Section after 314.72(F)]

Article 315

Article 315 Flexible Cords and Flexible Cables

Part I. General

315.1 Scope.

This article covers general requirements, applications, and construction specifications for flexible cords and flexible cables.

315.2 Other Articles.

Flexible cords and flexible cables shall comply with this article and with the applicable provisions of other articles of this *Code* .

315.3 Suitability.

Flexible cords and flexible cables and their associated fittings shall be suitable for the conditions of use and location.

315.4 Types.

Flexible cords and flexible cables shall conform to the description in Table 400.4 . The use of flexible cords and flexible cables other than those in Table 400.4 shall require permission by the authority having jurisdiction.

Table 400.4 Flexible Cords and Flexible Cables

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	Nominal Insulation Thickness mm	Nominal Insulation Thickness m
Lamp cord	C	300 600	18–16 15–10	2 or more	Thermoset or thermoplastic	18–16 15–10	0.76 1.14	3 4
Elevator cable	E 1,2,3,4	300 or 600	20–2	2 or more	Thermoset	20–16 15–12 12–10 8–2	0.51 0.76 1.14 1.52	2 3 4 6
						20–16 15–12 12–10 8–2	0.51 0.76 1.14 1.52	2 3 4 6
Elevator cable	EO 1,2,4	300 or 600	20–2	2 or more	Thermoset	20–16 15–12 12–10	0.51 0.76 1.14	2 3 4

						8–2	1.52	6
Elevator cable	ETP 2,4	300 or 600						
	ETT 2,4	300 or 600						
Electric vehicle cable	EV 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica-tions, and optical fiber cables	Thermoset with optional nylon	18–15	0.76 (0.51)	3 (2
						14–10	1.14 (0.76)	4 (3
						8–2	1.52 (1.14)	6 (4
						1–4/0	2.03 (1.52)	8 (6
						250–500	2.41 (1.90)	9 (7
	EVJ 5,6	300	18–12			18–12	0.76 (0.51)	3 (2
	EVE 5,6	1000	18–500	2 or more plus equipment grounding	Thermoplastic elastomer with optional nylon	18–15	0.76 (0.51)	3 (2

				conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables		14–10	1.14 (0.76)	4 (3
						8–2	1.52 (1.14)	6 (4
						1–4/0	2.03 (1.52)	8 (6
						250– 500	2.41 (1.90)	9 (7
	EVJE 5,6	300	18–12			18–12	0.76 (0.51)	3 (2
	EVT 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	Thermoplastic with optional nylon	18–15	0.76 (0.51)	3 (2
						14–10	1.14 (0.76)	4 (3
						8–2	1.52 (1.14)	6 (4
						1–4/0	2.03 (1.52)	8 (6
						250– 500	2.41 (1.90)	9 (7
	EVJT 5,6	300	18–12			18–12	0.76 (0.51)	3 (2
Portable power cable	G	2000	12–500	2–6 plus equipment grounding conductor(s)	Thermoset	12–2 1–4/0 250–500	1.52 2.03 2.41	6 8 9

	G-GC [7]	2000	12–500	3–6 plus equipment grounding conductors and 1 ground check conductor	Thermoset	12–2 1–4/0 250–500	1.52 2.03 2.41	6 8 9
Heater cord	HPD	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.38 0.76	1 3
Parallel heater cord	HPN [8]	300	18–12	2 or 3	Oil-resistant thermoset	18–16 15 14 12	1.14 1.52 2.41	4 6 9
Thermoset jacketed heater cords	HSJ	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.76 1.14	3 4
	HSJW	300	18–12		Thermoset			
	HSJO	300	18–12		Oil-resistant thermoset			
	HSJOW [9]	300	18–12					
	HSJOO	300	18–12					
	HSJOOW [9]	300	18–12					
Non-integral parallel cords	NISP-1	300	20–18	2 or 3	Thermoset	20–18	0.38	1
	NISP-2	300	18–16			18–16	0.76	3
	NISPE-1 [8]	300	20–18		Thermoplastic elastomer	20–18	0.38	1
	NISPE-2 [8]	300	18–16			18–16	0.76	3
	NISPT-1 [8]	300	20–18		Thermoplastic	20–18	0.38	1
	NISPT-2 [8]	300	18–16			18–16	0.76	3

Twisted portable cord	PD	300 600	18–16 14–10	2 or more	Thermoset or thermoplastic	18–16 15–10	0.76 1.14	3 4
Portable power cable	PPE [7]	2000	12–500	1–6 plus optional equipment grounding conductor(s)	Thermoplastic elastomer	12–2 1–4/0 250–500	1.52 2.03 2.41	6 8 9
Hard service cord	S [7]	600	18–2	2 or more	Thermoset	18–15 14–10 8–2	0.76 1.14 1.52	3 4 6
Flexible stage and lighting power cable	SC [7,10]	600	8–250	1 or more	Thermoset	8–2 1–4/0 250	1.52 2.03 2.41	6 8 9
	SCE [7,10]	600			Thermoplastic elastomer			
	SCT [7,10]	600			Thermoplastic			
Hard service cord	SE [7]	600	18–2	2 or more	Thermoplastic elastomer	18–15 14–9 8–2	0.76 1.14 1.52	3 4 6
	SEW [7, 9]	600						
	SEO [7]	600						

	SEOW [7,9]	600						
	SEOO [7]	600			Oil-resistant thermoplastic elastomer			
	SEOOW [7,9]	600						
Junior hard service cord	SJ	300	18–10	2–6	Thermoset	18–11 10	0.76 1.14	3 4
	SJE	300			Thermoplastic elastomer			
	SJEW [9]	300						
	SJEO	300						
	SJEOW [9]	300						
	SJEOO	300			Oil-resistant thermoplastic elastomer			
	SJEOOW [9]	300						

	SJO	300			Thermoset			
	SJOW [9]	300						
	SJOO	300			Oil-resistant thermoset			
	SJOOW [9]	300						
	SJT	300			Thermoplastic			
	SJTW [9]	300						
	SJTO	300				18–12 10	0.76 1.14	3 4
	SJTOW [9]	300						
	SJTOO	300			Oil-resistant thermoplastic			
	SJTOOW [9]	300						
Hard service cord	SO [7]	600	18–2	2 or more	Thermoset	18–15	0.76	3
	SOW [7,9]	600						
	SOO [7]	600			Oil-resistant thermoset	14–9 8–2	1.14 1.52	4 6
	SOOW [7,9]	600						

All thermoset parallel cord	SP-1	300	20–18	2 or 3	Thermoset	20–18	0.76	3
	SP-2	300	18–16			18–16	1.14	4
	SP-3	300	18–10			18–16 15–14 12 10	1.52 2.03 2.41 2.80	6 8 9 11
All elastomer (thermo-plastic) parallel cord	SPE-1 [8]	300	20-18	2 or 3	Thermoplastic elastomer	20–18	0.76	3
	SPE-2 [8]	300	18–16			18–16	1.14	4
	SPE-3 [8]	300	18–10			18–16 15–14 12 10	1.52 2.03 2.41 2.80	6 8 9 11
All thermoplastic parallel cord	SPT-1	300	20–18	2 or 3	Thermoplastic	20–18	0.76	3
	SPT-1W [9]	300		2				
	SPT-2	300	18–16	2 or 3		18–16	1.14	4
	SPT-2W [9]	300		2				

	SPT-3	300	18–10	2 or 3		18–16 15–14 12 10	1.52 2.03 2.41 2.80	6 8 9 11
Range, dryer cable	SRD	300	10–4	3 or 4	Thermoset	10–4	1.14	4
	SRDE	300	10–4	3 or 4	Thermoplastic elastomer			
	SRDT	300	10–4	3 or 4	Thermoplastic			
Hard service cord	ST [7]	600	18–2	2 or more	Thermoplastic	18–15 14–9 8–2	0.76 1.14 1.52	3 4 6
	STW [7,9]	600						
	STO [7]	600						
	STOW [7, 9]	600						
	STOO [7]	600			Oil-resistant thermoplastic			
	STOOW [7]	600						
Vacuum cleaner cord	SV	300	18–16	2 or 3	Thermoset	18–16	0.38	1

	SVE	300			Thermoplastic elastomer			
	SVEO	300						
	SVEOO	300			Oil-resistant thermoplastic elastomer			
	SVO	300			Thermoset			
	SVOO	300			Oil-resistant thermoset			
	SVT	300			Thermoplastic			
	SVTO	300			Thermoplastic			
	SVTOO	300			Oil-resistant thermoplastic			
Parallel tinsel cord	TPT [11]	300	27	2	Thermoplastic	27	0.76	3
Jacketed tinsel cord	TST [11]	300	27	2	Thermoplastic	27	0.38	1
Portable power cable	W [7]	2000	12–500 501–1000	1–6 1	Thermoset	12–2 1–4/0	1.52 2.03	6 8

						250–500	2.41	9
						501–1000	2.80	11

Notes:

All types listed in Table 400.4 shall have individual conductors twisted together, except for Types HPN, SP-1, SP-2, SP-3, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, SPT-1W, SPT-2W, TPT, NISP-1, NISP-2, NISPT-1, NISPT-2, NISPE-1, NISPE-2, and three-conductor parallel versions of SRD, SRDE, and SRDT.

The individual conductors of all cords, except those of heat-resistant cords, shall have a thermoset or thermoplastic insulation, except that the equipment grounding conductor, where used, shall be in accordance with 400.23(B).

[1] Rubber-filled or varnished cambric tapes shall be permitted as a substitute for the inner braids.

[2] Elevator traveling cables for operating control and signal circuits shall contain nonmetallic fillers as necessary to maintain concentricity. Cables shall have steel supporting members as required for suspension by 620.41. In locations subject to excessive moisture or corrosive vapors or gases, supporting members of other materials shall be permitted. Where steel supporting members are used, they shall run straight through the center of the cable assembly and shall not be cabled with the copper strands of any conductor.

In addition to conductors used for control and signaling circuits, Types E, EO, ETP, and ETT elevator cables shall be permitted to incorporate in the construction one or more 20 AWG telephone conductor pairs, one or more coaxial cables, or one or more optical fibers. The 20 AWG conductor pairs shall be permitted to be covered with suitable shielding for telephone, audio, or higher frequency communications circuits; the coaxial cables shall consist of a center conductor, insulation, and a shield for use in video or other radio frequency communications circuits. The optical fiber shall be suitably covered with flame-retardant thermoplastic. The insulation of the conductors shall be rubber or thermoplastic of a thickness not less than specified for the other conductors of the particular type of cable. Metallic shields shall have their own protective covering. Where used, these components shall be permitted to be incorporated in any layer of the cable assembly but shall not run straight through the center.

[3] Insulations and outer coverings that meet the requirements as flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the *Code* type designation.

[4] Elevator cables in sizes 20 AWG through 14 AWG are rated 300 volts, and sizes 10 AWG through 2 AWG are rated 600 volts. 12 AWG is rated 300 volts with a 0.76 mm (30 mil) insulation thickness and 600 volts with a 1.14 mm (45 mil) insulation thickness.

[5] Conductor size for Types EV, EVJ, EVE, EVJE, EVT, and EVJT cables apply to nonpower-limited circuits only. Conductors of power-limited (data, signal, or communications) circuits may extend beyond the stated AWG size range. All conductors shall be insulated for the same cable voltage rating.

[6] Insulation thickness for Types EV, EVJ, EVEJE, EVT, and EVJT cables of nylon construction is indicated in parentheses.

[7] Types G, G-GC, S, SC, SCE, SCT, SE, SEO, SEOO, SEW, SEOW, SEOOW, SO, SOO, SOW, SOOW, ST, STO, STOO, STW, STOW, STOOW, PPE, and W shall be permitted for use on theater stages, in garages, and elsewhere where flexible cords are permitted by this *Code* .

[8] The third conductor in Type HPN shall be used as an equipment grounding conductor only. The insulation of the equipment grounding conductor for Types SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, NISPT-1, NISPT-2, NISPE-1, and NISPE-2 shall be permitted to be thermoset polymer.

[9] Cords that comply with the requirements for outdoor cords and are so listed shall be

permitted to be designated as weather and water resistant with the suffix “W” after the *Code* type designation. Cords with the “W” suffix are suitable for use in wet locations and are sunlight resistant.

[10] The required outer covering on some single-conductor cables may be integral with the insulation.

[11] Types TPT and TST shall be permitted in lengths not exceeding 2.5 m (8 ft) where attached directly, or by means of a special type of plug, to a portable appliance rated at 50 watts or less and of such nature that extreme flexibility of the cord is essential.

400.5 Ampacities for Flexible Cords and Flexible Cables.

(A)_ Ampacity Tables.

Table 400.5(A)(1) provides the ampacities, and Table 400.5(A)(2) provides the ampacities for flexible cords and flexible cables with not more than three current-carrying conductors. These tables shall be used in conjunction with applicable end-use product standards to ensure selection of the proper size and type. Where cords and cables are used in ambient temperatures other than 30°C (86°F), the temperature correction factors from Table 310.15(B)(1) that correspond to the temperature rating of the cord or cable shall be applied to the ampacity in Table 400.5(A)(1) and Table 400.5(A)(2). Cords and cables rated 105°C shall use correction factors in the 90°C column of Table 310.15(B)(1) for temperature correction. Where the number of current-carrying conductors exceeds three, the ampacity of each conductor shall be reduced from the three-conductor rating as shown in Table 400.5(A)(3).

Informational Note: See Informative Annex B, Table B.2(11), for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Table 400.5(A)(1) Ampacity for Flexible Cords and Flexible Cables

[Based on Ambient Temperature of 30°C (86°F). See 400.13 and Table 400.4.]

Copper Conductor Size (AWG)	Thermoplastic Types TPT, TST	Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO, NISP-1, NISP-2 Thermoplastic Types ETP, ETT, NISPE-1, NISPE-2, NISPT-1, NISPT-2, SE, SEW, SEO, SEOO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W, SPT-3, ST, STW, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVEOO, SVT, SVTO, SVTOO		Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW
		Column A [1]	Column B [2]	
27 [3]	0.5	—	—	—
20	—	5 [4]	5	—
18	—	7	10	10
17	—	9	12	13
16	—	10	13	15
15	—	12	16	17
14	—	15	18	20
13	—	17	21	—
12	—	20	25	30
11	—	23	27	—
10	—	25	30	35
9	—	29	34	—
8	—	35	40	—
7	—	40	47	—
6	—	45	55	—
5	—	52	62	—
4	—	60	70	—
3	—	70	82	—

Copper Conductor Size (AWG)	Thermoplastic Types TPT, TST	Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO, NISP-1, NISP-2	Thermoplastic Types ETP, ETT, NISPE-1, NISPE-2, NISPT-1, NISPT-2, SE, SEW, SEO, SEOO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W, SPT-3, ST, STW, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVEOO, SVT, SVTO, SVTOO	Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW
2	—	80	95	—

1 The currents under Column A apply to three-conductor cords and other multiconductor cords connected to utilization equipment so that only three-conductors are current-carrying.

2 The currents under Column B apply to two-conductor cords and other multiconductor cords connected to utilization equipment so that only two conductors are current-carrying.

3 Tinsel cord.

4 Elevator cables only.

5 7 amperes for elevator cables only; 2 amperes for other types.

Table 400.5(A)(2) Ampacity of Cable Types SC, SCE, SCT, PPE, G, G-GC, and W

[Based on Ambient Temperature of 30°C (86°F). See Table 400.4.]

Copper Conductor Size (AWG or kcmil)	Temperature Rating of Cable								
	60°C (140°F)			75°C (167°F)			90°C (194°F)		
	D 1	E 2	F 3	D 1	E 2	F 3	D 1	E 2	F 3
12	—	31	26	—	37	31	—	42	35
10	—	44	37	—	52	43	—	59	49
8	60	55	48	70	65	57	80	74	65
6	80	72	63	95	88	77	105	99	87
4	105	96	84	125	115	101	140	130	114
3	120	113	99	145	135	118	165	152	133
2	140	128	112	170	152	133	190	174	152
1	165	150	131	195	178	156	220	202	177
1/0	195	173	151	230	207	181	260	234	205
2/0	225	199	174	265	238	208	300	271	237
3/0	260	230	201	310	275	241	350	313	274
4/0	300	265	232	360	317	277	405	361	316
250	340	296	259	405	354	310	455	402	352
300	375	330	289	445	395	346	505	449	393

Copper Conductor Size (AWG or kcmil)	Temperature Rating of Cable								
	60°C (140°F)			75°C (167°F)			90°C (194°F)		
	D [1]	E [2]	F [3]	D [1]	E [2]	F [3]	D [1]	E [2]	F [3]
350	420	363	318	505	435	381	570	495	433
400	455	392	343	545	469	410	615	535	468
500	515	448	392	620	537	470	700	613	536
600	575	—	—	690	—	—	780	—	—
700	630	—	—	755	—	—	855	—	—
750	655	—	—	785	—	—	885	—	—
800	680	—	—	815	—	—	920	—	—
900	730	—	—	870	—	—	985	—	—
1000	780	—	—	935	—	—	1055	—	—

[1] The ampacities under subheading D shall be permitted for single-conductor Types SC, SCE, SCT, PPE, and W cable only where the individual conductors are not installed in raceways and are not in physical contact with each other except in lengths not to exceed 600 mm (24 in.) where passing through the wall of an enclosure.

[2] The ampacities under subheading E apply to two-conductor cables and other multiconductor cables connected to utilization equipment so that only two conductors are current-carrying.

[3] The ampacities under subheading F apply to three-conductor cables and other multiconductor cables connected to utilization equipment so that only three conductors are current-carrying.

Table 400.5(A)(3) Adjustment Factors for More Than Three Current-Carrying Conductors in a Flexible Cord or Flexible Cable

Number of Conductors	Percent of Value in Table 400.5(A)(1) and Table 400.5(A)(2)
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to meet the requirements of a current-carrying conductor.

In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, a common conductor carries approximately the same current as the line-to-neutral currents of the other conductors and shall be considered to be a current-carrying conductor.

On a 4-wire, 3-phase, wye circuit where more than 50 percent of the load consists of nonlinear

loads, there are harmonic currents present in the neutral conductor and the neutral conductor shall be considered to be a current-carrying conductor.

An equipment grounding conductor shall not be considered a current-carrying conductor.

Where a single conductor is used for both equipment grounding and to carry unbalanced current from other conductors, as provided for in 250.140 for electric ranges and electric clothes dryers, it shall not be considered as a current-carrying conductor.

(B) Ultimate Insulation Temperature.

In no case shall conductors be associated together in such a way with respect to the kind of circuit, the wiring method used, or the number of conductors such that the limiting temperature of the conductors is exceeded.

(C) Engineering Supervision.

Under engineering supervision, conductor ampacities shall be permitted to be calculated in accordance with 310.14(B) .

400.6 Markings.

(A) Standard Markings.

Flexible cords and flexible cables shall be marked by means of a printed tag attached to the coil reel or carton. The tag shall contain the information required in 310.8(A) . Types S, SC, SCE, SCT, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, STOO, SEW, SEOW, SEOOW, SJEW, SJEOW, SJEOOW, SJOW, SJTW, SJTOW, SJTOOW, SOW, SOOW, STW, STOW, and STOOW flexible cords and G, G-GC, PPE, and W flexible cables shall be durably marked on the surface at intervals not exceeding 610 mm (24 in.) with the type designation, size, and number of conductors. Required markings on tags, cords, and cables shall also include the maximum operating temperature of the flexible cord or flexible cable.

(B) Optional Markings.

Flexible cords and cable types listed in Table 400.4 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistance, and so forth.

400.10 Uses Permitted.

(A) Uses.

Flexible cords and flexible cables shall be used only for the following:

(1) Pendants.

(2) Wiring of luminaires.

(3) Connection of portable luminaires, portable and mobile signs, or appliances.

(4) Elevator cables.

(5) Wiring of cranes and hoists.

(6) Connection of utilization equipment to facilitate frequent interchange.

(7) Prevention of the transmission of noise or vibration.

(8) Appliances where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance and repair, and the appliance is intended or identified for flexible cord connection.

(9) Connection of moving parts.

(10) Where specifically permitted elsewhere in this *Code* .

(11) Between an existing receptacle outlet and an inlet, where the inlet provides power to an additional single receptacle outlet. The wiring interconnecting the inlet to the single receptacle outlet shall be a Chapter 3 wiring method. The inlet, receptacle outlet, and Chapter 3 wiring method, including the flexible cord and fittings, shall be a listed assembly specific for this application.

(B) Attachment Plugs.

Where used as permitted in 400.10(A)(3) , (A)(6), and (A)(8), each flexible cord shall be equipped with an attachment plug and shall be energized from a receptacle outlet or cord connector body.

Exception: As permitted in 368.56 .

400.12 Uses Not Permitted.

Unless specifically permitted in 400.10 , flexible cords, flexible cables, cord sets, and power supply cords shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

Exception to (4): Flexible cord and flexible cable shall be permitted to be attached to building surfaces in accordance with 368.56(B) and 590.4 .

(5) Where concealed by walls, floors, or ceilings or located above suspended or dropped ceilings

Exception to (5): Flexible cords, flexible cables, and power supply cords shall be permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by 300.22(C)(3) .

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: For proper application see UL 817, *Cord Sets and Power-Supply Cords* , and UL 62, *Flexible Cords and Cables* .

315.13 Splices.

Flexible cord shall be used only in continuous lengths without splice or tap where initially installed in applications permitted by 400.10(A) . The repair of hard-service cord and junior hard-service cord (see Trade Name column in Table 400.4) 14 AWG and larger shall be permitted if conductors are spliced in accordance with 110.14(B) and the completed splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.

315.14 Pull at Joints and Terminals.

Flexible cords and flexible cables shall be connected to devices and to fittings so that tension is not transmitted to joints or terminals.

Exception: Listed portable single-pole devices that are intended to accommodate such tension at their terminals shall be permitted to be used with single-conductor flexible cable.

Informational Note: Some methods of preventing pull on a cord from being transmitted to joints or terminals include knotting the cord, winding with tape, and using support or strain-relief fittings.

315.15 In Show Windows and Showcases.

Flexible cords used in show windows and showcases shall be Types S, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJOO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, STOO, SEW, SEOW, SEOOW, SJEW, SJEOW, SJEOOW, SJOW, SJOOW, SJTW, SJTOW, SJTOOW, SOW, SOOW, STW, STOW, or STOOW.

Exception No. 1: For the wiring of chain-supported luminaires.

Exception No. 2: As supply cords for portable luminaires and other merchandise being displayed or exhibited.

315.16 Overcurrent Protection.

Flexible cords not smaller than 18 AWG, and tinsel cords or cords having equivalent characteristics of smaller size approved for use with specific appliances, shall be considered as protected against overcurrent in accordance with 240.5 .

315.17 Protection from Damage.

Flexible cords and flexible cables shall be protected by bushings or fittings where passing through holes in covers, outlet boxes, or similar enclosures.

In industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation, flexible cords and flexible cables shall be permitted to be installed in aboveground raceways that are no longer than 15 m (50 ft) to protect the flexible cord or flexible cable from physical damage. Where more than three current-carrying conductors are installed within the raceway, the ampacity shall be adjusted in accordance with Table 400.5(A)(3) .

Part II. Construction Specifications

315.20 Labels.

Flexible cords shall be examined and tested at the factory and labeled before shipment.

315.21 Construction.

(A) Conductors.

The individual conductors of a flexible cord or flexible cable shall have copper flexible stranding and shall not be smaller than the sizes specified in Table 400.4 .

(B) Nominal Insulation Thickness.

The nominal thickness of insulation for conductors of flexible cords and flexible cables shall not be less than specified in Table 400.4 .

315.22 Grounded-Conductor Identification.

One conductor of flexible cords that is intended to be used as a grounded circuit conductor shall have a continuous marker that readily distinguishes it from the other conductor or conductors. The identification shall consist of one of the methods indicated in 400.22(A) through (F).

(A) Colored Braid.

A braid finished to show a white or gray color and the braid on the other conductor or conductors finished to show a readily distinguishable solid color or colors.

(B) Tracer in Braid.

A tracer in a braid of any color contrasting with that of the braid and no tracer in the braid of the other conductor or conductors. No tracer shall be used in the braid of any conductor of a flexible cord that contains a conductor having a braid finished to show white or gray.

Exception: In the case of Types C and PD and cords having the braids on the individual conductors finished to show white or gray. In such cords, the identifying marker shall be permitted to consist of the solid white or gray finish on one conductor, provided there is a colored tracer in the braid of each other conductor.

(C) Colored Insulation.

A white or gray insulation on one conductor and insulation of a readily distinguishable color or colors on the other conductor or conductors for cords having no braids on the individual conductors.

For jacketed cords furnished with appliances, one conductor having its insulation colored light blue, with the other conductors having their insulation of a readily distinguishable color other than white or gray.

Exception: Cords that have insulation on the individual conductors integral with the jacket.

The insulation shall be permitted to be covered with an outer finish to provide the desired color.

(D) Colored Separator.

A white or gray separator on one conductor and a separator of a readily distinguishable solid color on the other conductor or conductors of cords having insulation on the individual conductors integral with the jacket.

(E) Tinned Conductors.

One conductor having the individual strands tinned and the other conductor or conductors having the individual strands untinned for cords having insulation on the individual conductors integral with the jacket.

(F) Surface Marking.

One or more ridges, grooves, or white stripes located on the exterior of the cord so as to identify one conductor for cords having insulation on the individual conductors integral with the jacket.

315.23 Equipment Grounding Conductor Identification.

A conductor intended to be used as an equipment grounding conductor shall have a continuous identifying marker readily distinguishing it from the other conductor or conductors. Conductors having a continuous green color or a continuous green color with one or more yellow stripes shall not be used for other than equipment grounding conductors. Cords or cables consisting of integral insulation and a jacket without a nonintegral equipment grounding conductor shall be permitted to be green. The identifying marker shall consist of one of the methods in 400.23(A) or (B).

(A) Colored Braid.

A braid finished to show a continuous green color or a continuous green color with one or more yellow stripes.

(B) Colored Insulation or Covering.

For cords having no braids on the individual conductors, an insulation of a continuous green color or a continuous green color with one or more yellow stripes.

315.24 Attachment Plugs.

Where a flexible cord is provided with an equipment grounding conductor and equipped with an attachment plug, the attachment plug shall comply with 250.138(A) and (B).

Part III. Portable Cables Over 600 Volts, Nominal

315.30 Scope.

Part III applies to single and multiconductor portable cables used to connect mobile equipment and machinery.

315.31 Construction.

(A) Conductors.

The conductors shall be 12 AWG copper or larger and shall employ flexible stranding.

(B) Equipment Grounding Conductor(s).

An equipment grounding conductor(s) shall be provided in cables with three or more conductors. The total area shall not be less than that of the size of the equipment grounding conductor required in 250.122 .

315.32 Shielding.

All shields shall be connected to an equipment grounding conductor.

315.33 Equipment Grounding Conductors.

Equipment grounding conductors shall be connected in accordance with Parts VI and VII of Article 250.

315.34 Minimum Bending Radii.

The minimum bending radii for portable cables during installation and handling in service shall be adequate to prevent damage to the cable.

315.35 Fittings.

Connectors used to connect lengths of cable in a run shall be of a type that locks firmly together. Provisions shall be made to prevent opening or closing these connectors while energized. Suitable means shall be used to eliminate tension at connectors and terminations.

315.36 Splices and Terminations.

Portable cables shall not contain splices unless the splices are of the permanent molded, vulcanized types in accordance with 110.14(B) . Terminations on portable cables rated over 600 volts, nominal, shall be accessible only to authorized and qualified personnel.

Statement of Problem and Substantiation for Public Input

Please see PI 905. Flexible cord and cable is a wiring method and it is time the code recognize the versatile and yet restrictive wiring method

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 905-NFPA 70-2020 [Article 400]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Sun Apr 26 11:05:02 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: There was no technical substantiation submitted that justifies the proposed changes for moving this to Chapter 3 for fixed wiring methods. Flexible cords and flexible cables are appropriately located in Chapter 4.

Public Input No. 4294-NFPA 70-2020 [Article 320]

Article 320 Armored Cable:~~- Type -~~ (AC)

Part I. General

320.1 Scope.

This article covers the use, installation, and construction specifications for armored cable, Type AC.

320.2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Armored Cable, Type AC.

A fabricated assembly of insulated conductors in a flexible interlocked metallic armor. See 320.100.

320.6 Listing Requirements.

Type AC cable and associated fittings shall be listed.

Part II. Installation

320.10 Uses Permitted.

Type AC cable shall be permitted as follows:

(1) For feeders and branch circuits in both exposed and concealed installations

(2) In cable trays

(3) In dry locations

(4) Embedded in plaster finish on brick or other masonry, except in damp or wet locations

(5) To be run or fished in the air voids of masonry block or tile walls where such walls are not exposed or subject to excessive moisture or dampness

Informational Note: The “Uses Permitted” is not an all-inclusive list.

320.12 Uses Not Permitted.

Type AC cable shall not be used as follows:

(1) Where subject to physical damage

(2) In damp or wet locations

(3) In air voids of masonry block or tile walls where such walls are exposed or subject to excessive moisture or dampness

(4) Where exposed to corrosive conditions

(5) Embedded in plaster finish on brick or other masonry in damp or wet locations

320.15 Exposed Work.

Exposed runs of cable, except as provided in 300.11(B), shall closely follow the surface of the building finish or of running boards. Exposed runs shall also be permitted to be installed on the underside of joists where supported at each joist and located so as not to be subject to physical damage.

320.17 Through or Parallel to Framing Members.

Type AC cable shall be protected in accordance with 300.4(A), (C), and (D) where installed through or parallel to framing members.

320.23 In Accessible Attics.

Type AC cables in accessible attics or roof spaces shall be installed as specified in 320.23(A) and (B).

(A) Cables Run Across the Top of Floor Joists.

Where run across the top of floor joists, or within 2.1 m (7 ft) of the floor or floor joists across the face of rafters or studding, the cable shall be protected by guard strips that are at least as high as the cable. Where this space is not accessible by permanently installed stairs or ladders, protection shall only be required within 1.8 m (6 ft) of the nearest edge of the scuttle hole or attic entrance.

(B) Cable Installed Parallel to Framing Members.

Where the cable is installed parallel to the sides of rafters, studs, or ceiling or floor joists, neither guard strips nor running boards shall be required, and the installation shall also comply with 300.4(D).

320.24 Bending Radius.

Bends in Type AC cable shall be made such that the cable is not damaged. The radius of the curve of the inner edge of any bend shall not be less than five times the diameter of the Type AC cable.

320.30 Securing and Supporting.

(A) General.

Type AC cable shall be supported and secured by staples; cable ties listed and identified for securement and support; straps, hangers, or similar fittings; or other approved means designed and installed so as not to damage the cable.

(B) Securing.

Unless otherwise permitted, Type AC cable shall be secured within 300 mm (12 in.) of every outlet box, junction box, cabinet, or fitting and at intervals not exceeding 1.4 m (4½ ft).

(C) Supporting.

Unless otherwise permitted, Type AC cable shall be supported at intervals not exceeding 1.4 m (4½ ft).

Horizontal runs of Type AC cable installed in wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.4 m (4½ ft) intervals.

(D) Unsupported Cables.

Type AC cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable

(2) Is not more than 600 mm (2 ft) in length at terminals where flexibility is necessary

(3) Is not more than 1.8 m (6 ft) in length from the last point of cable support to the point of connection to a luminaire(s) or other electrical equipment and the cable and point of connection are within an accessible ceiling

For the purposes of this section, Type AC cable fittings shall be permitted as a means of cable support.

320.40 Boxes and Fittings.

At all points where the armor of AC cable terminates, a fitting shall be provided to protect wires from abrasion, unless the design of the outlet boxes or fittings is such as to afford equivalent protection, and, in addition, an insulating bushing or its equivalent protection shall be provided between the conductors and the armor. The connector or clamp by which the Type AC cable is fastened to boxes or cabinets shall be of such design that the insulating bushing or its equivalent will be visible for inspection. Where change is made from Type AC cable to other cable or raceway wiring methods, a box, fitting, or conduit body shall be installed at junction points as required in 300.15.

320.80 Ampacity.

The ampacity shall be determined in accordance with 310.14.

(A) Thermal Insulation.

Armored cable installed in thermal insulation shall have conductors rated at 90°C (194°F). The ampacity of cable installed in these applications shall not exceed that of a 60°C (140°F) rated conductor. The 90°C (194°F) rating shall be permitted to be used for ampacity adjustment and correction calculations; however, the ampacity shall not exceed that of a 60°C (140°F) rated conductor.

Where more than two Type AC cables containing two or more current-carrying conductors in each cable are installed in contact with thermal insulation, caulk, or sealing foam without maintaining spacing between cables, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1).

(B) Cable Tray.

The ampacity of Type AC cable installed in cable tray shall be determined in accordance with 392.80(A).

Part III. Construction Specifications

320.100 Construction.

Type AC cable shall have an armor of flexible metal tape and shall have an internal bonding strip of copper or aluminum in intimate contact with the armor for its entire length.

320.104 Conductors.

Insulated conductors shall be of a type listed in Table 310.4(A) or those identified for use in this cable. In addition, the conductors shall have an overall moisture-resistant and fire-retardant fibrous covering. For Type ACT, a moisture-resistant fibrous covering shall be required only on the individual conductors.

320.108 Equipment Grounding Conductor.

Type AC cable shall provide an adequate path for fault current as required by 250.4(A)(5) or (B)(4) to act as an equipment grounding conductor.

320.120 Marking.

The cable shall be marked in accordance with 310.8, except that Type AC shall have ready identification of the manufacturer by distinctive external markings on the cable armor throughout its entire length.

Statement of Problem and Substantiation for Public Input

The only revision in this Public Input is to the Title of the Article.
The word "Type" is used over 1,200 times in the NEC and often it is not necessary.
With the Cable articles the word is used more than it is ever spoken. When people discuss or write issues regarding a cable wiring method they just say "AC Cable" they do not use the word Type. The Revised Style Manual references if the defined term in Article 100 includes an acronym it is permitted to use just the acronym any subsequent time it is referenced in the NEC.
CMP-6 should consider revising all the definitions under their purview to include an acronym and not to use the word "Type". The use of the word type should also be remove through out the article if

possible.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 09:36:23 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The use of the word “Type” is necessary when referencing cable article. It adds not only clarity and usability but it also provides designation when referencing different types of a specific cable. The removal may be effective in other sections of the NEC- however; it is necessary in this article to provide a clear link between the product standards and the NEC.

Public Input No. 3525-NFPA 70-2020 [Section No. 320.2]

(Relocate all definitions in the 320. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

320. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Armored Cable, Type AC.

A fabricated assembly of insulated conductors in a flexible interlocked metallic armor. See 320.100.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:18:09 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 4312-NFPA 70-2020 [Definition: Armored Cable, Type AC.]

(Relocate this definition to Article 100)

Armored Cable, ~~Type~~ (AC) .

A fabricated assembly of insulated conductors in a flexible interlocked metallic armor.

Informational Note: See 320.100, for the construction characteristics of AC Cable .

Statement of Problem and Substantiation for Public Input

"The definition needs to be relocated to Article 100 per the revised NEC Style Manual, 2.2.2.
The Term ""Type"" has been removed for clarity. An Informational Note was added regarding section 320.100.
CMP-6 should consider revising the all definitions under their purview to include an acronym and not to use the word ""Type"". The use of the word type should also be remove through out the articles if possible."

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 09:58:50 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 2275-NFPA 70-2020 [New Section after 320.6]

320.8 Reconditioning

Armored Cable: Type AC shall not be permitted to be reconditioned.

Statement of Problem and Substantiation for Public Input

This revision is needed to clarify that listed Armored Cable: Type AC is not intended to be reconditioned.

Submitter Information Verification

Submitter Full Name: Brian Deacy
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 13 11:57:46 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The addition of a new code section to address reconditioning of Type AC Cable is not necessary. No substantiation was provided to clarify how Type AC Cable can be reconditioned or that a problem exists.

Public Input No. 736-NFPA 70-2020 [Section No. 320.23(A)]

(A) Cables Run Across the Top ~~of Floor Joists~~ of Joists .

Where run across the top ~~of floor joists~~ of joists , or within 2.1 m (7 ft) of the floor~~ or floor joists~~ , or joists, across the face of rafters or studding, the cable shall be protected by guard strips that are at least as high as the cable. Where this space is not accessible by permanently installed stairs or ladders, protection shall only be required within 1.8 m (6 ft) of the nearest edge of the scuttle hole or attic entrance.

Statement of Problem and Substantiation for Public Input

Many attics do not have floor joists, they have ceiling joists. Deleting the qualifier "floor" causes this section to apply to both situations.

Submitter Information Verification

Submitter Full Name: Eric Stromberg
Organization: Los Alamos National Laboratory
Affiliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Sat Mar 21 21:44:13 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8453-NFPA 70-2021
Statement: The term “floor” has been removed to provide clarity when enforcing this requirement.

Public Input No. 1385-NFPA 70-2020 [Section No. 320.30(C)]

(C) Supporting.

Unless otherwise permitted, Type AC cable shall be supported at intervals not exceeding 1.4 m (4½ ft).

Horizontal runs of Type AC cable installed in or on wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.4 m (4½ ft) intervals.

Statement of Problem and Substantiation for Public Input

The practice in the industry is to install cables on top of framing members without securing the cables except for vertical runs. There is not technical reason to allow cables within framing members without support any more than if the cable was above the framing member. The labor required to secure every cable per the NEC securement requirements is not necessary.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 02 09:43:35 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Horizontal runs of AC cable shall be considered supported and secured only if installed “in” framing members. Allowing AC cables to be installed on top of framing members without providing securement is inadequate and could result in potential damage to the cable assembly and terminations.

Public Input No. 2579-NFPA 70-2020 [Section No. 320.30(D)]

(D) Unsupported Cables.

Type AC cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable

(2) Is not more than 600 mm (2 ft) in length at terminals where flexibility is necessary

(3) Is not more than 1.8 m (6 ft) in length from the last point of cable support to the point of connection to a luminaire(s) or other electrical equipment and the cable and point of connection are within an accessible ceiling

For the purposes of ~~this section~~ 320.30(D) , Type AC cable fittings shall be permitted as a means of cable support.

Statement of Problem and Substantiation for Public Input

The current language permits the connectors to be used for support for the complete section. The permission to use the connectors as the supports was only intended to apply to first level subdivision (D)

Submitter Information Verification

Submitter Full Name: Don Ganiere
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 24 20:02:22 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8405-NFPA 70-2021

Statement: Providing the sentence -“Type AC cable fittings shall be used as a means of cable support” is more appropriately located in 320.30(A) as it applies to all sections. When establishing a measurement- the support at the box with the fitting is the starting point.

This first revision relocates and revises the last sentence of 320.30(D) to the last sentence of 320.30(A).

Type AC cable fittings shall be permitted as a means of cable support.

Public Input No. 3527-NFPA 70-2020 [Section No. 322.2]

(Relocate all definitions in the 320.2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

322.2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Flat Cable Assembly, Type FC.

An assembly of parallel conductors formed integrally with an insulating material web specifically designed for field installation in surface metal raceway.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:24:47 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 4061-NFPA 70-2020 [Section No. 322.56(B)]

(B) Taps.

Taps shall be made between any phase conductor and the grounded conductor or any other phase conductor by means of devices and fittings identified for the use. Tap devices shall be rated at not less than 15 amperes, or more than 300 volts to ground, and shall be color-coded in accordance ~~with the requirements of~~ with 322.120(C).

Statement of Problem and Substantiation for Public Input

Deleting the words "the requirements of" does not change the meaning of the section.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 19:39:53 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8629-NFPA 70-2021
Statement: Deleting the words "the requirements of" does not change the meaning of the section.

Public Input No. 3528-NFPA 70-2020 [Section No. 324.2]

(Relocate all definitions in the 324. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

324. 2 Definitions.

The definitions in this section shall apply only within this article.

Bottom Shield.

A protective layer that is installed between the floor and Type FCC flat conductor cable to protect the cable from physical damage and may or may not be incorporated as an integral part of the cable.

Cable Connector.

A connector designed to join Type FCC cables without using a junction box.

FCC System.

A complete wiring system for branch circuits that is designed for installation under carpet squares.

Informational Note: The FCC system includes Type FCC cable and associated shielding, connectors, terminators, adapters, boxes, and receptacles.

Insulating End.

An insulator designed to electrically insulate the end of a Type FCC cable.

Metal Shield Connections.

Means of connection designed to electrically and mechanically connect a metal shield to another metal shield, to a receptacle housing or self-contained device, or to a transition assembly.

Top Shield.

A grounded metal shield covering under-carpet components of the FCC system for the purposes of providing protection against physical damage.

Transition Assembly.

An assembly to facilitate connection of the FCC system to other wiring systems, incorporating (1) a means of electrical interconnection and (2) a suitable box or covering for providing electrical safety and protection against physical damage.

Type FCC Cable.

Three or more flat copper conductors placed edge-to-edge and separated and enclosed within an insulating assembly.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:27:04 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 1318-NFPA 70-2020 [Section No. 324.60]

324.60 Equipment Grounding ~~and Bonding~~ Conductor .

All metal shields, boxes, receptacle housings, and self-contained devices shall be electrically continuous to the equipment grounding conductor of the supplying branch circuit. All such electrical connections shall be made with connectors identified for this use. The electrical resistivity of such shield system shall not be more than that of one conductor of the Type FCC cable used in the installation.

Statement of Problem and Substantiation for Public Input

According to the NFPA Style Manual, the Section Title needs to reflect the content of the rule. The rule is about the equipment grounding conductor, not about 'Grounding or Bonding.'

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 01 13:46:18 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Changing the title does not adequately reflect the requirements of the section.

Public Input No. 3529-NFPA 70-2020 [Section No. 326.2]

(Relocate all definitions in the 326. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

326. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Integrated Gas Spacer Cable, Type IGS.

A factory assembly of one or more conductors, each individually insulated and enclosed in a loose fit, nonmetallic flexible conduit as an integrated gas spacer cable rated 0 volts through 600 volts.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:28:03 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 3531-NFPA 70-2020 [Section No. 330.2]

(Relocate all definitions in the 330. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

330. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Metal Clad Cable, Type MC.

A factory assembly of one or more insulated circuit conductors with or without optical fiber members enclosed in an armor of interlocking metal tape, or a smooth or corrugated metallic sheath.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:30:55 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 2325-NFPA 70-2020 [New Section after 330.6]

348.8 Reconditioning

FMC shall not be permitted to be reconditioned.

Statement of Problem and Substantiation for Public Input

This revision is needed to clarify that listed Flexible Metal Conduit is not intended to be reconditioned.

Submitter Information Verification

Submitter Full Name: Brian Deacy
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 14 15:07:18 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The addition of a new code section to address reconditioning of Type MC Cable is not necessary. No substantiation was provided to clarify how Type MC Cable can be reconditioned or that a problem exists.

Public Input No. 149-NFPA 70-2019 [Section No. 330.10(A)]

(A) General Uses.

Type MC cable shall be permitted as follows:

(1) For services, feeders, and branch circuits.

(2) For power, lighting, control, and signal circuits.

(3) Indoors or outdoors.

(4) Exposed or concealed.

(5) To be direct buried where identified for such use.

(6) In cable tray where identified for such use.

(7) In any raceway.

(8) As aerial cable on a messenger.

(9) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

(10) In dry locations and embedded in plaster finish on brick or other masonry except in damp or wet locations.

(11) In damp or wet locations where a corrosion-resistant jacket is provided over the metallic covering and any of the following conditions are met:

(12) The metallic covering is impervious to moisture.

(13) A jacket resistant to moisture is provided under the metal covering.

(14) The insulated conductors under the metallic covering are listed for use in wet locations.

(15) Where single-conductor cables are used, all phase conductors and, where used, the grounded conductor shall be grouped together to minimize induced voltage on the sheath.

Statement of Problem and Substantiation for Public Input

Greetings CMP,

First, I did not intend for the a), b) or c) to be underlined as that was a terraview issue. The only portion I added was the "damp or" part of item 11.

Second, there has been quite a bit of confusion in the electrical industry of the ratings of Type MC Cable. The UL 1569 Standard doesn't address "damp" but does address dry and wet locations. It is common knowledge that anything rating that is WET can be used in DAMP. So without the guidance of the UL Standard we need to fix that product standard gap in the National Electrical Code. It is 100% acceptable to use a PVC Jacketed MC rated for a wet and corrosive environment in a damp location as it is a lesser restricted location. So it stands to reason we would add "damp" to the item 11 location requirements to address the use of a dry location only product in damp locations. Again, UL 1569 is silent on Damp Locations even if the inner conductors are typically rated for a wet location.

Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: ElectricianLIVE.com
Street Address:
City:
State:
Zip:
Submittal Date: Mon Nov 25 16:55:02 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8407-NFPA 70-2021
Statement: This revision will provide requirements for the installation of MC cable in damp locations to be the same as wet locations.

Public Input No. 1171-NFPA 70-2020 [New Section after 330.30(B)]

Exception:

securing within 300mm (12 in.) shall not be required when going through a stud knockout within 150mm (6 in.) or less from any box.

Statement of Problem and Substantiation for Public Input

cost effective, and utilization of "equipment/tools" that is already available.

Submitter Information Verification

Submitter Full Name: mikayla gonzalez
Organization: E Light Electric
Street Address:
City:
State:
Zip:
Submittal Date: Wed May 20 18:47:27 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Requirements exist for securing and supporting of MC cable. Relaxing the requirements with an exception to not require securement if supported with a stud knockout within 6” or less of a box fails to address the concern of possible strain being placed on the cable and fittings.

Public Input No. 1173-NFPA 70-2020 [Section No. 330.30(B)]

(B) Securing.

Unless otherwise provided, cables shall be secured at intervals not exceeding 1.8 m (6 ft). Cables ~~containing four or fewer conductors sized no larger than 10 AWG~~ shall be secured within 300 mm (12 in.) of every box, cabinet, fitting, or other cable termination. In vertical installations, listed cables with ungrounded conductors 250 kcmil and larger shall be permitted to be secured at intervals not exceeding 3 m (10 ft).

Statement of Problem and Substantiation for Public Input

unstable cables out of a box

Submitter Information Verification

Submitter Full Name: Carlos Aragon
Organization: Elight
Street Address:
City:
State:
Zip:
Submittal Date: Wed May 20 22:23:09 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The requirement in 330.30(B) is specific to smaller cable construction. As the cable size increases – the supporting requirements are relaxed to accommodate the larger cables which provide a more rigid construction.

Public Input No. 4266-NFPA 70-2020 [Sections 330.30(B), 330.30(C)]

Sections 330.30(B), 330.30(C)

(B) Securing.

Unless otherwise ~~provided~~ permitted , cables shall be secured at intervals not exceeding 1.8 m (6 ft). Cables containing four or fewer conductors sized no larger than 10 AWG shall be secured within 300 mm (12 in.) of every box, cabinet, fitting, or other cable termination. In vertical installations, listed cables with ungrounded conductors 250 kcmil and larger shall be permitted to be secured at intervals not exceeding 3 m (10 ft).

(C) Supporting.

Unless otherwise ~~provided~~ permitted , cables shall be supported at intervals not exceeding 1.8 m (6 ft).

Horizontal runs of Type MC cable installed in wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.8-m (6-ft) intervals.

Statement of Problem and Substantiation for Public Input

Changing the wording to “permitted” will place this in line with 320.30(B)(C) when addressing support and securement as these cables are closely related.

Submitter Information Verification

Submitter Full Name: Mark Wolff
Organization: MRW electric
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 08:48:53 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8411-NFPA 70-2021

Statement: Changing the word “provided” to “permitted in this Code” in this section provides consistency with section 320.30(B) and (C) .

Providing the sentence -“Type MC cable fittings shall be used as a means of cable support” is more appropriately located in 330.30(A) as it applies to all sections. When establishing a measurement- the support at the box with the fitting is the starting point.

This first revision relocates and revises the last sentence of 330.30(D) to the last sentence of 330.30(A).

Public Input No. 1108-NFPA 70-2020 [New Section after 330.30(C)]

330.30 Securing and Supporting.

(C). Supporting.

Exception: Where joists do not exceed 5ft in distance across each section, horizontal runs of Type MC cables fished between joist in concealed spaces shall be supported within 1.8m (6ft) from the last point of securement and in intervals not to exceed 3.048m (10ft) thereafter.

Statement of Problem and Substantiation for Public Input

Joists can be a distance of 5ft from one row to the next. Extending supports to every other joist would cost effective and time efficient. The code change would still ensure the minimum requirement necessary for safety by keeping the initial 6ft support after the 12 in. required for securing out of every box, cabinet fitting, or other cable termination. However, after the first 6ft the interval extends to 10ft.

Submitter Information Verification

Submitter Full Name: Nija Jones
Organization: E Light Electric Services Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 16 16:07:11 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The conditions described in the exception had referenced an installation where cables are fished between joists in concealed spaces. MC cable has requirements for both securing and supporting and the allowances for this type of installation are provided in 330.30(D).

Public Input No. 1386-NFPA 70-2020 [Section No. 330.30(C)]

(C) Supporting.

Unless otherwise provided, cables shall be supported at intervals not exceeding 1.8 m (6 ft).

Horizontal runs of Type MC cable installed in or on wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.8-m (6-ft) intervals.

Statement of Problem and Substantiation for Public Input

The practice in the industry is to install cables on top of framing members without securing the cables except for vertical runs. There is not technical reason to allow cables within framing members without support any more than if the cable was above the framing member. The labor required to secure every cable per the NEC securement requirements is not necessary.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 02 09:48:52 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Horizontal runs of MC cable shall be considered supported and secured only if installed “in” framing members. Allowing MC cables to be installed on top of framing members without providing securement is inadequate and could result in potential damage to the cable assembly and terminations.

Public Input No. 1713-NFPA 70-2020 [Section No. 330.30(D)]

(D) Unsupported Cables.

Type MC cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical.

(2) Is not more than 1.8 m (6 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are ~~within~~ above a an accessible ceiling or located more than 3 m (10 ft) above the finish grade .

(3) Is Type MC of the interlocked armor type in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation.

For the purpose of this section, Type MC cable fittings shall be permitted as a means of cable support.

Statement of Problem and Substantiation for Public Input

No. 1. You can locate wiring 'within' a ceiling, since the definition of a ceiling (dictionary) is "the upper interior surface of a room or other similar compartment."
No. 2. Permit the 6' unsupport support rules for wiring above 10', regarless if it's above an accessible ceiling. This is a common practice.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jun 25 14:46:39 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The proposed language references an undefined term “above the finish grade.” Clarity would need to be provided if the intent was above finished floor (AFF). Substantiation was not provided to validate if 10’ is an adequate elevation to relax the requirements if not located above an accessible ceiling.

Public Input No. 2580-NFPA 70-2020 [Section No. 330.30(D)]

(D) Unsupported Cables.

Type MC cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical.

(2) Is not more than 1.8 m (6 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are within an accessible ceiling.

(3) Is Type MC of the interlocked armor type in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation.

For the purpose of ~~this section~~ 330.30(D) , Type MC cable fittings shall be permitted as a means of cable support.

Statement of Problem and Substantiation for Public Input

The current language permits the connectors to be used for support for the complete section. The permission to use the connectors as the supports was only intended to apply to first level subdivision (D)

Submitter Information Verification

Submitter Full Name: Don Ganiere
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 24 20:05:48 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8411-NFPA 70-2021

Statement: Changing the word “provided” to “permitted in this Code” in this section provides consistency with section 320.30(B) and (C) .

Providing the sentence -“Type MC cable fittings shall be used as a means of cable support” is more appropriately located in 330.30(A) as it applies to all sections. When establishing a measurement- the support at the box with the fitting is the starting point.

This first revision relocates and revises the last sentence of 330.30(D) to the last sentence of 330.30(A).

Public Input No. 3124-NFPA 70-2020 [Section No. 330.30(D)]

(D) Unsupported Cables.

Type MC cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical. Cable installed in this manner must be supported and secured within 6 feet from each access point.

(2) Is not more than 1.8 m (6 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are within an accessible ceiling.

(3) Is Type MC of the interlocked armor type in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation.

For the purpose of this section, Type MC cable fittings shall be permitted as a means of cable support.

Statement of Problem and Substantiation for Public Input

My understanding is that the intent of 330.30 D 1 is to allow an installer to not have to remove already installed building finishes. I think there needs to be clarity to the code user that when access is available the cable needs to be supported at the access point.

Submitter Information Verification

Submitter Full Name: Kyle Mackenzie
Organization: Polise Consulting Engineer
Street Address:
City:
State:
Zip:
Submittal Date: Sat Sep 05 07:14:37 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The concern that the submitter has is addressed in the requirements of Section 330.30(B) and(C).

Public Input No. 1151-NFPA 70-2020 [New Section after 330.31]

330.32 Insulating Bushings

At all points where a connector or clamp is used in a junction point, an insulating bushing or its equivalent protection shall be provided between the conductors and the armor.

Statement of Problem and Substantiation for Public Input

Sharp edges on metal sheath may damage wires when tightening the connector.

Submitter Information Verification

Submitter Full Name: serbando montes
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Mon May 18 20:53:17 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Providing an Insulating Bushing is a requirement in 320.40 for terminating AC cables, however; it's not required for terminating MC cables. Adding new section 330.32, 330.40, and 330.118 would provide a conflict with the product listing for MC cables. The fittings used with MC cable are required to be listed and any use of an insulating bushing would be optional.

Public Input No. 1218-NFPA 70-2020 [New Section after 330.31]

330.40 Boxes and Fittings:

At all points where the armor of MC cable terminates, a fitting shall be provided to protect wires from abrasion, unless the design of the outlet boxes or fittings is such as to afford equivalent protection. Where change is made from Type MC cable to other cable or raceway wiring methods, a box, fitting, or conduit body shall be installed at junction points as required in 300.15.

Statement of Problem and Substantiation for Public Input

Article 330 Metal-Clad Cable: Type MC does not adequately address the interaction between MC cable and boxes and fittings. I recommend language similar to that found in section 320.40 for AC cable less the language addressing insulating bushings.

Submitter Information Verification

Submitter Full Name: Gary Hein
Organization: Submission is independent of employer.
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 23 09:29:33 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Providing an Insulating Bushing is a requirement in 320.40 for terminating AC cables, however; it's not required for terminating MC cables. Adding new section 330.32, 330.40, and 330.118 would provide a conflict with the product listing for MC cables. The fittings used with MC cable are required to be listed and any use of an insulating bushing would be optional.

Public Input No. 1272-NFPA 70-2020 [Section No. 330.104]

330.104 Conductors.

For ungrounded, grounded, and equipment grounding conductors, the minimum conductor sizes shall be 14 AWG copper, nickel, or nickel-coated copper and 12 AWG aluminum or copper-clad aluminum.

For control and signal conductors minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, ~~14 AWG~~ 12 AWG copper-clad aluminum, and 12 AWG aluminum.

Statement of Problem and Substantiation for Public Input

Rationale:
A manufacturer of copper-clad aluminum testified to the NFPA Standards Council that permitting 14 AWG copper-clad aluminum in these applications creates an electrical hazard.

From NFPA Standards Council agenda August 6-7, 2019 Attachment 19-8-3-n, pages 8 and 9:

Inconsistent acceptance or rejection of testing data provided. Where the panel rejected the testing data provided to add the ampacities to Tables 310.16 and 310.17, they used this same data, now stating it was acceptable for adding 14 AWG copper-clad aluminum to section 330.104 and 336.104 but limiting the use to control and signaling. While this may seem a good thing, it in fact creates what could become a very serious hazard.

Submitter Information Verification

Submitter Full Name: Megan Hayes
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 28 10:09:52 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This issue is being resolved through actions taken in first revisions.

Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]

330.104 Conductors.

For ungrounded, grounded, and equipment grounding conductors, the minimum conductor sizes shall be 14 AWG copper, nickel, ~~or nickel~~ nickel -coated copper ~~and 12 AWG aluminum or~~ , or copper-clad aluminum and 12 AWG aluminum .

For control and signal conductors minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, 14 AWG copper-clad aluminum, and 12 AWG aluminum.

Additional Proposed Changes

File Name	Description	Approved
Proposed_330.104_Draft_Fnl.docx	Word file attached for clarity.	
Terminal_and_Conductor_Temperature_Testing_Part_I_Fnl.pdf	Terminal temperature static heating test report as requested by task group.	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in metal clad cables.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	Branch circuit AFCI protection added 10 amps
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	Branch circuit ratings added 10 amps
Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	Individual branch circuit receptacle applications and limitations
Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]	Branch circuit applications and limitations
Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]	Summary branch circuit applications and limitations
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	14 AWG copper-clad aluminum OCPD requirements
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	10 amperes added as standard OCPD rating
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	Branch circuit conductor ratings added 14 AWG copper-clad aluminum
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	14 AWG copper-clad aluminum added for cables
Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]	Table 310.16 added ampacities for 14 AWG copper-clad aluminum
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	

Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]

Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]

Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]

Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]

Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]

Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]

Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: IEC
Affiliation: NEC Correlating Committee Task Group
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 07 10:35:29 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8420-NFPA 70-2021

Statement: The minimum conductor sizes for copper and copper-clad aluminum are being reduced to 16 AWG copper and 14 AWG copper-clad aluminum. These revisions are based on testing submitted in support of the use of copper-clad aluminum conductors for 10 amp circuits, and the decades of successful use of 16 AWG copper conductors in fixture wire, motor wiring, control wiring, and other current-carrying applications as permitted in the NEC.

The ampacities are based on laboratory testing and equivalent conductivity of conductors.

330.104 Conductors

For ungrounded, grounded, and equipment grounding conductors, the minimum conductor sizes shall be 14 AWG copper, nickel, ~~or~~ nickel-coated copper ~~and 12 AWG aluminum,~~ or copper-clad aluminum and 12 AWG aluminum.

For control and signal conductors minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, 14 AWG copper-clad aluminum, and 12 AWG aluminum.

Substantiation:

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in metal clad cables.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is

that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Public Input No. 1163-NFPA 70-2020 [New Section after 330.116]

330.118 Anti-Short Bushing.

Type MC must be installed with an Anti-Short Bushing placed into the end of the sheathing. The Anti-Short Bushing must be sized in relation to the size of the sheathing.

Statement of Problem and Substantiation for Public Input

Most Type MC manufacturers require Anti-Short Bushings to be required, yet some do not. Many inspectors will fail an inspection if the MC does not have the bushing. Making it standard code, would make MC installations safer and support the "field code" which some inspectors require.

Submitter Information Verification

Submitter Full Name: andrew young
Organization: E Light Electric
Street Address:
City:
State:
Zip:
Submittal Date: Tue May 19 18:15:14 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Providing an Insulating Bushing is a requirement in 320.40 for terminating AC cables, however; it's not required for terminating MC cables. Adding new section 330.32, 330.40, and 330.118 would provide a conflict with the product listing for MC cables. The fittings used with MC cable are required to be listed and any use of an insulating bushing would be optional.

Public Input No. 3533-NFPA 70-2020 [Section No. 332.2]

(Relocate all definitions in the 332. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

332. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Mineral-Insulated, Metal-Sheathed Cable, Type MI.

A factory assembly of one or more conductors insulated with a highly compressed refractory mineral insulation and enclosed in a liquidtight and gastight continuous copper or alloy steel sheath.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:41:58 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 3534-NFPA 70-2020 [Section No. 334.2]

(Relocate all definitions in the 334. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

334. 2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Nonmetallic-Sheathed Cable.

A factory assembly of two or more insulated conductors enclosed within an overall nonmetallic jacket.

Type NM.

Insulated conductors enclosed within an overall nonmetallic jacket.

Type NMC.

Insulated conductors enclosed within an overall, corrosion resistant, nonmetallic jacket.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:43:41 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 2326-NFPA 70-2020 [New Section after 334.6]

334.8 Reconditioning

Nonmetallic-Sheathed Cable: Types NM and NMC shall not be permitted to be reconditioned.

Statement of Problem and Substantiation for Public Input

This revision is needed to clarify that listed Nonmetallic-Sheathed Cable: Types NM and NMC are not intended to be reconditioned.

Submitter Information Verification

Submitter Full Name: Brian Deacy
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 14 15:11:47 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: It is unclear what reconditioning means when applied to wire and cable. Including this language might cause confusion in the field for applications such as splicing or repairs.

Public Input No. 2955-NFPA 70-2020 [Section No. 334.10]

334.10 Uses Permitted.

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings permitted to be of Types III, IV-HT , and V construction.

(3) Other structures permitted to be of Types III, IV-HT , and V construction. Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV-HT , or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

(A) Type NM.

Type NM cable shall be permitted as follows:

(1) For both exposed and concealed work in normally dry locations except as prohibited in 334.10(3)

(2) To be installed or fished in air voids in masonry block or tile walls

(B) Type NMC.

Type NMC cable shall be permitted as follows:

(1) For both exposed and concealed work in dry, moist, damp, or corrosive locations, except as prohibited by 334.10(3)

(2) In outside and inside walls of masonry block or tile

(3) In a shallow chase in masonry, concrete, or adobe protected against nails or screws by a steel plate at least 1.59 mm (1⁄16 in.) thick and covered with plaster, adobe, or similar finish

Statement of Problem and Substantiation for Public Input

The 2021 International Building Code added three new types of construction to Type IV buildings that exceeds original four or five limit. Type IV-HT corresponds with original type IV construction in the building code prior to adding these new three types. Before NM cable is allowed to be used in Type IV-A, B, or C, technical substantiation needs to be provided.

Submitter Information Verification

Submitter Full Name: Megan Hayes
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 03 13:50:39 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The proposed addition of adding the suffix “HT” to the selected cable types is without merit. There was no technical justification submitted to support the addition without consideration of the other types A, B, C for the measures of protection associated with the HT/Mass Timber construction. Additional technical information would be helpful.

Public Input No. 4676-NFPA 70-2020 [Sections 334.10, 334.12]

Sections 334.10, 334.12

334.10 Uses Permitted.

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings ~~permitted to be of Types III, IV, and V construction~~ .

(3) Other structures ~~permitted to be of Types III, IV, and V construction~~ . Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

~~Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction* , or the applicable building code, or both.~~

~~Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]~~

(4) Cable trays

~~in structures permitted to be Types III~~

•

• ,

~~IV, or V~~

•

• where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

~~Types I and II construction where~~

•

• Where installed within raceways

~~permitted to be installed in Types I and II construction~~

•

• .

(A) Type NM.

Type NM cable shall be permitted as follows:

(1) For both exposed and concealed work in normally dry locations except as prohibited in 334.10(3)

(2) To be installed or fished in air voids in masonry block or tile walls

(B) Type NMC.

Type NMC cable shall be permitted as follows:

(1) For both exposed and concealed work in dry, moist, damp, or corrosive locations, except as prohibited by 334.10(3)

(2) In outside and inside walls of masonry block or tile

(3) In a shallow chase in masonry, concrete, or adobe protected against nails or screws by a steel plate at least 1.59 mm (**1**⁄**16** in.) thick and covered with plaster, adobe, or similar finish

334.12 Uses Not Permitted.

(A) Types NM and NMC.

Types NM and NMC cables shall not be permitted as follows:

(1) In any dwelling or structure not specifically permitted in 334.10(1) , (2), (3), and (5)

(2) In any non-sprinklered building or structure exceeding four floors or any sprinklered building or structure exceeding five floors.

(3) Exposed within a dropped or suspended ceiling cavity in other than one- and two-family and multifamily dwellings

(4) As service-entrance cable

(5) In commercial garages having hazardous (classified) locations as defined in 511.3

(6) In theaters and similar locations, except where permitted in 518.4(B)

(7) In motion picture studios

(8) In storage battery rooms

(9) In hoistways or on elevators or escalators

(10) Embedded in poured cement, concrete, or aggregate

(11) In hazardous (classified) locations, except where specifically permitted by other articles in this *Code*

(B) Type NM.

Type NM cables shall not be used under the following conditions or in the following locations:

(1) Where exposed to corrosive fumes or vapors

(2) Where embedded in masonry, concrete, adobe, fill, or plaster

(3) In a shallow chase in masonry, concrete, or adobe and covered with plaster, adobe, or similar finish

(4) In wet or damp locations

Statement of Problem and Substantiation for Public Input

Section 336-5 of the 1999 National Electrical Code® restricted the use of Nonmetallic-Sheathed Cable in any multifamily dwelling or other structure exceeding three floors above grade. During the 2002 NEC® code cycle there were at least 13 public inputs submitted attempting to remove the three-floor restriction, including 3 PI's changing the text to reference other standards or building codes. All the PI's were rejected by the code making panel because technical substantiation was not provided to justify expanding the use of Type NM Cable. The committee also noted that mandatory references to other documents did not comply with the NEC Style Manual. The code panel members were correct in their

actions. There was no technical substantiation submitted plus section 4.2 of the NEC® Style Manual states that references to other standards shall not be in mandatory Code text.

With the recent changes to the IBC and NFPA 5000, the panel's reasons for rejecting have been substantiated. The 2021 IBC has increased the number of stories for Type IV construction from 5 to 18 floors. NM Cable will now be permitted to be installed in buildings up to 18 stories high or 24 stories when referencing NFPA 5000. These building code changes indirectly expanded the use of NM Cable without input or review from the public or members of CMP 6. According to the meeting minutes from the July 10-13, 2001 Standards Council meeting, the council overturned the panels action because "In practice, this permits the use of NM cable in buildings no greater than four or five floors above grade". The Standards Council felt that increasing by one or two floors was a modest and rational expansion. When making their decision they were not considering an increase of 15 floors. This proposal removes the references to other standards and returns the requirements to what has been allowed since the 2002 NEC®.

The formatting in Terra View underlined all the text after 334.10(4). The only new text should have been 334.12(2) restricting NM cable to 4 and 5 floors.

Submitter Information Verification

Submitter Full Name: Jay Burris
Organization: Wheatland Tube (Div. of Zekelm
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 16:40:43 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The proposed addition of adding the suffix "HT" to the selected cable types is without merit. There was no technical justification submitted to support the addition without consideration of the other types A, B, C for the measures of protection associated with the HT/Mass Timber construction. Additional technical information would be helpful.

Public Input No. 3410-NFPA 70-2020 [Section No. 334.10(B)]

(B) Type NMC.

Type NMC cable shall be permitted as follows:

(1) For both exposed and concealed work in dry, ~~moist~~ wet , damp, or corrosive locations, except as prohibited by 334.10(3)

(2) In outside and inside walls of masonry block or tile

(3) In a shallow chase in masonry, concrete, or adobe protected against nails or screws by a steel plate at least 1.59 mm (1⁄16 in.) thick and covered with plaster, adobe, or similar finish

Statement of Problem and Substantiation for Public Input

The proposed revision is to change "moist" to "wet". The language currently allows NMC to be used in dry, damp, corrosive and "moist" locations. Moist is not defined in the NEC, but wet locations are defined in Article 100. The construction of this type of cable (NMC) is intended to be used in wet locations, and currently UF-B is often listed additionally as NMC.

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 14:08:39 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8434-NFPA 70-2021
Statement: We agree with removal of “moist” and replacing with “wet”. UL 719 standard would need to be modified to be rated for wet locations.

Public Input No. 1613-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings permitted to be of Types III, IV, and V construction.

(3) Other structures permitted to be of Types III, IV, and V construction. Cables shall be concealed within walls, floors, or ~~ceilings that provide~~ ceilings where the interior surface provides a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Input

Adding the text "interior" make it clear that the outside wall of a building doesn't have to have 15 min protection. Example: Outside metal walls of a building don't have a 15-min finish rating, so the way the language is written, one could not install romex on the outside walls of a building, but they could for the interior walls.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 24 12:51:51 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The change in wording from “ceilings that provide” to “ceilings where the interior surface provides” does not add clarity to the existing requirement for a thermal barrier. Also, the use of “interior” does not specifically define the interior of the room/occupancy and could

infer “interior” of the concealed wall, floor, and ceiling.

Public Input No. 216-NFPA 70-2019 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings permitted to be of Types III, IV, and V construction up to five (5) stories in height above ground .

(3) Other structures permitted to be of Types III, IV, and V construction up to five (5) stories in height above ground . Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Input

The change from the "3-story rule" to types of construction was made before the 2021 IBC proposed to allow Type IV mass timber construction up to 18 stories. It seems worthwhile for the electrical and fire community to deliberate on such expansion of NM use here rather than incorporate such a change passively.

Submitter Information Verification

Submitter Full Name: David Shapiro
Organization: Safety First Electrical
Street Address:
City:
State:
Zip:
Submittal Date: Sat Dec 28 12:43:09 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: The proposed addition of adding the suffix “HT” to the selected cable types is without merit. There was no technical justification submitted to support the addition without

consideration of the other types A, B, C for the measures of protection associated with the HT/Mass Timber construction. Additional technical information would be helpful.

Public Input No. 23-NFPA 70-2019 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings permitted to be of Types III, IV, and V construction.

(3) Other structures permitted to be of Types III, IV, and V construction. Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies. For the purpose of this section, cables located in attics and underfloor areas that are not designed to be occupied, shall be considered concealed.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Input

Many of these “other structures” are wired with NM cable throughout the walls, soffits and joist spaces. These spaces meet the definition of concealed. Attics and underfloor spaces that have access do not meet the definition of concealed. Allowing NM cable in attics and underfloor spaces with access will result in a more consistent wiring method, possibly saving junction points where the wiring method has to switch from NM to another cable or raceway system.

Submitter Information Verification

Submitter Full Name: Gary Sonnen
Organization: State of Idaho Division of Building Safety
Street Address:
City:
State:
Zip:
Submittal Date: Mon Nov 04 13:17:50 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: The Sections 334.15 and 334.23 provide direction for other structures covered in

334.10(3).

Public Input No. 2618-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings and their detached garages permitted to be of Types III, IV, and V construction.

(3) Other structures permitted to be of Types III, IV, and V construction. Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Input

This input is being submitted on behalf of the Minnesota Department of Labor and Industry. The Department's 15 office/field staff, and 65 plus contract electrical inspectors complete over 150,000 electrical inspections annually and are involved in the daily enforcement and interpretation of the National Electrical Code.
Detached multifamily garages should be allowed to use NM cable without the 15-minute thermal barrier. If an installer wanted to use NM cable in a multifamily garage, the requirements would fall under (3). (3) mandates the cable to be behind a 15- minute thermal barrier. The thermal barrier is used mainly used to allow the occupants the time to exit a building in the event of a fire. Typically, the detached multifamily garage(s) are a single garage stall that has minimal provisions for receptacles and/or lights. The additional provisions for the thermal barrier does not compromise safety. NM cable has a proven track record of being a safe, and less expensive wiring method if installed properly.

Submitter Information Verification

Submitter Full Name: Dean Hunter
Organization: Minnesota Department of Labor
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 26 08:21:03 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8432-NFPA 70-2021
Statement: The allowance for detatched garages was added since this was a similar construction and installation type. The informational note was revised to align with the Style Manual.

Public Input No. 2798-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12 :

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings shall be permitted to be

~~of Types III, IV, and V construction.Other structures permitted to be of Types III, IV, and V construction.~~
used in the following construction:

a) Type III

b) Type IV (2HH) without the provisions for Mass Timber floor increases

c) Type V

(3) Other structures shall be permitted to be used in the following constructions:

a) Type III

b) Type IV (2HH) without the provisions for Mass Timber floor increases

c) Type V

Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction* , or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

Information Note No. 3: Type IV (2HH) without the provisions for Mass Timber floor increases is sourced from NFPA 5000 and is equivalent to the international Building Code (IBC) Type IV-HT construction.

(1) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(2) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Input

This Public Input revises 334.10(2), 334.10(3) and adds Informational Note No. 3. Build construction Types were placed into a list for usability. The wonderful TerraView program and it's limited abilities underlined current text that wasn't changed. I apologize to the panel for this and the additional work and interpolating it might has caused.

Both the 2021 NFPA 5000 and the 2021 International Building Code (IBC) added provisions or additional Type IV types of construction to buildings design that exceeds the original four or five floor limits.

NFPA 5000 expanded on Section 7.5 to add provisions for Mass Timber. For example, Section 7.5.3.1.2., Type IV (2HH) is permitted to reach 24 stories for residential occupancies per the provisions for Mass Timber floor increases.

The revision to NFPA 5000 changed the requirements within the NEC, Section 334.10 without following the NFPA procedures including the submission of a Public Input proposal with technical substantiation, Code Panel Review, and Public Review. This conflicts with ANSI procedures for Code development.

The “Type IV (2HH) without the provisions for Mass Timber floor increases” proposed corresponds with original Type IV used in prior editions of the NEC and correlates with the construction types found in NFPA 5000 codes prior to adding these new provisions.

“Type IV (2HH) without the provisions for Mass Timber floor increases” (2021 NFPA 5000) and “Type IV-HT” (2021 IBC) are equivalent to the Type IV found in the 2020 NEC and previous editions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2833-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]	Revision to 334.10(4)
Public Input No. 2833-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: ABB Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 01 12:45:39 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The proposed addition of adding the suffix “HT” to the selected cable types is without merit. There was no technical justification submitted to support the addition without consideration of the other types A, B, C for the measures of protection associated with the HT/Mass Timber construction. Additional technical information would be helpful.

Public Input No. 2833-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings permitted to be of Types III, IV, and V construction.

(3) Other structures permitted to be of Types III, IV, and V construction. Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV (2HH) without the provisions for Mass Timber floor increases , or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Input

This Public Input revises 334.10(4). Both the 2021 NFPA 5000 and the 2021 International Building Code (IBC) added provisions or additional Type IV types of construction to buildings design that exceeds the original four or five floor limits. NFPA 5000 expanded on Section 7.5 to add provisions for Mass Timber. For example, Section 7.5.3.1.2., Type IV (2HH) is permitted to reach 24 stories for residential occupancies per the provisions for Mass Timber floor increases. The revision to NFPA 5000 changed the requirements within the NEC, Section 334.10 without following the NFPA procedures including the submission of a Public Input proposal with technical substantiation, Code Panel Review, and Public Review. This conflicts with ANSI procedures for Code development. The “Type IV (2HH) without the provisions for Mass Timber floor increases” proposed corresponds with original Type IV used in prior editions of the NEC and correlates with the construction types found in NFPA 5000 codes prior to adding these new provisions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2798-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]	Corrections to 334.10(2), (3), and Informational Note 3 (NEW)
Public Input No. 2798-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: David Kendall

Organization: ABB Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 02 09:13:57 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The proposed addition of adding the suffix “HT” to the selected cable types is without merit. There was no technical justification submitted to support the addition without consideration of the other types A, B, C for the measures of protection associated with the HT/Mass Timber construction. Additional technical information would be helpful.

Public Input No. 3428-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings and detached multi-family garages permitted to be of Types III, IV, and V construction.

(3) Other structures permitted to be of Types III, IV, and V construction. Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Input

Detached multi-family garages should be allowed to use Type NM cable without the 15-minute thermal barrier. If an installer wanted to use Type NM cable in a multi-family garage, the requirements would fall under (3). (3) mandates the Type NM cable to be behind a 15- minute thermal barrier. The thermal barrier is mainly used to allow the occupants the time to exit a building in the event of a fire. Typically, the detached multi-family garage(s) are a single garage stall that has minimal provisions for receptacles and/or lighting outlets. The additional provisions for eliminating the thermal barrier in detached garages does not compromise safety. Type NM cable has a proven track record of being a safe, and less expensive wiring method if installed properly.

Submitter Information Verification

Submitter Full Name: Rudolph Garza
Organization: IAEI
Affiliation: IAEI
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 14:36:44 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8432-NFPA 70-2021

Statement: The allowance for detatched garages was added since this was a similar construction and installation type. The informational note was revised to align with the Style Manual.

Public Input No. 537-NFPA 70-2020 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings permitted to be of Types III, IV, and V construction.

(3) Other structures permitted to be of Types III, IV, and V construction. Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018 , *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(5) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Exception to (2) and (3): For buildings or structures required to be of Type I or Type II construction, Type NM, or Type NMC cables shall be permitted to be used, provided that where so applied in buildings or structures exceeding three stories above grade, circuits run in Type NM or NMC cable shall not leave the floor or dwelling unit from which the circuits originate. Cables shall be installed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire- rated assemblies.

Statement of Problem and Substantiation for Public Input

There is really no good substantiation to restrict NM type cables from being safely installed in these buildings under the proposed revisions. For these installations, the NM will be protected by being installed within a wall, floor or ceiling providing a thermal barrier. Other nonmetallic wiring methods such as PVC conduit, RTRC conduit, LFNC, surface nonmetallic raceways, and nonmetallic wireways are permitted in these buildings and structures without any thermal barrier. This proposed revision will allow NM cables to be installed in a similar manner to ENT which requires a thermal barrier per 362.10(2). Article 400 allows the use of flexible cords and cables to be installed and used exposed in these buildings. Nonmetallic fire alarm cables are permitted. Nonmetallic communication cables are permitted. Nonmetallic Class 2 and 3 control and signal cables are permitted.Thousands upon thousands of feet of nonmetallic Power Over Ethernet (PoE) cables can be installed. Why can't NM cable be used? This long standing restriction on NM cable needs to be removed! Restricting the NM cable from leaving the dwelling unit or floor of origin as proposed will minimize the risk from possible fire spread.

Submitter Information Verification

Submitter Full Name: Russ Leblanc

Organization: Leblanc Consulting Services

Street Address:
City:
State:
Zip:
Submittal Date: Wed Feb 26 09:12:39 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: Type I and Type II construction is not currently included in (2) and (3), therefore the proposed Exception to (2) and (3) cannot work as it is not included. Additional technical substantiation is needed.

Public Input No. 1270-NFPA 70-2020 [Section No. 334.12]

334.12 Uses Not Permitted.

(A) Types NM and NMC.

Types NM and NMC cables shall not be permitted as follows:

(1) In any dwelling or structure not specifically permitted in 334.10(1), (2), (3), and (5)

(2) Exposed within a dropped or suspended ceiling cavity in other than one- and two-family and multifamily dwellings

(3) As service-entrance cable

(4) In commercial garages having hazardous (classified) locations as defined in 511.3

(5) In theaters and similar locations, except where permitted in 518.4(B)

(6) In motion picture studios

(7) In storage battery rooms

(8) In hoistways or on elevators or escalators

(9) Embedded in poured cement, concrete, or aggregate

(10) In hazardous (classified) locations, except where specifically permitted by other articles in this *Code*

(11) Where subject to physical damage except as permitted by 334.15.

(B) Type NM.

Type NM cables shall not be used under the following conditions or in the following locations:

(1) Where exposed to corrosive fumes or vapors

(2) Where embedded in masonry, concrete, adobe, fill, or plaster

(3) In a shallow chase in masonry, concrete, or adobe and covered with plaster, adobe, or similar finish

(4) In wet or damp locations

Statement of Problem and Substantiation for Public Input

Nonmetallic-Sheathed Cable is not permitted to be used in an area of physical damage. This proposed addition is for better clarity and usability.

Submitter Information Verification

Submitter Full Name: Megan Hayes
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 28 09:59:47 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8438-NFPA 70-2021
Statement: Nonmetallic-Sheathed Cable is to be protected and not subject to physical damage. NM cable is not suitable for direct burial and is therefore prohibited from being directly buried.

Public Input No. 1014-NFPA 70-2020 [Section No. 334.12(A)]

(A) Types NM and NMC.

Types NM and NMC cables shall not be permitted as follows:

(1) In any dwelling or structure not specifically permitted in 334.10(1), (2), (3), and (5)

(2) Exposed ~~within~~ above a dropped or suspended ceiling ~~cavity~~ with removable tiles in other than one- and two-family and multifamily dwellings

(3) As service-entrance cable

(4) In commercial garages having hazardous (classified) locations as defined in 511.3

(5) In theaters and similar locations, except where permitted in 518.4(B)

(6) In motion picture studios

(7) In storage battery rooms

(8) In hoistways or on elevators or escalators

(9) Embedded in poured cement, concrete, or aggregate

(10) In hazardous (classified) locations, except where specifically permitted by other articles in this *Code*

Additional Proposed Changes

File Name	Description	Approved
NM_cable_above_a_dropped_drywall_ceiling.jpg	dropped drywall ceiling	
NM_cable_above_suspended_ceiling.jpg	suspended drywall ceiling	

Statement of Problem and Substantiation for Public Input

This revision is needed to clarify that NM cable installed above dropped or suspended ceilings with removable tiles would be considered exposed, while NM cable installed above a dropped or suspended ceiling of solid drywall or wire mesh and plaster is actually considered "concealed" per definitions of "concealed" in Article 100. The present wording seems to prohibit the use on NM type cables installed above a solid drywall ceiling because of the wording "within the cavity" being used. Many types of suspended or dropped ceilings exist. Some have removable tiles. Some do not. NM cable installed above suspended ceilings with removable tiles is considered "exposed" by definition. NM cable installed behind solid suspended ceilings with no removable tiles is actually considered "concealed". This revision will help clarify this rule.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 09 10:46:36 EDT 2020

Committee: NEC-P06

Committee Statement

Resolution: The wording proposed is a change that could allow the use of exposed NM and NMC in an area that is often used as a plenum space.


NM cable can be installed above
a dropped drywall ceiling


NM cable can be installed above
a suspended drywall ceiling

Public Input No. 1219-NFPA 70-2020 [Section No. 334.15(B)]

(B) Protection from Physical Damage.

Cable shall be protected from physical damage where necessary by rigid metal conduit, intermediate metal conduit, electrical metallic tubing, Schedule 80 PVC conduit, Type RTRC marked with the suffix -XW, or other approved means. Where passing through a floor, the cable shall be enclosed in rigid metal conduit, intermediate metal conduit, electrical metallic tubing, Schedule 80 PVC conduit, Type RTRC marked with the suffix -XW, or other approved means extending at least 150 mm (6 in.) above the floor. Conduit or tubing shall be provided with a suitable insulating bushing or adapter at the point the cable enters the raceway.

Type NMC cable installed in shallow chases or grooves in masonry, concrete, or adobe shall be protected in accordance with the requirements in 300.4(F) and covered with plaster, adobe, or similar finish.

Statement of Problem and Substantiation for Public Input

Provide language requiring conduit or tubing to be provided with a suitable insulating bushing or adaptor at the point where the cable(s) enter/leave the raceway.

Proposed change will provide consistency with other abrasion protection requirements when cable is installed in conduit or tubing in other articles; for example 334.15 (C), 300.5 (H), 300.15 (C), etc.

Submitter Information Verification

Submitter Full Name: Gary Hein
Organization: Submission is independent of employer.
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 23 10:16:20 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8439-NFPA 70-2021
Statement: The change will provide consistency with other abrasion protection requirements when cable is installed in conduit or tubing.

Public Input No. 1220-NFPA 70-2020 [Section No. 334.15(C)]

(C) In Unfinished Basements and Crawl Spaces.

Where cable is run at angles with joists in unfinished basements and crawl spaces, it shall be permissible to secure cables not smaller than two 6 AWG or three 8 AWG conductors directly to the lower edges of the joists. Smaller cables shall be run either through bored holes in joists or on running boards. Nonmetallic-sheathed cable installed on the wall of an unfinished basement shall be permitted to be installed in a listed conduit or tubing or shall be protected in accordance with 300.4. Conduit or tubing shall be provided with a suitable insulating bushing or adapter at the point the cable enters the raceway. The sheath of the nonmetallic-sheathed cable shall extend through the conduit or tubing and into the outlet, device or ~~device~~ junction box not less than 6 mm (¼ in.). The cable shall be secured within 300 mm (12 in.) of the point where the cable enters the conduit or tubing. Metal conduit, tubing, and metal outlet boxes shall be connected to an equipment grounding conductor complying with the provisions of 250.86 and 250.148.

Statement of Problem and Substantiation for Public Input

Add language covering nonmetallic-sheathed cable when installed in conduit or tubing on the wall of an unfinished basement when spliced in box that is not an outlet or device box. For example, a junction box.

Current language states “The sheath of the nonmetallic-sheathed cable shall extend through the conduit of tubing and into the outlet or device box not less than 6 mm (1/4 in).” Nonmetallic-sheathed cable when spliced in a junction box should also be required to have the sheath of the nonmetallic-sheathed cable extend through the conduit of tubing and into the junction box not less than 6 mm (1/4 in).

Submitter Information Verification

Submitter Full Name: Gary Hein
Organization: Submission is independent of employer.
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 23 10:24:39 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8443-NFPA 70-2021

Statement: The change will provide consistency with other abrasion protection requirements when cable is installed in conduit or tubing. Other changes were made to follow the NEC Style Manual 4.1.3 Reference Structure.

Public Input No. 4140-NFPA 70-2020 [Section No. 334.15(C)]

(C) In Unfinished Basements and Crawl Spaces.

Where cable is run at angles with joists in unfinished basements and crawl spaces, it shall be permissible to secure cables not smaller than two 6 AWG or three 8 AWG conductors directly to the lower edges of the joists. Smaller cables shall be run either through bored holes in joists or on running boards. Nonmetallic-sheathed cable installed on the wall of an unfinished basement shall be permitted to be installed in a listed conduit or tubing or shall be protected in accordance with 300.4. Conduit or tubing shall be provided with a suitable insulating bushing or adapter at the point the cable enters the raceway. The sheath of the nonmetallic-sheathed cable shall extend through the conduit or tubing and into the outlet or device box not less than 6 mm (¼ in.). The cable shall be secured within 300 mm (12 in.) of the point where the cable enters the conduit or tubing. Metal conduit, tubing, and metal outlet boxes shall be connected to an equipment grounding conductor complying ~~with the provisions of~~ with 250.86 and 250.148.

Statement of Problem and Substantiation for Public Input

Deleting the words "the provisions of" does not change the meaning of the section.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 21:50:13 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8443-NFPA 70-2021
Statement: The change will provide consistency with other abrasion protection requirements when cable is installed in conduit or tubing. Other changes were made to follow the NEC Style Manual 4.1.3 Reference Structure.

Public Input No. 1501-NFPA 70-2020 [Section No. 334.24]

334.24 Bending Radius.

Bends in Types NM and NMC cable shall be so made that the cable will not be damaged. The radius of the curve of the inner edge of any bend during or after installation shall not be less than five times the diameter of the cable. For flat cables, the thickness of the cable shall be used to determine the bending radius.

Statement of Problem and Substantiation for Public Input

The current text of 334.24 is frustratingly unclear when applied to many of the NM cables that are in common use today, as they are flat, not round, leaving it ambiguous whether the thickness (minor diameter) or width (major diameter) is to be used to determine the minimum cable bend radius. NEMA RV-2 2011 3.10 also leaves this unspecified, giving installers and inspectors no guidance on the matter; some commentators (most notably Christel Hunter, in the answer to Q10 in the Jul/Aug 2015 Code Hunter column in IAEI Magazine) apply the major-diameter rule from Chapter 9, Table 1, Note 9, but that's overly conservative in that it prohibits bends that are routinely made by installers all over the country (say, at the top plate of a wall). In particular, using the minor diameter (thickness) for a Southwire NM-B or NM-B-PCS cable yields a bend radius of just under 1" for a 12/2 NM-B cable and just over 1" for a 12/3 NM-B-PCS cable, while using the major diameter yields a minimum bend radius ranging from 2" for the 12/2 NM-B cable to nearly 4.5" for the 12/3 NM-B-PCS cable, something I doubt the CMP intends here. Furthermore, the UL 719 mandrel test does not change the mandrel diameter for different width flat cables, only for different gauge wires, which weighs towards thickness, not width, being the determinant of minimum bend radius for flat NM cables.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1502-NFPA 70-2020 [Section No. 340.24]	
Public Input No. 1503-NFPA 70-2020 [Section No. 338.24]	

Submitter Information Verification

Submitter Full Name: Lucas Thode
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 10 10:48:35 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8519-NFPA 70-2021

Statement: The change in wording provides the minimal clarity for description pertaining to minor and major diameters per the axis of the flat cable.

To be consistent with other Sections the language submitted should be the same and

include the word “major” for clarity to using the diameter dimension to determine the radius of the bend. The change in wording provides the minimal clarity for description pertaining to minor and major diameters.

Public Input No. 1269-NFPA 70-2020 [Section No. 334.30]

334.30 Securing and Supporting.

Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) of every cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. The cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in.). Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

Informational Note No. 1: See 314.17 (B)(2) Exception and (B)(3) regarding securement requirements.

(A) Horizontal Runs Through Holes and Notches.

In other than vertical runs, cables installed in accordance with 300.4 shall be considered to be supported and secured where such support does not exceed 1.4-m (4½-ft) intervals and the nonmetallic-sheathed cable is securely fastened in place by an approved means within 300 mm (12 in.) of each box, cabinet, conduit body, or other nonmetallic-sheathed cable termination.

Informational Note: See 314.17(B)(1) for support where nonmetallic boxes are used.

(B) Unsupported Cables.

Nonmetallic-sheathed cable shall be permitted to be unsupported where the cable:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable.

(2) Is not more than 1.4 m (4½ ft) from the last point of cable support to the point of connection to a luminaire or other piece of electrical equipment and the cable and point of connection are within an accessible ceiling in one-, two-, or multifamily dwellings.

(C) Wiring Device Without a Separate Outlet Box.

A wiring device identified for the use, without a separate outlet box, and incorporating an integral cable clamp shall be permitted where the cable is secured in place at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) from the wiring device wall opening, and there shall be at least a 300 mm (12 in.) loop of unbroken cable or 150 mm (6 in.) of a cable end available on the interior side of the finished wall to permit replacement.

Statement of Problem and Substantiation for Public Input

An informational note is being added to refer to Section 314.17 for additional securement requirements. The indicated references point to enforceable exceptions regarding securement of the cables entering a box.

Submitter Information Verification

Submitter Full Name: Megan Hayes
Organization: Nema
Street Address:
City:
State:

Zip:

Submittal Date: Thu May 28 09:55:03 EDT 2020

Committee: NEC-P06

Committee Statement

Resolution: The references cited per the proposed informational note do not follow the NEC Style Manual per 3.1.3 to provide “additional usability”.

Public Input No. 1387-NFPA 70-2020 [Section No. 334.30]

334.30 Securing and Supporting.

~~be considered to be supported and secured~~

~~Nonmetallic-sheathed~~

(A) General. Type NM cable shall be supported and secured by staples

~~,~~

; cable ties listed and identified for securement and support

~~, or~~

; straps, hangers, or similar fittings ; or other approved means designed and installed so as not to damage the cable

~~, at intervals not exceeding 1.4 m (4 1/2 ft) and within 300 mm (12 in~~

.

(B) Securing. Unless otherwise permitted, Type NM cable shall be secured within 300 mm (12 in .) of every

~~cable entry into enclosures such as outlet boxes~~

outlet box , junction

~~boxes~~

box ,

~~cabinets~~

cabinet , or

~~fittings. The cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in.). Flat cables shall not be stapled on edge.~~

~~Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.~~

~~**(A)** Horizontal Runs Through Holes and Notches.~~

~~In other than vertical runs, cables installed in accordance with 300.4 shall~~

fitting and at intervals not exceeding 1.4 m (4 1/2 ft).

(C) Supporting.

Unless otherwise permitted, Type NM cable shall be supported at intervals not exceeding 1.4 m (4 1/2 ft).

Horizontal runs of Type NM cable installed in or on wooden or metal framing members or similar supporting means shall be considered supported where such support does not exceed 1.4

-

m (4 1

/

/2

-

ft) intervals

~~and the nonmetallic-sheathed cable is securely fastened in place by an approved means within 300 mm (12 in~~

.

~~) of each box, cabinet, conduit body, or other nonmetallic-sheathed cable termination.~~

Informational Note: See 314.17(B)(1) for support where nonmetallic boxes are used.

(~~B~~ D) Unsupported Cables.

Nonmetallic-sheathed cable shall be permitted to be unsupported where the cable:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable.

(2) Is not more than 1.4 m (4½ ft) from the last point of cable support to the point of connection to a luminaire or other piece of electrical equipment and the cable and point of connection are within an accessible ceiling in one-, two-, or multifamily dwellings.

(~~C~~ E) Wiring Device Without a Separate Outlet Box.

A wiring device identified for the use, without a separate outlet box, and incorporating an integral cable clamp shall be permitted where the cable is secured in place at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) from the wiring device wall opening, and there shall be at least a 300 mm (12 in.) loop of unbroken cable or 150 mm (6 in.) of a cable end available on the interior side of the finished wall to permit replacement.

Statement of Problem and Substantiation for Public Input

The revisions of (A), (B), and (C) were simply a 100% extract from 320.30(A), (B), and (C). It's always of value to have exact requirements from different wiring methods to state the requirement the same. The only 'technical' change was adding 'or on' to new 334.30(C) to allow the cable to be considered secured and supported when placed on framing members.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 02 10:00:17 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The proposed changes do not add clarity or usability to the Code.

Public Input No. 2026-NFPA 70-2020 [Section No. 334.30]

334.30 Securing and Supporting.

Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) of every cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. The cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in.). Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

(A) Horizontal Runs Through Holes and Notches.

In other than vertical runs, cables installed in accordance with 300.4 shall be considered to be supported and secured where such support does not exceed 1.4-m (4½-ft) intervals and the nonmetallic-sheathed cable is securely fastened in place by an approved means within 300 mm (12 in.) of each box, cabinet, conduit body, or other nonmetallic-sheathed cable termination.

Informational Note: See 314.17(B)(1) for support where nonmetallic boxes are used.

(B) Unsupported Cables.

Nonmetallic-sheathed cable shall be permitted to be unsupported where the cable:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable.

(2) Is not more than 1.4 m (4½ ft) from the last point of cable support to the point of connection to a luminaire or other piece of electrical equipment and the cable and point of connection are within an accessible ceiling in one-, two-, or multifamily dwellings.

(C) Wiring Device Without a Separate Outlet Box.

A wiring device identified for the use, without a separate outlet box, and incorporating an integral cable clamp shall be permitted where the cable is secured in place at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) from the wiring device wall opening, and there shall be at least a 300 mm (12 in.) loop of unbroken cable or 150 mm (6 in.) of a cable end available on the interior side of the finished wall to permit replacement.

(D) Mechanically Securing Nonmetallic Cables. Where nonmetallic-sheathed cable is used, the sheath shall extend not less than 6 mm (¼ in.) inside equipment and beyond any cable clamp.

Statement of Problem and Substantiation for Public Input

The revisions of (A), (B), and (C) were simply a 100% extract from 320.30(A), (B), and (C). It is always of value to have exact requirements from different wiring methods state the requirement in the same manner. The only technical change was adding “or on” to the new 334.30(C) to allow the cable to be considered secured and supported when placed on framing members. This change eliminates the requirement to secure an NM cable where it connects to a wireway as a wireway is not one of the items in the list. It also eliminates the securing requirement within 12” of equipment. Sometimes a general requirement is much better than a list as the general requirement can be all inclusive. I suggest that the securement simply apply to “every cable entry.”

Submitter Information Verification

Submitter Full Name: Mike Holt

Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jul 26 10:46:20 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8481-NFPA 70-2021
Statement: This requirement was added to ensure protection of the insulated conductors when they enter any type of electrical component.

Public Input No. 1305-NFPA 70-2020 [Section No. 334.30 [Excluding any Sub-Sections]]

Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) of every cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. ~~The cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in.). Flat~~ Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

Statement of Problem and Substantiation for Public Input

300.4(D) tells us that cables supported parallel to framing members must be maintained. If it isn't maintained, nail plates are required. 'Maintaining' is enforceable.

We see this excess or service loop a lot at can lights. If installers desire a service loop, install the excess cable on the other side of the required 8" or 12" staple or support. The staple shouldn't be so tight that the cable would be damaged and the luminaires or boxes could shift or cable could be gained if say drywallers knicked conductor(s) in a box with a router. The 8" and 12" for NM cable could stay how it was in 2017. Service loops can be achieved without the 18" re-write. Cables that are outside a wall or below a joist space violate 300.4(D).

Submitter Information Verification

Submitter Full Name: Norman Feck
Organization: State of Colorado
Street Address:
City:
State:
Zip:
Submittal Date: Fri May 29 08:21:16 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Removal of the sentence eliminates the provision of up to 18 inches. The 8 inches and 12 inches are accommodated by this 18 inch length.

Public Input No. 3281-NFPA 70-2020 [Section No. 334.30 [Excluding any Sub-Sections]]

~~Nonmetallic~~ Unless otherwise permitted, Nonmetallic -sheathed cable shall be ~~supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at~~ supported at intervals not exceeding 1.4 m (4½ ft) and ~~within~~ secured within 300 mm (12 in.) of every cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings~~. The cable~~ , by cable ties listed and identified for securement and support, staples, straps, hangers, or similar fittings designed and installed so as not to damage the cable.The cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in.). ~~Flat~~ Hammer driven supports installed over the cable shall not be used. Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

Statement of Problem and Substantiation for Public Input

Firstly addressing the addition of " Unless otherwise permitted" places this section in line with wording that is included in other sections such as 320.30. Secondly addressing "support and secured". By grouping these two words together creates a problem for new fastening products and supports to be approved by listing agencies such as UL, CSA, ETL, etc. Products that may be suitable for cable support may not get approval due to the restriction of testing of the additional component of securement. For example, a cable laying on top of a rafter in an attic space is widely accepted as suitable support, but by code would be in violation due to the fact it isn't secured. Thirdly addressing the change of order of cable supports. Giving the reader a listed and identified product first, then giving staples, straps, hangers, or similar fittings as they are similar and often interchangeable among products descriptions. Lastly addressing the addition of "Hammer driven supports installed over the cable shall not be used". Article 300.4 states where subject to physical damage, conductors, raceways and cables shall be protected. This statement is critical to the safety of our wiring systems. If the wiring can be damaged, we must protect against it. These protections start at the installation process. For some of the fasteners the Article instructs the reader to use, the possibility of damage to the conductors hidden within the cable exists with current hammer driven supports installed over the cable. The safety of the cable is in question due to the possibility that the installer missed the fastener, striking the cable, or over-driving the fastener causing damage that may or may not be evident. Further protections for these cables must be addressed for "installed so as not to damage the cable" to be adhered to. Noting that the force it takes to install these fasteners varies greatly upon factors that are unknown, such as, distance and force of swing, weight of the hammer, type of material the fastener is attached to, etc. Also we must consider the positioning of the installer, the angles and positions at which these fasteners are attached and the conditions at which they are installed. For example, from the floor standing, laying down in a dark crawl space, crouched within an attic space, and in locations with barely enough room for the installer to safely swing a hammer with perfect accuracy. Within these unknown factors, no electrical inspection could ever determine if the cable was ever struck with enough force to damage it. Along with the total number of these fasteners and locations to be in view within the structure for a proper inspection to be performed. Final example: If every fastener driven over the cable took 10 strikes(approx) to install, and every house took 500 fasteners(approx). It would mean 5000 potential damaging hammer strikes the installer took towards the cable. Multiplying an average of 1 million housing starts in the U.S. every month, equates to 5 billion potentially damaging hammer strikes every month. By including the new wording we clearly indicate that we intend to keep the safety of the cable in mind during the installation process as we move away from past practices, to safer and smarter fastening techniques to further insure against inadvertent physical damage at points of support and securement.

Submitter Information Verification

Submitter Full Name: Mark Wolff
Organization: MRW electric
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 07 14:37:41 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The manipulation of language does not provide additional clarity to the user based on the supporting and securing intervals with distances indicated. Preventing the use of a specific tool to prevent poor workmanship is misdirected for qualified installers.

Public Input No. 411-NFPA 70-2020 [Section No. 334.30 [Excluding any Sub-Sections]]

Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) of every cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. The cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in.).~~ Flat~~ This extra cable length is only permitted if there is a cable clamp mechanism installed with or connected to the enclosure. Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

Statement of Problem and Substantiation for Public Input

this will align 334.30 with the requirement of 314.17 (B)(2) and the exception. If there is no cable clamp present at the box then strapping is required within 8". This also ensures that the outer sheath of the NM cable extends 1/4" into the box or enclosure.

Submitter Information Verification

Submitter Full Name: aaron stroud
Organization: City of Sioux falls
Street Address:
City:
State:
Zip:
Submittal Date: Mon Feb 03 17:03:02 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: Boxes are required to have securing per the entry of the cable in accordance with Section 314.17. The applicable requirements of 314.17(B)(2) protect the cable and is only the exception that provides the relief for when using a specific box restricting the distance for securing and supporting to within 8 inches.

Public Input No. 3591-NFPA 70-2020 [Section No. 334.40(B)]

(B) Devices of Insulating Material.

Self-contained switches, self-contained receptacles, and nonmetallic-sheathed cable interconnector devices of insulating material that are listed shall be permitted to be used without boxes in exposed cable wiring and for repair wiring in existing buildings where the cable is concealed. Where listed for the purpose, interconnector devices shall be permitted to be used in one- and two-family dwellings in concealed locations without junction boxes. Openings in such devices shall form a close fit around the outer covering of the cable, and the device shall fully enclose the part of the cable from which any part of the covering has been removed. Where connections to conductors are by binding-screw terminals, there shall be available as many terminals as conductors.

Statement of Problem and Substantiation for Public Input

Residential one- and two-family construction - particularly in areas where increasing affordable housing stock is a critical need - is embracing systems of pre-panelized walls, pods, or kitting of rooms with some factory pre-assembly of mechanical and electrical components. In general, these construction methods do not necessarily mean the building could be considered a manufactured building or closed construction where NEC Section 545.13 would already be applicable and allow concealed connectors.

When panels or pods arrive at the construction site and need to be interconnected electrically, one approach could be wire whips pre-installed in one portion of the pod or kit, pre-cut to length to extend from one prefab panel or pod junction box to an adjacent panel or pod junction box. However, there is a higher likelihood of damage to the extra length of cable during shipping, and higher likelihood of wasted wire with this approach. Allowing concealed NM connectors to be installed on-site at the junctions of these panelized walls or pods could help avoid conductor damage, speed up residential construction and possibly lower costs without affecting safety or durability. To insure longevity and durability of connections, as they will not be accessible for maintenance after installation, it should be required that the connector used be listed for the specific purpose.

Interconnector devices can be designed and manufactured for non-metallic sheathed cable with ultimate safety, durability and ease of installation for this application. As an example, connectors have been widely adopted by the solar industry that have long life expectancies for higher voltage systems (up to 1500Vdc) and designed to be installed in much harsher environments than in an enclosed wall (outdoor exposure rated with life expectancy in the decades). Insulation displacement contact technology and other connector design factors will help insure that field-made connections will be highly reliable and require no maintenance.

Interconnector devices are already allowed by the NEC to be installed concealed in closed factory construction per 545.13, and concealed in walls for repair purposes per this Section, but not currently allowed to be installed concealed in new construction. If such devices are already deemed safe to be concealed in a wall, then it seems that there has already been sufficient technical justification that would also allow for their use in new construction.

Submitter Information Verification

Submitter Full Name: Rebekah Hren
Organization: IPPNC LLC
Street Address:
City:
State:

Zip:

Submittal Date: Wed Sep 09 08:28:11 EDT 2020

Committee: NEC-P06

Committee Statement

Resolution: FR-8520-NFPA 70-2021

Statement: The existing language already permits repairs in one-and-two family dwellings as it simply refers to “buildings.” The change would now allow for use of these listed devices in both existing and new buildings and is not limited to repair wiring.

Public Input No. 170-NFPA 70-2019 [Section No. 334.80]

334.80 Ampacity.

The ampacity of Types NM and NMC cable shall be determined in accordance with 310.14. The ampacity shall not exceed that of a 60°C (140°F) rated conductor. The 90°C (194°F) rating shall be permitted to be used for ampacity adjustment and correction calculations, provided the final calculated ampacity does not exceed that of a 60°C (140°F) rated conductor. The ampacity of Types NM and NMC cable installed in cable trays shall be determined in accordance with 392.80(A).

Where more than two NM cables containing two or more current-carrying conductors are installed, without maintaining spacing between the cables, through the same opening in wood framing that is to be sealed with thermal insulation, caulk, or sealing foam, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1) and the provisions of 310.14(A)(2), Exception, shall not apply.

Where more than two NM cables containing two or more current-carrying conductors are installed in contact with thermal insulation without maintaining spacing between cables, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1) and the provisions of 310 . 14(A)(2) , Exception, shall not apply.

Statement of Problem and Substantiation for Public Input

Greetings CMP Members,

The allowance per the exception to 310.14(A)(2) that apply to portions of a circuit, the higher ampacity shall be permitted to be used if the total portion(s) of the circuit with lower ampacity does not exceed the lesser of 3.0 m (10 ft) or 10 percent of the total circuit. This is typically best utilized in raceways where their is adequate annular space afforded by adhering to the raceway fill rules in Chapter 9, Table 1, which in conjunction with the heat sink effect on the conductors serves to help protect the insulation from the potential effects caused by violation 310.15(C)(1). However, in a Type NM-B there is no annular space and the cables are usually also in contact with thermal insulation as well, the conductor itself can only heat sink so much as evident in why we exclude the use of 310.14(A)(2) Exception already in 334.80 with regards to running more than two Type NM-B Cables with 2 or more current carrying conductors through wood framing members with openings. The exact same effect is happening for multiple feet and 310.14(A)(2) exception is not prohibited from use yet running that same bundle through a opening in a framed member to be sealed would invoke a statement where 310.14(A)(2) Exception doesn't apply.

My point is this, the NEC prohibits the use of 310.14(A)(2) Exception for Type NM-B where more than two Type NM-B cables with 2 or more current carrying conductors are run through a opening in a framing member and subsequently sealed, be it thermal insulation, foam, chalk which is usually only the thickness of the framing member. However, in the very next paragraph the Type NM-B where two or more Type NM-B with 2 or more current carrying conductors are installed in direct contact with thermal insulation, the same conductors as above, and now the exception in 310.14(A)(2) can be applied. This makes no sense at all.

My public input resolved this issue. You simply can't say the conductors will act as a heat sink in the small portion through opening in framing members to be sealed and not permit 310.14(A)(2) Exception and then stick the same condition in thermal insulation and now all of a sudden the heat sink will be better when in fact it will be worse due to all the thermal insulation for a longer, maintained distance.

Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: ElectricianLIVE.com
Street Address:
City:
State:
Zip:
Submittal Date: Thu Dec 05 22:00:16 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8521-NFPA 70-2021

Statement: A limitation was added to prohibit the use of the exception in 310.14(A)(2) and this will require all ungrounded and grounded conductors in thermal insulation (e.g. foam, caulk, etc.) to be considered current carrying for the purpose of ampacity adjustment. The removal of “the provisions of” is in accordance with the NEC style manual.

Public Input No. 4141-NFPA 70-2020 [Section No. 334.80]

334.80 Ampacity.

The ampacity of Types NM and NMC cable shall be determined in accordance with 310.14. The ampacity shall not exceed that of a 60°C (140°F) rated conductor. The 90°C (194°F) rating shall be permitted to be used for ampacity adjustment and correction calculations, provided the final calculated ampacity does not exceed that of a 60°C (140°F) rated conductor. The ampacity of Types NM and NMC cable installed in cable trays shall be determined in accordance with 392.80(A).

Where more than two NM cables containing two or more current-carrying conductors are installed, without maintaining spacing between the cables, through the same opening in wood framing that is to be sealed with thermal insulation, caulk, or sealing foam, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1) ~~and the provisions of~~ and 310.14(A)(2), Exception, shall not apply.

Where more than two NM cables containing two or more current-carrying conductors are installed in contact with thermal insulation without maintaining spacing between cables, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1).

Statement of Problem and Substantiation for Public Input

Deleting the words "the provisions of" does not change the meaning of the section.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 21:51:43 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8521-NFPA 70-2021
Statement: A limitation was added to prohibit the use of the exception in 310.14(A)(2) and this will require all ungrounded and grounded conductors in thermal insulation (e.g. foam, caulk, etc.) to be considered current carrying for the purpose of ampacity adjustment. The removal of “the provisions of” is in accordance with the NEC style manual.

Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]

334.104 Conductors.

The 600-volt insulated power conductors shall be sizes 14 AWG through 2 AWG copper, or copper clad aluminum conductors or sizes 12 AWG through 2 AWG aluminum. For control and signaling conductors minimum conductor sizes shall 18 AWG copper, nickel, or nickel-coated copper , 14 AWG copper -clad aluminum ~~conductors. Control and signaling conductors shall be no smaller than 18 AWG copper.~~ , and 12 AWG Aluminum. .

Additional Proposed Changes

File Name	Description	Approved
Proposed_334.104_Draft_Fnl.docx	Word file attached for clarity of what is being revised or added.	
Terminal_and_Conductor_Temperature_Testing_Part_I_Fnl.pdf	Terminal and NM-B temperature static heating test report as requested by task group.	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in nonmetallic-sheathed cables. The proposed change to this section allows for the use of a 14awg copper-clad aluminum conductor

along with additional language to provide consistency with the allowances provided for control and signaling conductors in sections 330.104 and 336.104.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	Branch circuit AFCI protection added 10 amps
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	Branch circuit ratings added 10 amps
Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	Individual branch circuit receptacle applications and limitations
Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]	Branch circuit applications and limitations added 10 amps
Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]	Summary branch circuit applications and limitations add 10 amps
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	14 AWG copper-clad aluminum OCPD added
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	10 ampere OCPD added as standard device rating
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	14 AWG copper-clad aluminum branch circuit conductor
Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]	Table 310.16 ampacities for 14 AWG copper-clad aluminum added
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	14 AWG copper-clad aluminum added for cables

Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]	Applications and limitations for snap switches
Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]	Applications and limitations for receptacles
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	
Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]	
Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]	
Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]	
Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]	

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: IEC
Affiliation: NEC Correlating Committee Task Group
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 07 10:41:29 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8435-NFPA 70-2021

Statement: The minimum conductor sizes for copper and copper-clad aluminum are being reduced to 16 AWG copper and 14 AWG copper-clad aluminum. These revisions are based on testing submitted in support of the use of copper-clad aluminum conductors for 10 amp circuits, and the decades of successful use of 16 AWG copper conductors in fixture wire, motor wiring, control wiring, and other current-carrying applications as permitted in the NEC. For clarity and consistency edits were incorporated to reflect other code articles for conductor types.

334.104 Conductors.

The 600-volt insulated power conductors shall be sizes 14 AWG through 2 AWG copper, or copper-clad aluminum conductors or sizes 12 AWG through 2 AWG aluminum ~~or copper-clad aluminum~~ conductors.

For Control and signaling conductors minimum conductor sizes shall be ~~no smaller than~~ 18 AWG copper, nickel, or nickel-coated copper, ~~or~~ 14 AWG copper-clad aluminum, and 12 AWG Aluminum.

Substantiation

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in nonmetallic-sheathed cables. The proposed change to this section allows for the use of a 14awg copper-clad aluminum conductor along with additional language to provide consistency with the allowances provided for control and signaling conductors in sections 330.104 and 336.104.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Public Input No. 171-NFPA 70-2019 [Section No. 334.112]

334.112 Insulation.

The insulated power conductors shall be one of the types listed in Table 310.4(A) that are suitable for branch-circuit wiring or one that is identified for use in these cables. Conductor insulation shall be rated at 90°C (194°F).

Informational Note: Types NM ~~,~~ and NMC ~~, and NMS~~ cable identified by the markings NM-B ~~,~~ and NMC-B ~~, and NMS-B~~ meet this requirement.

Statement of Problem and Substantiation for Public Input

Greetings CMP,

The reference to Type NMS and NMS-B has been removed from section 334.116 and no manufacturer produces it. It should be removed for usability and clarity.

Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: ElectricianLIVE.com
Street Address:
City:
State:
Zip:
Submittal Date: Thu Dec 05 23:59:09 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: FR-8437-NFPA 70-2021
Statement: The reference to Type NMS and NMS-B have been removed since these types no longer exist in Article 334.

Public Input No. 3536-NFPA 70-2020 [Section No. 336.2]

(Relocate all definitions in the 336. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

336. 2 Definition.

The definition in this section shall apply within this article and throughout this *Code*.

Power and Control Tray Cable, Type TC.

A factory assembly of two or more insulated conductors, with or without associated bare or covered equipment grounding conductors, under a nonmetallic jacket.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:45:45 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 2327-NFPA 70-2020 [New Section after 336.6]

336.8 Reconditioning

Power and Control Tray Cable: Type TC shall not be permitted to be reconditioned.

Statement of Problem and Substantiation for Public Input

This revision is needed to clarify that listed Power and Control Tray Cable: Type TC shall not be permitted to be reconditioned.

Submitter Information Verification

Submitter Full Name: Brian Deacy
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 14 15:15:04 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Cables are not able to be reconditioned, so no need to prohibit it.

Public Input No. 4320-NFPA 70-2020 [New Section after 336.10]

(12) Type TC-ER may be installed as service-entrance cable in accordance with 230.43 where identified for such use.

Additional Proposed Changes

File Name	Description	Approved
336_add_service.docx		

Statement of Problem and Substantiation for Public Input

In the 2020 NEC, TC-ER cable was added to 230.43, however it was not added to the uses permitted in 336.10. This proposal correct the oversight.

TC-ER cable has not been evaluated for use as a service entrance cable. In order to indicate that a TC-ER cable is suitable for use as a service entrance, an overload test, similar to that used for other cables that can be used as a service entrance (SE and MC) should be required. A joist pull test and a sunlight resistance test should be part of the evaluation to evaluate the cables for pulling thru joists and use outdoors. Tray cables complying with these requirements should be identifiable to show that they are suitable for use as a service entrance and to differentiate them from TC-ER which has not been evaluated for such conditions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4325-NFPA 70-2020 [Section No. 230.43]	
Public Input No. 4325-NFPA 70-2020 [Section No. 230.43]	

Submitter Information Verification

Submitter Full Name: Susan Stene
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 10:03:46 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8524-NFPA 70-2021
Statement: The term “In” was changed to “For” for clarity and consistency.

A list item (12) was added for permitted uses for Type TC-ER cable to correlate with 230.43 and 230.44. This will also initiate appropriate listing requirements to ensure that the cable is suitable for use as service conductors.

The language was modified to clarify that the control conductors are being used for control circuits.

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

a. The cable is Type TC-ER.

b. The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

c. The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

d. The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

e. The cable is secured at intervals not exceeding 1.8 m (6 ft).

f. Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B).

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(8) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(9) In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by *334.80* or *340.80*.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(10) Direct buried, where identified for such use.

(11) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

(12) Type TC-ER may be installed as service-entrance cable in accordance with 230.43 where identified for such use.

Rationale

In the 2020 NEC, TC-ER cable was added to 230.43, however it was not added to the uses permitted in 336.10. This proposal correct the oversight.

TC-ER cable has not been evaluated for use as a service entrance cable. In order to indicate that a TC-ER cable is suitable for use as a service entrance, an overload test, similar to that used for other cables that can be used as a service entrance (SE and MC) should be required. A joist pull test and a sunlight resistance test should be part of the evaluation to evaluate the cables for pulling thru joists and use outdoors. Tray cables complying with these requirements should be identifiable to show that they are suitable for use as a service entrance and to differentiate them from TC-ER which has not been evaluated for such conditions.

Public Input No. 150-NFPA 70-2019 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In one- and two-family dwelling units, Type TC-ER-JP cable ~~containing both power and control conductors~~ shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

Greetings CMP Members,

Firstly, Teraview made an error and underlined all of item 7 through 13, which was not my intent so please disregard the systems abnormality.

Second, my edit was simply to remove the following phrase from item 9. The " containing both power and control conductors" as it has become irrelevant to limit the expanded use to those cables that must contain both power and control to meet this allowance. The construction of the cable assembly is the same regardless of the conductors inside the assembly. As I have stated before, Type TC-ER-JP is a nonmetallic cable assembly with sheathing twice as thick as typical Type SE-R (Service Entrance-Round) yet contains the exact same insulated conductors. Why would it be acceptable to install Type SE-R in these one and two family dwellings and not permit the same for Type TC-ER-JP which is more robust and more suited to reduce the potential sheathing damage exposure found in many attics, such as metal gussets.

Let's recap - The Inner Conductors are IDENTICAL to Type SE-R, the sheathing is twice as thick as Type SE-R but we are not going to allow another wiring method that is superior to Type SE-R, such as Type TC-ER-JP be used in the same applications? The securing requirements, if you choose to take up that task, can be identical to those of Type SE-R as shown in 338.10(4) that reference the user to part II of Article 334.

Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: ElectricianLIVE.com
Street Address:
City:
State:
Zip:
Submittal Date: Mon Nov 25 17:02:14 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: Submitter did not provide substantiation that the current construction yields a hazard.

Public Input No. 190-NFPA 70-2019 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray ~~and~~ or raceway and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER , or TC-ER-HL .

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER , or TC-ER-HL shall be permitted to transition between cable trays and between cable trays

~~and~~

a.

or raceways and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this

Code.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

Type TC and TC-ER cable is permitted to be installed in raceways, not just cable tray. The same rule for transitioning from a cable tray to equipment is no different than transitioning from the end of a raceway to the equipment and should be allowed.

Submitter Information Verification

Submitter Full Name: Paul Guidry
Organization: Fluor Enterprises, Inc.
Affiliation: Associated Builders and Contractors
Street Address:
City:
State:
Zip:
Submittal Date: Wed Dec 18 14:26:47 EST 2019
Committee: NEC-P06

Committee Statement

Resolution: Raceways are to be complete systems continuous from the supply point to the utilization equipment point. Therefore the cable exiting would be within the equipment enclosure, and TC-ER is not needed.

Public Input No. 2093-NFPA 70-2020 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in

~~industrial establishments~~

a. controlled access establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

b. The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

c. The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

d. The cable is secured at intervals not exceeding 1.8 m (6 ft).

e. Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(10) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(11) In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(12) Direct buried, where identified for such use.

(13) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

This shouldn't be limited to industrial locations. It should apply to any location that has controlled access where only trained workers are able to service the installation. The Department of Energy facilities, for example, are not necessarily "industrial" but have extremely strict rules for working on the premises. The contractors must undergo extensive training, work packages must be created, means and methods must all be approved. This is part of a series of proposals to change "industrial locations/premises/occupancies/wiring-systems/..." to "controlled access locations."

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2047-NFPA 70-2020 [Section No. 110.21(A)(2)]	
Public Input No. 2048-NFPA 70-2020 [Section No. 110.24(B)]	
Public Input No. 2049-NFPA 70-2020 [Section No. 110.70]	
Public Input No. 2050-NFPA 70-2020 [Section No. 210.8(B)]	
Public Input No. 2051-NFPA 70-2020 [Section No. 210.8(B)]	
Public Input No. 2052-NFPA 70-2020 [Section No. 210.9]	
Public Input No. 2053-NFPA 70-2020 [Section No. 210.18]	
Public Input No. 2054-NFPA 70-2020 [Section No. 215.11]	
Public Input No. 2087-NFPA 70-2020 [Section No. 225.37]	
Public Input No. 2088-NFPA 70-2020 [Section No. 225.52(A)]	
Public Input No. 2090-NFPA 70-2020 [Section No. 230.205(C)]	
Public Input No. 2091-NFPA 70-2020 [Section No. 240.21(C)(3)]	
Public Input No. 2092-NFPA 70-2020 [Section No. 300.50(A) [Excluding any Sub-Sections]]	
Public Input No. 2094-NFPA 70-2020 [Section No. 368.56(B)]	

Submitter Information Verification

Submitter Full Name: Eric Stromberg
Organization: Los Alamos National Laboratory
Affiliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jul 29 21:42:57 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Controlled Access changes the meaning of the section beyond current meaning of industrial.

Public Input No. 3420-NFPA 70-2020 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and ~~where~~ 336.30. Where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Additional Proposed Changes

File Name	Description	Approved
336.10_PI_change.docx	Code Change PI 336.10	

Statement of Problem and Substantiation for Public Input

Type NM cable has a different weight. New article 336.30 shows proper supporting measurements in regard to different size TC cable. Adding this gives more clarification for the support securing of the TC cable.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3418-NFPA 70-2020 [New Section after 336.24]	

Submitter Information Verification

Submitter Full Name: Jesse Dunk
Organization: Generac
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 14:23:40 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The installation requirements are already established in Section 336.10(9) that refers you to Article 334. The supporting and securing requirements for Type TC cable used in one and two family dwellings is identical to those required for type SE used in same sizes for branch circuits and feeders.

336.10 Uses Permitted.
Type TC cable shall be permitted to be used as follows:

1. For power, lighting, control, and signal circuits.
2. In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).
3. In raceways.
4. In outdoor locations supported by a messenger wire.
5. For Class 1 circuits as permitted in Parts II and III of Article 725.
6. For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.
7. Between a cable tray and the utilization equipment or device(s), provided all of the following apply:
    1. The cable is Type TC-ER.
    2. The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.
    3. The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.
    4. The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."
    5. The cable is secured at intervals not exceeding 1.8 m (6 ft).
    6. Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B).

        Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

8. Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.
9. In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and 336.30. Where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

    Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

10. Direct buried, where identified for such use.
11. In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Public Input No. 354-NFPA 70-2020 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In one, two -family and ~~two~~ multi -family dwelling units, Type TC-ER-JP cable ~~containing both~~ containing power ~~and~~ or control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340. ~~Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by , excluding the ampacity limitations of 334.80 or 340 .80~~

~~*Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.*~~

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code* .

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

Terra server messed up. the only change is in number (9). the ampacity restrictions for all other installations is unreasonable and provides no additional safety benefit, as it would be used in the same manner as the Generator feeder. This is a robust cable with many applications and should not be limited to having both control and power circuits necessary to allow this section to apply.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 23 11:01:15 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: Submitter did not provide substantiation that the current construction yields a hazard. This cable will be used in the same locations currently restricted to 60C, and terminate to same equipment. Submitter provided no technical substantiation to include multi-family.

Public Input No. 356-NFPA 70-2020 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In one, two -family and ~~two~~ multi -family dwelling units, Type TC-ER-JP cable ~~containing both power and control conductors~~ shall be permitted for branch circuits and feeders. Type TC-ER-JP cable ~~used as interior wiring~~ shall be installed per the requirements of ~~Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.~~

~~*Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80 .*~~

~~Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.~~

338.10 (B)

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code* .

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

this reference to two articles and exclusion of .80 is the use is already include in article 338 and for usability this article should be referenced

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 23 11:38:27 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: Submitter did not provide substantiation that the current construction yields a hazard. This cable will be used in the same locations currently restricted to 60C, and terminate to same equipment. Submitter provided no technical substantiation to include multi-family.

Public Input No. 3987-NFPA 70-2020 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In one- and two-family dwelling units,Type TC-ER-JP cable ~~containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable~~ used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

Many questions have arisen about the use of TC-ER-JP type cable concerning the cable's suitability for use as a wiring method in or on 1 and 2 family dwellings. Is the cable safer for use if it contains a control conductor in addition to power and light conductors? Recent editions of the NEC have permitted the use outside of the dwelling for PV wiring. If the cable is a safe wiring method for these uses if would follow that TC cable would be safe for other general wiring at dwellings.

Submitter Information Verification

Submitter Full Name: David Humphrey
Organization: County of Henrico, Virginia
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 16:49:34 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Insufficient substantiation was provided to expand the use of this type of cable beyond the permitted use where both power and control are necessary within a single cable assembly.

Public Input No. 4009-NFPA 70-2020 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) ~~In~~ At one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

This is a companion public input. If the intent of the cmp is to allow TC cable on the exterior of a one and two family dwelling not contained in a raceway, underground where so identified, or as messenger supported wiring than a single word change from In to at will make clear the panels intent and permit this outdoor use in much the same manner as UF cable outside at dwelling units.

Submitter Information Verification

Submitter Full Name: David Humphrey
Organization: County of Henrico, Virginia
Street Address:
City:
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Zip:
Submittal Date: Wed Sep 09 17:20:16 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8524-NFPA 70-2021
Statement: The term “In” was changed to “For” for clarity and consistency.

A list item (12) was added for permitted uses for Type TC-ER cable to correlate with 230.43 and 230.44. This will also initiate appropriate listing requirements to ensure that the cable is suitable for use as service conductors.

The language was modified to clarify that the control conductors are being used for control circuits.

Public Input No. 4017-NFPA 70-2020 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and ~~control conductors shall~~ conductors of a control circuit as defined by Article 100 shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Input

Control conductors are not clearly defined in this section. The definition of a control circuit is clearly defined in Article 100 as a circuit directing the performance of a controller but not carrying the main power current. As control (conductor) is not neatly defined the question becomes would any type of control conductor such as remote control conductor or simply a "controlled conductor" that may carry the main power current of a circuit meet the requirements of this section? The text as revised makes clear that a control conductor is a conductor of a control circuit as defined by Article 100.

Submitter Information Verification

Submitter Full Name: David Humphrey
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Submittal Date: Wed Sep 09 17:32:37 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8524-NFPA 70-2021
Statement: The term “In” was changed to “For” for clarity and consistency.

A list item (12) was added for permitted uses for Type TC-ER cable to correlate with 230.43 and 230.44. This will also initiate appropriate listing requirements to ensure that the cable is suitable for use as service conductors.

The language was modified to clarify that the control conductors are being used for control circuits.

Public Input No. 4004-NFPA 70-2020 [Sections 336.10, 336.12]

Sections 336.10, 336.12

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(15) In the interior of one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

(17) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

336.12 Uses Not Permitted.

Type TC tray cable shall not be installed or used as follows:

(1) Installed where it will be exposed to physical damage

(2) Installed outside a raceway or cable tray system, except as permitted in 336.10(4), 336.10(7), 336.10(9), and 336.10(10)

(3) Used where exposed to direct rays of the sun, unless identified as sunlight resistant

Statement of Problem and Substantiation for Public Input

This section begins with IN one and two family dwellings. This appears to limit the cable to only inside wiring of one and two family dwelling unless installed outside in a raceway, direct burial where identified, or as messenger supported wiring. If this is indeed the case than changing the text as suggested will make these requirements clear . Many are suggesting that (In) actually means at one and two family dwellings. Reference to Article 340 for outside use lends to further confusion on this issue.

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Submittal Date: Wed Sep 09 17:04:32 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This application is not limited to the interior of the dwelling unit.

Public Input No. 3418-NFPA 70-2020 [New Section after 336.24]

TITLE OF NEW CONTENT

Type your content here ...

336.30 Securing and Supporting. Type TC cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, size 8 awg or smaller at intervals not exceeding 1.4 m (4 1/2 ft), 6 awg or larger at intervals not exceeding 0.9144 m (3 ft) and within 300 mm (12 in) of every cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. The Cable length between the cable entry and the closest cable support shall not exceed 450 mm (18 in).

_____ Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

(1) **Horizontal Runs Through Holes and Notches.** In other than vertical runs, cables installed in accordance with 300.4 shall be considered to be supported and secured where such support does not exceed .9144 m (3 ft) intervals and TC-ER-JP is securely fastened in place by an approved means within 300 mm (12 in) of each box, cabinet, conduit body, or other nonmetallic-sheathed cable termination.

(1) **Unsupported Cables.** TC cable shall be permitted to be unsupported where the cable:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable.

(2) Is not more than .9144 m (3 ft) from the last point of cable support to the point of connection to a luminaire or other piece of electrical equipment and the cable and point of connection are within an accessible ceiling in one-, two-, or multifamily dwellings.

(1) **Wiring Device Without a Separate Outlet Box.** A wiring Device identified for the use, without a separate outlet box, and incorporating an integral cable clamp shall be permitted where the cable is secured in place at intervals not exceeding .9144 m (3 ft) and within 300 mm (12 in) from the wiring device wall opening, and there shall be at least 300 mm (12 in) loop of unbroken cable or 150 mm (6 in) of a cable end available on the interior side of the finished wall to permit replacement.

Additional Proposed Changes

File Name	Description	Approved
336.10_PI_change.docx	336.30 PI Support Change	

Statement of Problem and Substantiation for Public Input

Type TC cable has a different weight then NM cable. The larger size cable will sag when it is not properly supported within 3 ft of each support. Adding this article defines the support measurement for TC for 8 awg and less, with 6 awg and larger with its respective measurements.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3420-NFPA 70-2020 [Section No. 336.10]	

Submitter Information Verification

Submitter Full Name: Jesse Dunk
Organization: Generac
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 14:23:16 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The installation requirements are already established in Section 336.10(9) that refers you to Article 334. The supporting and securing requirements for Type TC cable used in one and two family dwellings is identical to those required for type SE used in same sizes for branch circuits and feeders.

336.10 Uses Permitted.
Type TC cable shall be permitted to be used as follows:

1. For power, lighting, control, and signal circuits.
2. In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).
3. In raceways.
4. In outdoor locations supported by a messenger wire.
5. For Class 1 circuits as permitted in Parts II and III of Article 725.
6. For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.
7. Between a cable tray and the utilization equipment or device(s), provided all of the following apply:
    1. The cable is Type TC-ER.
    2. The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.
    3. The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.
    4. The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."
    5. The cable is secured at intervals not exceeding 1.8 m (6 ft).
    6. Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.119(B).

        Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

8. Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.
9. In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and 336.30. Where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

    Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

10. Direct buried, where identified for such use.
11. In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Public Input No. 1273-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]

For ungrounded, grounded, and equipment grounding conductors, the conductor sizes shall be 14 AWG through 1000 kcmil copper, nickel, or nickel-coated copper and 12 AWG through 1000 kcmil aluminum or copper-clad aluminum. Insulation types shall be one of the types listed in Table 310.4(A) or Table 310.4(B) that is suitable for branch circuit and feeder circuits or one that is identified for such use.

For control and signal conductors, the minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, ~~14~~ 12 AWG copper-clad aluminum, and 12 AWG aluminum.

Statement of Problem and Substantiation for Public Input

Rationale:
A manufacturer of copper-clad aluminum testified to the NFPA Standards Council that permitting 14 AWG copper-clad aluminum in these applications creates an electrical hazard.

From NFPA Standards Council agenda August 6-7, 2019 Attachment 19-8-3-n, pages 8 and 9:

Inconsistent acceptance or rejection of testing data provided. Where the panel rejected the testing data provided to add the ampacities to Tables 310.16 and 310.17, they used this same data, now stating it was acceptable for adding 14 AWG copper-clad aluminum to section 330.104 and 336.104 but limiting the use to control and signaling. While this may seem a good thing, it in fact creates what could become a very serious hazard.

Submitter Information Verification

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Organization: Nema
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City:
State:
Zip:
Submittal Date: Thu May 28 10:13:59 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: This issue is being resolved through actions taken in first revisions.

Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]

For ungrounded, grounded, and equipment grounding conductors, the conductor sizes shall be 14 AWG through 1000 kcmil copper, nickel, ~~or~~ nickel-coated copper~~ and~~ , or copper-clad aluminum, and 12 AWG through 1000 kcmil aluminum~~ or copper-clad aluminum~~ . Insulation types shall be one of the types listed in Table 310.4(A) or Table 310.4(B) that is suitable for branch circuit and feeder circuits or one that is identified for such use.

For control and signal conductors, the minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, 14 AWG copper-clad aluminum, and 12 AWG aluminum.

Additional Proposed Changes

File Name	Description	Approved
Proposed_336.104_Draft_Fnl.docx	Word file attached for clarity.	
Terminal_and_Conductor_Temperature_Testing_Part_I_Fnl.pdf	Terminal temperature static heating test report as requested by task group	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in power and control tray cables.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	Branch circuit AFCI protection added 10 amps
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	Branch circuit ratings added 10 amps
Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	Individual branch circuit receptacles applications and limitations
Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]	Branch circuit applications and limitations added 10 amps
Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]	Summary branch circuit applications and limitations added 10 amps
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	14 AWG copper-clad aluminum OCPD rating set
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	10 amperes added as standard OCPD device rating
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	14 AWG copper-clad aluminum added for branch circuit conductors
Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]	Table 310.16 ampacities for 14 AWG copper-clad aluminum added
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]	Applications and limitations for snap switches

Public Input No. 3259-NFPA 70-2020 [Section No. 406.3] Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)] Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)] Public Input No. 3247-NFPA 70-2020 [Section No. 330.104] Public Input No. 3248-NFPA 70-2020 [Section No. 334.104] Public Input No. 3251-NFPA 70-2020 [Section No. 340.104] Public Input No. 3256-NFPA 70-2020 [Section No. 404.14] Public Input No. 3259-NFPA 70-2020 [Section No. 406.3] Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]	Applications and limitations for receptacles

Submitter Information Verification

Submitter Full Name: David Hittinger
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Affiliation: NEC Correlating Committee Task Group
Street Address:
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Submittal Date: Mon Sep 07 10:49:03 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8613-NFPA 70-2021
Statement: Added allowance for 14 AWG Copper-Clad Aluminum and 16 AWG copper for grounded, ungrounded and equipment grounding conductors. First revisions are being made in other parts of the Code for correlation.

336.104

336.104 Conductors.

For ungrounded, grounded, and equipment grounding conductors, the conductor sizes shall be 14 AWG through 1000 kcmil copper, nickel, ~~or nickel~~ nickel-coated copper, or copper-clad aluminum, and 12 AWG through 1000 kcmil aluminum~~or copper-clad aluminum~~. Insulation types shall be one of the types listed in Table 310.4(A) or Table 310.4(B) that is suitable for branch circuit and feeder circuits or one that is identified for such use.

For control and signal conductors, the minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, 14 AWG copper-clad aluminum, and 12 AWG aluminum.

Substantiation

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in power and control tray cables.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Public Input No. 1805-NFPA 70-2020 [Article 337]

~~**Article 337**~~ Article 328 Marine Shipboard Cable: Type P Cable

Part I. General

~~**337**~~ **328 .1** Scope.

This article covers the use, installation, and construction specifications for up through 2000 volt Type P cable (armored and unarmored).

~~**337**~~ **328 .2** Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Marine Shipboard Cable, Type P. ~~**Cable**~~

A factory assembly of one or more insulated flexible tinned copper conductors, with associated equipment grounding conductor(s), with or without a braided metallic armor and with an overall nonmetallic jacket.

~~**337**~~ **328 .6** Listing Requirements.

Type P cables and associated fittings shall be listed.

Part II. Installation

~~**337**~~ **328 .10** Uses Permitted.

Type P cable shall be permitted to be used:

(1) Under engineering supervision in industrial installations where conditions of maintenance and supervision ensure that only qualified persons monitor and service the system.

(2) In hazardous (classified) locations where specifically permitted by other articles in this *Code*.

~~**337**~~ **328 .12** Uses Not Permitted.

Type P cable shall not be installed or used:

(1) Where it will be exposed to physical damage

(2) Where not specifically permitted by other articles in the *Code*

~~**337**~~ **328 .24** Bending Radius.

The minimum bending radii during installations and handling in service shall be adequate to prevent damage to the cable.

~~**337**~~ **328 .30** Securing and Supporting.

Type P cable shall be supported and secured by cable ties listed and identified for securement and support; straps, hangers, or similar fittings; or other approved means designed and installed so as not to damage the cable.

~~**337**~~ **328 .31** Single Conductors.

Where single-conductor cables are used, the installation shall comply with 300.20.

~~**337**~~ **328 .80** Ampacity.

The ampacity of Type P cable shall be determined in accordance with 310.14(A) or 310.14(B) for 14 AWG and larger conductors. For 18 AWG and 16 AWG conductors the ampacities shall be determined in accordance with Table 402.5. When installed in cable tray, the ampacities shall be permitted to be determined in accordance with 392.80. The installation shall not exceed the temperature ratings of terminations and equipment.

Part III. Construction Specifications

~~337~~ 328 .104 Conductors.

Conductors shall be of tinned copper. Conductors shall employ flexible stranding. The minimum conductor size shall be 18 AWG.

~~337~~ 328 .108 Equipment Grounding Conductor.

An equipment grounding conductor complying with 250.122 shall be provided within the cable.

~~337~~ 328 .112 Insulation.

Insulated conductors shall be a thermoset type identified for use in Type P cable. All conductors shall be suitable for wet locations. The minimum wall thickness shall be 0.76 mm (30 mils).

~~337~~ 328 .114 Shield.

Metallic shield(s) shall be permitted over a single conductor or groups of conductors.

~~337~~ 328 .115 Jacket.

Single conductor cables and multiconductor cables shall have an overall nonmetallic jacket that is impervious to moisture, corrosion resistant, and sunlight resistant.

~~337~~ 328 .116 Armor.

Armor shall be permitted over the jacket. If provided, the armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor or as an equipment grounding conductor. A nonmetallic jacket that conforms to 337.115 shall be provided over the armor.

~~337~~ 328 .120 Marking.

Type P cable shall be marked in accordance with 310.8. When an armor is provided, the cable shall be marked accordingly.

Statement of Problem and Substantiation for Public Input

Type P cable is the only cable type that does not have a cable name in all of the cable articles 320 through 340 and since the cable name is technically Marine Shipboard cable it should lead "Type P' in the title. By moving the information to article 328 which is now vacant in the 2020 revision cycle the name of the cable will be in alphabetical order with the other cable articles as is the case with all of the articles, 320 through 340. Finally the title of the definition in newly numbered 328.2 to Marine Shipboard Cable, Type P, will match the wording of the definition titles in the other articles 320 through 340 (example see: 320.2 Armored Cable, Type AC).

Submitter Information Verification

Submitter Full Name: Tj Woods
Organization: Wyoming Electrical Jatc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jul 07 18:10:03 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8562-NFPA 70-2021

Statement: Change the title of the Article 337 to "Drilling Rig Cable" The title and scope were revised to provide a name for this cable. Code Making Panel 6 refers this recommendation to the Correlating Committee for review .

Public Input No. 3537-NFPA 70-2020 [Section No. 337.2]

(Relocate all definitions in the 337. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

337. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Type P. Cable

A factory assembly of one or more insulated flexible tinned copper conductors, with associated equipment grounding conductor(s), with or without a braided metallic armor and with an overall nonmetallic jacket.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:47:22 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 2938-NFPA 70-2020 [Section No. 337.80]

337.80 Ampacity.

The ampacity of Type P cable shall be determined in accordance with 310.14(A) or 310.14(B) for 14 AWG and larger conductors. For 18 AWG and 16 AWG conductors the ampacities shall be determined in accordance with Table 402.5 or 310 . 14(B) . When installed in cable tray, the ampacities shall be permitted to be determined in accordance with 392.80. The installation shall not exceed the temperature ratings of terminations and equipment.

Statement of Problem and Substantiation for Public Input

Within the oil & gas well drilling land rig industry, it is common practice for ampacity calculations of 18 AWG and 16 AWG Type P cable to be performed under engineering supervision using the general equation in 310.14 (B) as a basis. Therefore, providing for the use of 310.14(B) within Article 337 to determine the ampacity of 18 AWG and 16 AWG Type P cable will allow for this common practice.

Submitter Information Verification

Submitter Full Name: Mark Fillip
Organization: National Oilwell Varco
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 03 12:58:01 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8567-NFPA 70-2021
Statement: The reference to 310.14(B) was added to permit calculated ampacities for 18 AWG and 16 AWG conductors.

Public Input No. 3505-NFPA 70-2020 [Section No. 337.80]

337.80 Ampacity.

The ampacity of Type P cable shall be determined in accordance with 310.14(A) or 310.14(B) for 14 AWG and larger conductors. For 18 AWG and 16 AWG conductors the ampacities shall be determined in accordance with Table 402.5 or 310 . 14(B) . When installed in cable tray, the ampacities shall be permitted to be determined in accordance with 392.80. The installation shall not exceed the temperature ratings of terminations and equipment.

Statement of Problem and Substantiation for Public Input

Limiting the ampacities of #16 and #18 AWG Type P conductors to the values in Table 402.5 creates a major disparity between these values and those historically used in the Oil and Gas industry for decades without incident. The higher values are cited in the IEEE 45.8 and API 14F documents and are conservative given that the Type P insulation provided by all major manufacturers has been manufacturer and third party qualified at 125C conductor temperature and has been in operation at up to 110C in the industry successfully for decades. The equations in Article 310.14(B) are based on the well established Neher-McGrath method, are are aligned with IEEE 835, which is also the basis for the ampacity tables in industry standards IEEE 45,8 and API 14F. In addition, the use of the equations in 310.14(B) is consistent with their application to Type P conductor sizes #14 AWG and larger, as stated this Article.

Submitter Information Verification

Submitter Full Name: Gary Savage
Organization: Prysmian Group
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 18:47:29 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8567-NFPA 70-2021
Statement: The reference to 310.14(B) was added to permit calculated ampacities for 18 AWG and 16 AWG conductors.

Public Input No. 3380-NFPA 70-2020 [Section No. 337.108]

337.108 Equipment Grounding Conductor.

An equipment grounding conductor complying with 250.122 shall be provided within ~~the~~ multiconductor Type P cable.

Statement of Problem and Substantiation for Public Input

Single conductor Type P cables do not have an equipment ground within them. To avoid any potential confusion with regards to interpretation, 337.108 should explicitly state that a multiconductor Type P cable shall have an equipment grounding conductor complying with 250.122. While this may seem very obvious and was the intention, stating it explicitly will eliminate any ambiguity.

Submitter Information Verification

Submitter Full Name: Mark Fillip
Organization: National Oilwell Varco
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 12:42:24 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8568-NFPA 70-2021

Statement: Equipment grounding conductors are not required within a single conductor Type P cable. The text was revised to clarify that equipment grounding conductors are only required in multiconductor cables.

Public Input No. 3667-NFPA 70-2020 [Section No. 337.112]

337.112 Insulation.

Insulated conductors shall be a thermoset type identified for use in Type P cable. All conductors shall be suitable for wet locations (90C) . The minimum wall thickness shall be 0.76 mm (30 mils).

Statement of Problem and Substantiation for Public Input

The term "suitable for wet locations" does not provide an adequate description of the requirement. Insulation materials suitable for wet locations within the NEC, such as XHHW-2 and RHW-2, are required to pass a long term insulation resistance test in 90C water.

Submitter Information Verification

Submitter Full Name: Rudy Bright
Organization: Nexans AmerCable
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 10:29:28 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The internal conductors of Type P cable are tested to UL product standard requirements which will determine the wet location temperature rating.

Public Input No. 3493-NFPA 70-2020 [Section No. 337.115]

337.115 Jacket.

~~Single conductor~~ Multiconductor cables ~~and multiconductor cables~~ shall have an overall nonmetallic jacket that is impervious to moisture, corrosion resistant, and sunlight resistant. When installed external to an enclosure or industrial machinery, single conductor cables shall have an overall nonmetallic jacket that is impervious to moisture, corrosion resistant, and sunlight resistant.

Statement of Problem and Substantiation for Public Input

Single conductor and multiconductor Type P cables are used both internal and external to enclosures and drilling machinery within the oil & gas well drilling land rig industry. Single conductor Type P cables installed within enclosures and various drilling machines do not have an overall nonmetallic jacket since they are protected by the enclosure or drilling machine. Single conductor Type P cables that are installed external to an enclosure or drilling machinery do have an overall nonmetallic jacket. Article 337 needs to be revised as proposed to address this historical practice.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4701-NFPA 70-2020 [Section No. 337.115]	

Submitter Information Verification

Submitter Full Name: Mark Fillip
Organization: National Oilwell Varco
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 17:25:45 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8570-NFPA 70-2021

Statement: Revisions were made to permit single conductor cables without an overall jacket for installation in enclosures or machinery, or larger conductors with increased insulation thickness. Additional requirements were established for these applications.

Public Input No. 4659-NFPA 70-2020 [Section No. 337.115]

337.115 Jacket.

Single conductor cables and multiconductor cables shall have an overall nonmetallic jacket that is impervious to moisture, corrosion resistant, and sunlight resistant.Single conductor cables rated 2 kV only, with conductor sizes equal to or larger than 4/0 AWG, may use an increased insulation thickness in lieu of using a separate cable jacket. When insulation is used as an integral insulation and jacket, the material shall be sunlight resistant.

Statement of Problem and Substantiation for Public Input

Type P (XLPO) material has been an approved jacket material in common use on single conductor Type P cables #4/0 AWG and larger for decades. It is extruded as one thicker layer of material and is considered an integral jacket/ insulation as identified in UL 1309 and IEEE 1580. This change would prevent an unnecessary change is established industry design and working practices used for many years. If adopted, details regarding total wall thicknesses, etc. can be addressed in the fledgling UL 1309A covering NEC requirements for Type P listing.

Submitter Information Verification

Submitter Full Name: Gary Savage
Organization: Prysmian Group
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 16:26:11 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8570-NFPA 70-2021

Statement: Revisions were made to permit single conductor cables without an overall jacket for installation in enclosures or machinery, or larger conductors with increased insulation thickness. Additional requirements were established for these applications.

Public Input No. 4701-NFPA 70-2020 [Section No. 337.115]

337.115 Jacket.

~~Single conductor cables and multiconductor~~ Multiconductor cables shall have an overall nonmetallic jacket that is impervious to moisture, corrosion resistant, and sunlight resistant. When installed external to an enclosure or industrial machinery, single conductor cables shall have an overall ~~nonmetallic~~ nonmetalic jacket that is impervious to moisture, corrosion resistant, and sunlight resistant. Single conductor cables rated 2 kV only, with conductor sizes equal to or larger than 4/0 AWG, may use an increased insulation thickness in lieu of using a seperate cable jacket. When the insulation is used as an integral insulation and jacket, the insulation material shall be sunlight resistant.

Statement of Problem and Substantiation for Public Input

Single conductor Type P cables are used both internal and external to enclosures and drilling machinery within the oil & gas well drilling land rig industry. Single conductor Type P cables installed within enclosures and various drilling machines do not have an overall nonmetallic jacket since they are protected by the enclosure or drilling machine. Single conductor Type P cables that are installed external to an enclosure or drilling machinery do have either an overall non-metallic jacket or an integral insulation/jacket that satisfies the requirements for an overall jacket. It is noted that per IEEE Std. 1580 and UL-1309, single conductor Type P cables rated 2 kV with conductor sizes equal to or larger than 4/0 AWG may use an increased insulation thickness to satisfy the requirement of an overall jacket.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3493-NFPA 70-2020 [Section No. 337.115]	

Submitter Information Verification

Submitter Full Name: Mark Fillip
Organization: National Oilwell Varco
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 16:57:05 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8570-NFPA 70-2021
Statement: Revisions were made to permit single conductor cables without an overall jacket for installation in enclosures or machinery, or larger conductors with increased insulation thickness. Additional requirements were established for these applications.

Public Input No. 2936-NFPA 70-2020 [Section No. 337.116]

337.116 Armor.

Armor shall be permitted over the jacket. If provided, the armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze, tinned copper, stainless steel, or aluminum . The armor shall not be used as a current-carrying conductor or as an equipment grounding conductor. A nonmetallic jacket that conforms to 337.115 shall be provided over the armor.

Statement of Problem and Substantiation for Public Input

Type P cables with a metallic basket weave armor manufactured from metal other than commercial bronze, as specified in IEEE Std. 1580 and UL 1309, are in common use on oil & gas well drilling land rigs. More specifically, it is noted that cable product standard IEEE Std. 1580 allows commercial bronze, tinned copper, stainless steel, or aluminum wires to be used for the basket weave armor on Type P cable. Cable product standard UL 1309 allows commercial bronze, tinned copper, or aluminum wire to be used for basket weave armor. In summary, Article 337 should be revised to align with the historical industry practice of using commercial bronze, tinned copper, stainless steel, or aluminum for the basket weave armor on Type P cable.

Submitter Information Verification

Submitter Full Name: Mark Fillip
Organization: National Oilwell Varco
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 03 12:16:14 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8572-NFPA 70-2021
Statement: Additional armor metal options were added to recognize industry practices.

Public Input No. 3674-NFPA 70-2020 [Section No. 337.116]

337.116 Armor.

Armor shall be permitted over the jacket. If provided, the armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze, tinned copper, stainless steel, or aluminum . The armor shall not be used as a current-carrying conductor or as an equipment grounding conductor. A nonmetallic jacket that conforms to 337.115 shall be provided over the armor.

Statement of Problem and Substantiation for Public Input

Commercial bronze is only one of the materials allowed by the industry standards for Type P cables (UL 1309 and IEEE Std. 1580). These standards also allow for tinned copper, stainless steel, and aluminum. The inclusion of tinned copper is necessary because the industry uses a tinned copper basket weave armor on Variable Frequency Drive (VFD) power cables to serve as both armor and EMI shielding. The inclusion of stainless steel is necessary because some applications of the Type P cables require a higher degree of protection and longitudinal tensile strength.

Submitter Information Verification

Submitter Full Name: Rudy Bright
Organization: Nexans AmerCable
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 10:38:44 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Recognition of the armor as an EMI shield is not necessary. The NEC does not prohibit the tin copper armor from being used as an EMI shield.

Public Input No. 4503-NFPA 70-2020 [Section No. 337.116]

337.116 Armor.

Armor shall be permitted over the jacket. If provided, the armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze.or tinned copper The armor shall not be used as a current-carrying conductor or as an equipment grounding conductor. A nonmetallic jacket that conforms to 337.115 shall be provided over the armor.

Statement of Problem and Substantiation for Public Input

Tinned copper braided armor has been employed for decades in lieu of the more standard commercial bronze for certain applications such as in repeated or continuous flexing applications where it was found that the small, individual wires of the bronze braid would fatigue and break, which reportedly created issues under continued flexing. The accommodation for tinned copper braided armor is cited in UL 1309 and IEEE 1580.

Submitter Information Verification

Submitter Full Name: Gary Savage
Organization: Prysmian Group
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 14:21:38 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Recognition of the armor as an EMI shield is not necessary. The NEC does not prohibit the tin copper armor from being used as an EMI shield.

Public Input No. 4535-NFPA 70-2020 [Section No. 337.116]

337.116 Armor.

Armor shall be permitted over the jacket. If provided, the armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor or as an equipment grounding conductor with the exception that, in the case of multiconductorType P cables used in variable frequency drive applications, the tinned copper armor may be allowed to function as an EMI shield as well as armor . A nonmetallic jacket that conforms to 337.115 shall be provided over the armor.

Statement of Problem and Substantiation for Public Input

This change will allow users to reduce diameter, weight, bend radii, and cost in VFD cable designs as compared to designs that require another layer of bronze armor in addition to the tinned copper EMI shield . The larger, heavier cables are much more difficult to handle and install,
Tinned copper braided armor has been proven as an armor material in service for many years. IEC cables have utilized the tinned copper braided armor of marine cables in the dual function as both an armor and earthing conductor for decades. In fact, the tinned copper braided armor is more reliable than utilizing the continuously corrugated and welded (CCW) aluminum armor (such as in some Type MC cables) as a ground conductor, which is allowed in the Code for areas classified as Class I Division 2 and lower. Thus type of armor has demonstrated the propensity to break under repeated movement thus compromising the ground. By contrast, If a few wires happen to be broken during installation, the broken wires will reconnect with the shield circuit in the undamaged portion of the braid. An EMI shield differs from a grounding conductor in that one of its function is to carry only a fraction of the total common mode currents generated by the drive. The remainder and majority of this currents is conducted by the three symmetrical ground conductors present in the cable construction. Even in the event that the armor/ EMI shield was completely severed, the cable would continue operating with only a slight reduction in EMI mitigation. Of course, this would not occur except in the case of such gross damage to the cable that it would be obvious to the installer. The second function of the EMI shield is to provide 100% coverage of the core to prevent EMI "leakage" form the cable. A localized disruption of this shield will not have a perceptible leakage of EMI.

Submitter Information Verification

Submitter Full Name: Gary Savage
Organization: Prysmian Group
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 14:48:40 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Recognition of the armor as an EMI shield is not necessary. The NEC does not prohibit the tin copper armor from being used as an EMI shield.

Public Input No. 3539-NFPA 70-2020 [Section No. 338.2]

(Relocate all definitions in the 338. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

338. 2 Definitions.

The definition in this section shall apply within this article and throughout the *Code*.

Service-Entrance Cable.

A single conductor or multiconductor cable provided with an overall covering, primarily used for services, and of the following types:

Type SE.

Service-entrance cable having a flame-retardant, moisture-resistant covering.

Type USE.

Service-entrance cable, identified for underground use, having a moisture-resistant covering, but not required to have a flame-retardant covering.

Service-Entrance Conductor Assembly.

Multiple single-insulated conductors twisted together without an overall covering, other than an optional binder intended only to keep the conductors together.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:48:53 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 2328-NFPA 70-2020 [New Section after 338.6]

338.8 Reconditioning

Service-Entrance Cable: Types SE and USE shall not be permitted to be reconditioned.

Statement of Problem and Substantiation for Public Input

This revision is needed to clarify that listed Service-Entrance Cable: Types SE and USE is not intended to be reconditioned.

Submitter Information Verification

Submitter Full Name: Brian Deacy
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 14 15:17:59 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: It is unclear what reconditioning means when applied to wire and cable. Including this language might cause confusion in the field for applications such as splicing or repairs.

Public Input No. 3905-NFPA 70-2020 [Section No. 338.10(B)(4)]

(4) Installation Methods for Branch Circuits and Feeders.

Informational Note No. 1:

~~See~~

See 310.14(A)(3) for temperature limitation of conductors.

Informational Note No. 2:

~~For~~

For the installation of main power feeder conductors in dwelling units refer to 310.12 .

(a) *Interior Installations.*

(2) In addition to the provisions of this article, Type SE service-entrance cable used for interior wiring shall comply with the installation requirements of Part II of Article 334 , excluding 334.80 .

(3) Where more than two Type SE cables containing two or more current-carrying conductors in each cable are installed in contact with thermal insulation, caulk, or sealing foam without maintaining spacing between cables, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1) .

(4) For Type SE cable with ungrounded conductor sizes 10 AWG and smaller, where installed in contact with thermal insulation, the ampacity shall be in accordance with 60°C (140°F) conductor temperature rating. The maximum conductor temperature rating shall be permitted to be used for ampacity adjustment and correction purposes, if the final ampacity does not exceed that for a 60°C (140°F) rated conductor.

(e) *Exterior Installations.*

(6) In addition to the provisions of this article, service-entrance cable used for feeders or branch circuits, where installed as exterior wiring, shall be installed in accordance with Part I of Article 225 . The cable shall be supported in accordance with 334.30 .

(7) Type USE cable installed as underground feeder and branch circuit cable shall comply with Part II of Article 340 .

Exception: Single-conductor Type USE and multi-rated USE conductors shall not be subject to the ampacity limitations of Part II of Article 340.

Informational Note No. 1: See 310.14(A)(3) for temperature limitation of conductors.

Informational Note No. 2: For the installation of main power feeder conductors in dwelling units refer to 310.12 .

Statement of Problem and Substantiation for Public Input

This section shall comply with NEC Style Manual of relocation of Informational Notes. Informational Notes shall be located after the rule is applied. 3.1.3 Informational Notes. Informational notes contain explanatory information and shall be located directly after the rule they apply to.

No change, just relocation of Informational Notes.

Submitter Information Verification

Submitter Full Name: William Pancake
Organization: CAP Government
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 15:15:01 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8604-NFPA 70-2021
Statement: CMP6 agrees with following the text where applicable per NEC Style Manual 3.1.3. For clarity the informational notes do not add significant value in applying the other article sections referenced. Therefore, they are being deleted.

Public Input No. 4142-NFPA 70-2020 [Section No. 338.12(A)]

(A) Service-Entrance Cable.

Service-entrance cable (SE) shall not be used under the following conditions or in the following locations:

(1) Where subject to physical damage unless protected in accordance with 230.50(B)

(2) Underground with or without a raceway

(3) For exterior branch circuits and feeder wiring unless the installation complies ~~with the provisions~~ withPart I of ~~Part I of~~ Article 225 and is supported in accordance with 334.30 or is used as messenger-supported wiring as permitted in Part II of Article 396

Statement of Problem and Substantiation for Public Input

Deleting the words "the provisions of" does not change the meaning of the section.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 21:54:02 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8458-NFPA 70-2021
Statement: Editorial revision to align with the Style Manual.

Public Input No. 1503-NFPA 70-2020 [Section No. 338.24]

338.24 Bending Radius.

Bends in Types USE and SE cable shall be so made that the cable will not be damaged. The radius of the curve of the inner edge of any bend, during or after installation, shall not be less than five times the diameter of the cable. For flat cables, the thickness of the cable shall be used to determine the bending radius.

Statement of Problem and Substantiation for Public Input

This is another corollary to PI 1501 -- SE Style U cables are always found in a flat construction, and thus are also affected by the bend radius determination questions that affect flat NM and UF cables.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1501-NFPA 70-2020 [Section No. 334.24]	This PI doesn't make sense without the correlating changes for NM and UF cables
Public Input No. 1502-NFPA 70-2020 [Section No. 340.24]	This PI doesn't make sense without the correlating changes for NM and UF cables

Submitter Information Verification

Submitter Full Name: Lucas Thode
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 10 12:06:18 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8605-NFPA 70-2021

Statement: The change in wording provides the minimal clarity for description pertaining to minor and major diameters per the axis of the flat cable.

To be consistent with other Sections the language submitted should be the same and include the word “major” for clarity to using the diameter dimension to determine the radius of the bend. The change in wording provides the minimal clarity for description pertaining to minor and major diameters.

Public Input No. 3540-NFPA 70-2020 [Section No. 340.2]

(Relocate all definitions in the 340. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

340. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Underground Feeder and Branch-Circuit Cable, Type UF.

A factory assembly of one or more insulated conductors with an integral or an overall covering of nonmetallic material suitable for direct burial in the earth.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 21:50:50 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 2329-NFPA 70-2020 [New Section after 340.6]

340.8 Reconditioning

Underground Feeder and Branch-Circuit Cable: Type UF shall not be permitted to be reconditioned.

Statement of Problem and Substantiation for Public Input

This revision is needed to clarify that listed Underground Feeder and Branch-Circuit Cable: Type UF is not intended to be reconditioned.

Submitter Information Verification

Submitter Full Name: Brian Deacy
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 14 15:24:33 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: It is unclear what reconditioning means when applied to wire and cable. Including this language might cause confusion in the field for applications such as splicing or repairs.

Public Input No. 1502-NFPA 70-2020 [Section No. 340.24]

340.24 Bending Radius.

Bends in Type UF cable shall be so made that the cable is not damaged. The radius of the curve of the inner edge of any bend shall not be less than five times the diameter of the cable. For flat cables, the thickness of the cable shall be used to determine the bending radius.

Statement of Problem and Substantiation for Public Input

See PI No. 1501 -- many UF cables are flat, like their NM brethren, and thus are affected by the same "which dimension determines the minimum bending radius?" question.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1501-NFPA 70-2020 [Section No. 334.24]	Depends -- the two PIs only make sense together (flat NM and UF are the two most commonly encountered flat constructions out of all the Chapter 3 wiring methods)
Public Input No. 1503-NFPA 70-2020 [Section No. 338.24]	

Submitter Information Verification

Submitter Full Name: Lucas Thode
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 10 11:53:53 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8608-NFPA 70-2021

Statement: The change in wording provides the minimal clarity for description pertaining to minor and major diameters per the axis of the flat cable.

To be consistent with other Sections the language submitted should be the same and include the word “major” for clarity to using the diameter dimension to determine the radius of the bend. The change in wording provides the minimal clarity for description pertaining to minor and major diameters.

Public Input No. 3251-NFPA 70-2020 [Section No. 340.104]

340.104 Conductors.

The conductors shall be sizes ~~14 AWG~~ 14 AWG through 4/0 copper or ~~12 AWG aluminum or~~ copper-clad aluminum, or 12 AWG through 4/~~0 AWG~~ 0 AWG aluminum .

Additional Proposed Changes

File Name	Description	Approved
Proposed_340.104_Draft_Fnl.docx	Word file attached for clarity to show the revisions for clarity. Terra would not show 4/0 AWG.	
Terminal_and_Conductor_Temperature_Testing_Part_I_Fnl.pdf	Terminal temperature static heating test report as requested by task group	

Statement of Problem and Substantiation for Public Input

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in underground feeder and branch circuit cables.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2865-NFPA 70-2020 [Section No. 210.12]	Branch circuit AFCI added 10 amps
Public Input No. 2864-NFPA 70-2020 [Section No. 210.18]	Branch circuit ratings added 10 amps
Public Input No. 2866-NFPA 70-2020 [Section No. 210.21(B)]	Individual branch circuit receptacle applications and limitations
Public Input No. 3261-NFPA 70-2020 [Section No. 210.23]	Branch circuit applications and limitations added 10 amps
Public Input No. 3940-NFPA 70-2020 [Section No. 210.24]	Summary branch circuit applications and limitations added 10 amps
Public Input No. 3238-NFPA 70-2020 [Section No. 240.4(D)]	14 AWG copper-clad aluminum OCPD added
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	10 ampere OCPD added as standard device rating
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	Branch circuit conductors added 14 AWG copper-clad aluminum
Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]	Table 310.16 added ampacities for 14 AWG copper-clad aluminum
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	14 AWG copper-clad aluminum added for cables
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	14 AWG copper-clad aluminum added for cables
Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]	Applications and limitations for snap switches

Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]	Applications and limitations for receptacles
Public Input No. 3239-NFPA 70-2020 [Section No. 240.6(A)]	
Public Input No. 3241-NFPA 70-2020 [Section No. 310.3(A)]	
Public Input No. 3247-NFPA 70-2020 [Section No. 330.104]	
Public Input No. 3248-NFPA 70-2020 [Section No. 334.104]	
Public Input No. 3249-NFPA 70-2020 [Section No. 336.104 [Excluding any Sub-Sections]]	
Public Input No. 3256-NFPA 70-2020 [Section No. 404.14]	
Public Input No. 3259-NFPA 70-2020 [Section No. 406.3]	
Public Input No. 3960-NFPA 70-2020 [Section No. 310.21]	

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: IEC
Affiliation: NEC Correlating Committee Task Group
Street Address:
City:
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Zip:
Submittal Date: Mon Sep 07 10:54:21 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8606-NFPA 70-2021

Statement: The minimum conductor sizes for copper and copper-clad aluminum are being reduced to 16 AWG copper and 14 AWG copper-clad aluminum. These revisions are based on testing submitted in support of the use of copper-clad aluminum conductors for 10 amp circuits, and the decades of successful use of 16 AWG copper conductors in fixture wire, motor wiring, control wiring, and other current-carrying applications as permitted in the NEC. For clarity and consistency edits were incorporated to reflect other code articles for conductor types.

Public Input for 340.104

340.104 Conductors.

The conductors shall be sizes 14 AWG through 4/0 AWG copper or ~~12 AWG aluminum or~~ copper-clad aluminum, ~~through~~ or 12 AWG through 4/0 AWG aluminum ~~through 4/0 AWG~~.

Substantiation

Task Group Statement

This public input is submitted on behalf of the task group formed in accordance with the direction of the NFPA Standards Council in their Decisions D#19-2 and D#19-23. This task group was appointed to identify potential proposed changes to the 2020 edition of the NEC in the form of proposed Tentative Interim Amendments (TIAs) or to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Standards Council.

These proposed PIs relate to new requirements covering the use of copper-clad aluminum conductors throughout the NEC as a coordinated set of new or revised requirements. These Public Inputs should not be misconstrued by the CMPs as precluding consideration of other Public Inputs, with supporting test data, submitted now or in the future, for other potentially eligible conductor materials or sizes.

The task group members are; David Hittinger-Chair, Todd Crisman, Roland Deike, Thomas Domitrovich, Peter Graser, Christel Hunter, Chuck Mello, Ken Riedl, Susan Newman Scearce, Susan Stene, George Straniero, Frank Tse and Brian Rock. This task group of balanced interests provided the expertise to develop these public inputs covering the use of copper-clad aluminum conductors.

Public Inputs are being submitted in the following sections: Article 100, definition of "copper-clad aluminum", 210.12, 210.18, 210.21(B)(1), 210.23, 210.24, 210.52(B), 240.4(D), 240.6, 310.3(A), 310.3(B), Table 310.16, Table 310.17, 330.104, 334.104, 336.104, 340.104,404.14(D), and 406.3(D).

Summary of Change

This public input is part of a coordinated effort to introduce 14 AWG copper-clad aluminum into the NEC for branch circuit wiring. This is being done by adding an ampacity to the ampacity tables, and other coordinated changes needed throughout the Code. The change provided in this public input is one of those needed to recognize 14 AWG copper-clad aluminum in underground feeder and branch circuit cables.

Technical Substantiation

The application of energy efficient equipment and the implementation of Energy Codes for modern construction, provides more options for reduced branch circuit loading. The result is that many branch circuits are capable of having a conductor current rating and overcurrent

device rating of 10-Amperes. For example, a typical 75-watt equivalent LED lamp has a load rating of 12 watts. At 120 volts this is a load of 0.1 amps per lamp. A continuously loaded 10-ampere branch circuit for fixed lighting would be allowed to have 8 amps of load current, which would equate to 80 of these LED lamps. This is more lamps than found in a typical 2000 square foot home. Other examples are specific limited loads such as fire or burglar alarm panels, kitchen instant hot water dispensers, attic exhaust fans, and others. These specific loads on individual branch circuits only need one or a few amperes and could safely be installed on a 10-Ampere branch circuit. These lighting and specific appliance applications exist in both dwelling unit as well as commercial and industrial installations. There are cases today where equipment is being protected by a 15-Ampere circuit breaker, whereas a 10-Ampere overcurrent device and using 14 AWG Copper-Clad Aluminum conductors would provide a safe level of protection.

If accepted, this change will not result in 14 copper-clad aluminum being put into the market immediately. First, this NEC change to allow 14 AWG copper-clad aluminum as the smallest copper-clad aluminum conductor will permit introducing needed changes to many UL standards to allow 14 AWG cooper-clad aluminum as an individual listed conductor and to be used in cable assemblies. Second, the Code and wire and cable standard change will then allow changes to other UL standards for products and equipment recognizing 14 AWG copper-clad aluminum in those standards. Lastly, with required testing completed and listings provided, this change would then permit applications to be considered by designers and installers along with the other needed Code changes to ensure applications and limitations are properly set in the various Code installation and equipment requirements.

Public Input No. 3579-NFPA 70-2020 [Section No. 382.2]

(Relocate all definitions in the 382.2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

382. 2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Concealable Nonmetallic Extension.

A listed assembly of two, three, or four insulated circuit conductors within a nonmetallic jacket, an extruded thermoplastic covering, or a sealed nonmetallic covering. The classification includes surface extensions intended for mounting directly on the surface of walls or ceilings and concealed with paint, texture, joint compound, plaster, wallpaper, tile, wall paneling, or other similar materials.

Nonmetallic Extension.

An assembly of two insulated conductors within a nonmetallic jacket or an extruded thermoplastic covering. The classification includes surface extensions intended for mounting directly on the surface of walls or ceilings.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100.

Submitter Information Verification

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Submittal Date: Wed Sep 09 08:16:33 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 1271-NFPA 70-2020 [Section No. 382.26]

382. ~~26~~ 24 Bends.

(A) Nonmetallic Extensions.

A bend that reduces the normal spacing between the conductors shall be covered with a cap to protect the assembly from physical damage.

(B) Concealable Nonmetallic Extensions.

Concealable extensions shall be permitted to be folded back over themselves and flattened as required for installation.

Statement of Problem and Substantiation for Public Input

Renumber Section 382.26 to 382.24 for consistency with the other raceway articles. The renumbering will improve clarity and usability.

Submitter Information Verification

Submitter Full Name: Megan Hayes
Organization: Nema
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City:
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Zip:
Submittal Date: Thu May 28 10:04:17 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8628-NFPA 70-2021
Statement: Renumber Section 382.26 to 382.24 for consistency with the other raceway articles. The renumbering will improve clarity and usability.

Public Input No. 3595-NFPA 70-2020 [Section No. 394.2]

(Relocate all definitions in the 394.2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

394. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Concealed Knob-and-Tube Wiring.

A wiring method using knobs, tubes, and flexible nonmetallic tubing for the protection and support of single insulated conductors.

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
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Zip:
Submittal Date: Wed Sep 09 08:31:19 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 3872-NFPA 70-2020 [Section No. 394.104]

394.104 Conductors.

Conductors shall be of a type ~~specified by Article~~ identified in Table 310. 4(A) .

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to an entire article, other than Article 100. As such, it is proposed to revise this reference to point the user to the types identified in Table 310.4(A) instead of the generic reference to all of Article 310.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3875-NFPA 70-2020 [Section No. 398.104]	

Submitter Information Verification

Submitter Full Name: Richard Holub
Organization: The DuPont Company, Inc.
Street Address:
City:
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Submittal Date: Wed Sep 09 14:29:13 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8529-NFPA 70-2021
Statement: The text was revised to remove the reference to a whole article to comply with the NEC style manual section 4.1.4.

Public Input No. 3596-NFPA 70-2020 [Section No. 396.2]

(Relocate all definitions in the 396.2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

396. 2 Definitions.

Insulated Conductor.

This definition shall apply only within this article.

For the purposes of this article, an insulated conductor includes the following:

(1) Conductor types described in 310.4, and

(2) Overhead service conductors encased in a polymeric material that has been evaluated for the applied nominal voltage.

Informational Note: Evidence of evaluation for the applied nominal voltage can be given by certification that the conductors have met the requirements of ICEA S-76-474-2011, *Standard for Neutral Supported Power Cable Assemblies with Weather-Resistant Extruded Insulation Rated 600 Volts*.

Messenger-Supported Wiring.

This definition shall apply within this article and throughout the *Code*.

An exposed wiring support system using a messenger wire to support insulated conductors by any one of the following:

(1) A messenger with rings and saddles for conductor support

(2) A messenger with a field-installed lashing material for conductor support

(3) Factory-assembled aerial cable

(4) Multiplex cables utilizing a bare conductor, factory assembled and twisted with one or more insulated conductors, such as duplex, triplex, or quadruplex type of construction

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

Submitter Information Verification

Submitter Full Name: David Williams
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City:
State:
Zip:
Submittal Date: Wed Sep 09 08:32:31 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021

Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 1350-NFPA 70-2020 [Section No. 396.60]

396.60 Equipment Grounding Conductor .

~~The messenger shall be grounded as required by~~ 250.80 ~~and~~ 250.86 ~~for enclosure grounding~~ Where the messenger wire is not used as a circuit conductor, t he messenger shall be connected to the circuit equipment grounding conductor in accordance with 250.86 .

Statement of Problem and Substantiation for Public Input

No. 1. According to the NFPA Style Manual, the Section Title needs to reflect the content of the rule. The rule is about the equipment grounding conductor, not about 'Grounding.'
No. 2 Text revised to make it clear that we the rule is about the connection to the equipment grounding conductor, not 'ground.'
No. 3 Remove the reference to 250.80, since this is not how to connecte the equipment grounding conductor.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 01 17:09:46 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: There was no technical substantiation that connection to the equipment grounding conductor is the only means to ground the messenger wire when not used as a circuit conductor. Grounding of the messenger wire when used as an equipment grounding conductor is covered in 396.30(C).

Public Input No. 3598-NFPA 70-2020 [Section No. 398.2]

(Relocate all definitions in the 398. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

398. 2 Definition.

The definition in this section shall apply within this article and throughout the *Code*.

Open Wiring on Insulators.

An exposed wiring method using cleats, knobs, tubes, and flexible tubing for the protection and support of single insulated conductors run in or on buildings.

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 08:33:44 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 4557-NFPA 70-2020 [Section No. 398.15(C)]

(C) Exposed to Physical Damage.

Conductors within 2.1 m (7 ft) from the floor shall be considered exposed to physical damage. Where open conductors cross ceiling joists and wall studs and are exposed to physical damage, they shall be protected by one of the following methods:

(1) Guard strips not less than 25 mm (1 in.) nominal in thickness and at least as high as the insulating supports, placed on each side of and close to the wiring.

(2) A substantial running board at least 13 mm (½ in.) thick in back of the conductors with side protections. Running boards shall extend at least 25 mm (1 in.) outside the conductors, but not more than 50 mm (2 in.), and the protecting sides shall be at least 50 mm (2 in.) high and at least 25 mm (1 in.), nominal, in thickness.

(3) Boxing made in accordance with 398.15(C)(1) or (C)(2) and furnished with a cover kept at least 25 mm (1 in.) away from the conductors within. Where protecting vertical conductors on side walls, the boxing shall be closed at the top and the holes through which the conductors pass shall be bushed.

(4) Rigid metal conduit, intermediate metal conduit, rigid ~~nonmetallic conduit~~ polyvinyl chloride conduit , or electrical metallic tubing. When installed in metal piping, the conductors shall be encased in continuous lengths of approved flexible tubing.

Statement of Problem and Substantiation for Public Input

The 2008 NEC first referenced Reinforced Thermosetting Resin Conduit (RTRC) as a wiring method (Article 355). High Density Polyethylene Conduit (HDPE) first appeared in the 2005 NEC as Article 353. When Article 352 first changed (2008 NEC) to be titled “Rigid Polyvinyl Chloride Conduit” there were many changes throughout the Code to pick up this change and accordingly change text from “rigid nonmetallic conduit” to “rigid polyvinyl chloride conduit.”
In the 2002 NEC, this section referenced “rigid nonmetallic conduit” (as it still does in the 2020 NEC) before RTRC and HDPE appeared in the Code. This makes it clear that this section intended to permit only the use of rigid polyvinyl chloride conduit identified as “rigid nonmetallic conduit” as the other raceway types were not recognized by the NEC at the time. This term should be changed to rigid polyvinyl chloride and if the cmp wishes to add other types of nonmetallic raceways they should be listed separately as the metal raceways are.

Submitter Information Verification

Submitter Full Name: David Humphrey
Organization: County of Henrico, Virginia
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 15:08:27 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8533-NFPA 70-2021

Statement: The reference to “nonmetallic conduit” was deleted and replaced with the specific types of nonmetallic conduits, rigid polyvinyl chloride conduit (PVC), reinforced thermosetting resin conduit (RTRC), and high density polyethylene conduit (HDPE) as identified in the respective raceway articles. The acronyms for the other raceways were added for clarity and consistency.

Public Input No. 3875-NFPA 70-2020 [Section No. 398.104]

398.104 Conductors.

Conductors shall be of a type ~~specified by Article~~ identified in Table 310 .4(A).

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to an entire article, other than Article 100. As such, it is proposed to revise this reference to point to Table 310.4(A) instead of the entire article.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3872-NFPA 70-2020 [Section No. 394.104]	

Submitter Information Verification

Submitter Full Name: Richard Holub
Organization: The DuPont Company, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 14:33:32 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8534-NFPA 70-2021
Statement: The text was revised to reference Table 310.4(A) and remove the reference to a whole article to comply with section 4.1.4 of the NEC Style Manual.

Public Input No. 3599-NFPA 70-2020 [Section No. 399.2]

(Relocate all definitions in the 399. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

399. 2 Definition.

The definitions in this section shall apply only within this article.

Outdoor Overhead Conductors.

Single conductors, insulated, covered, or bare, installed outdoors on support structures in free air.

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
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Submittal Date: Wed Sep 09 08:34:29 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8304-NFPA 70-2021
Statement: All definitions have been moved to Article 100 to align with the Style Manual.

Public Input No. 400-NFPA 70-2020 [Article 400]

Article 400 Flexible Cords ~~and~~ , Flexible Cables, Cord Sets and Power Supply Cords

Part I. General

400.1 Scope.

This article covers general requirements, applications, and construction specifications for flexible cords ~~and~~ , flexible cables, cord sets and power supply cords .

400.2 Other Articles.

Flexible cords ~~and~~ , flexible cables, cord sets and power supply cords shall comply with this article and with the applicable provisions of other articles of this *Code*.

400.3 Suitability.

Flexible cords ~~and~~ , flexible cables, cord sets, power supply cords and their associated fittings shall be suitable for the conditions of use and location.

400.4 Types.

Flexible cords and flexible cables shall conform to the description in Table 400.4. The use of flexible cords and flexible cables other than those in Table 400.4 shall require permission by the authority having jurisdiction.

Table 400.4 Flexible Cords and Flexible Cables

Trade Name											
						Nominal Insulation Thickness					
Type Letter	Voltage	Use			AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm	mi	
Lamp cord	C	300 600	18–16 15–10	2 or more	Thermoset or thermoplastic	18–16 15–10	0.76 1.14	30 45	Cotton	None	
Elevator cable	E 1,2,3,4	300 or 600	20–2	2 or more	Thermoset	20–16 15–12 12–10 8–2	0.51 0.76 1.14 1.52	20 30 45 60	Cotton	Three cotto outer one flame retard and moist resist	
		20–16 15–12					0.51 0.76	20 30	Flexible nylon jacket		

						12–10	1.14	45					
						8–2	1.52	60					
Elevator cable	EO 1,2,4	300 or 600	20–2	2 or more	Thermoset	20–16	0.51	20	Cotton	Three cotton; outer one flame-retardant and moisture-resistant	Elevator lighting and control	Unclassified locations	
						15–12	0.76	30					
						12–10	1.14	45					
						8–2	1.52	60					
					One cotton and a neoprene jacket								
					Hazardous (classified) locations								
Elevator cable					ETP 2,4								300 or 600
					ETT 2,4								300 or 600
					Rayon	Thermo-plastic	Hazardous (classified) locations						
					None	One cotton or equivalent and a thermo-plastic jacket							
Electric vehicle	EV 5,6	1000	18–500	2 or more plus equipment grounding	Thermoset with optional nylon	18–15	0.76 (0.51)	30 (20)	Optional	Oil-resistant thermoset		Elec vehi char	

cable				conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables		14–10	1.14 (0.76)	45 (30)		
						8–2	1.52 (1.14)	60 (45)		
						1–4/0	2.03 (1.52)	80 (60)		
						250–500	2.41 (1.90)	95 (75)		
	EVJ 5,6	300	18–12			18–12	0.76 (0.51)	30 (20)		
EVE 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	Thermoplastic elastomer with optional nylon		18–15	0.76 (0.51)	30 (20)	Oil-resistant thermo- plastic elastomer	Extra-hard usage
						14–10	1.14 (0.76)	45 (30)		
						8–2	1.52 (1.14)	60 (45)		
						1–4/0	2.03 (1.52)	80 (60)		
						250– 500	2.41	95		

						(1.90)		(75)			
EVJE	5,6	300	18–12	18–12	0.76 (0.51)	30 (20)	Hard usage				
EVT 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	Thermoplastic with optional nylon	18–15	0.76 (0.51)	30 (20)	Optional	Oil-resistant thermo- plastic	Electric vehicle charging	We Lo
					14–10	1.14 (0.76)	45 (30)				
					8–2	1.52 (1.14)	60 (45)				
					1–4/0	2.03 (1.52)	80 (60)				
					250– 500	2.41 (1.90)	95 (75)				
	EVJT 5,6	300	18–12	18–12	0.76 (0.51)	30 (20)	Hard usage				
Portable power	G	2000	12–500	2–6 plus equipment grounding conductor(s)	Thermoset	12–2 1–4/0	1.52 2.03	60 80			

cable							250–500	2.41	95		

Oil-resistant thermoset	Portable and extra-hard usage

G-GC [7]	2000	12–500	3–6 plus equipment grounding conductors and 1 ground check conductor	Thermoset	12–2 1–4/0 250–500	1.52 2.03 2.41	60 80 95	

Oil-resistant thermoset

Heater cord	HPD	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.38 0.76	15 30	None	Cotton or rayon	Portable heaters	Dry loca- tions
Parallel heater cord	HPN [8]	300	18–12	2 or 3	Oil-resistant thermoset	18–16 15 14 12	1.14 1.52 2.41	45 60 95	None	Oil-resistant thermoset	Portable	Damp locations
Thermoset jacketed heater cords	HSJ	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.76 1.14	30 45	None	Cotton and thermoset	Portable or portable heater	Damp loca- tions
	HSJW	300	18–12									

Thermoset

Cotton and thermoset

HSJO	Damp loca- tions 300	18–12

	Cotton and oil-resistant thermoset								
	Damp and wet locations								
	HSJOW [9]	300	18–12						
	Damp locations								
	HSJOO	300	18–12						
	Oil-resistant thermoset								
	HSJOOW [9]	300	18–12						
	Damp and wet locations								
Non-integral parallel cords	NISP-1	300	20–18	2 or 3	Thermoset	20–18	0.38	15	None	Thermos
	NISP-2	300	18–16			18–16	0.76	30		
	NISPE-1 [8]	300	20–18		Thermoplastic elastomer	20–18	0.38	15		Thermo-plastic elastome
	NISPE-2 [8]	300	18–16			18–16	0.76	30		
	NISPT-1 [8]	300	20–18		Thermoplastic	20–18	0.38	15		Thermo-plastic
	NISPT-2 [8]	300	18–16			18–16	0.76	30		
Twisted portable cord	PD	300 600	18–16 14–10	2 or more	Thermoset or thermoplastic	18–16 15–10	0.76 1.14	30 45	Cotton	Cotton o rayon
Portable power cable	PPE [7]	2000	12–500	1–6 plus optional equipment grounding conductor(s)	Thermoplastic elastomer	12–2 1–4/0 250–500	1.52 2.03 2.41	60 80 95		
	Oil-resistant thermo-	Portable, extra-hard usage								

	plastic elastomer											
Hard service cord	S [7]	600	18–2	2 or more	Thermoset	18–15 14–10 8–2	0.76 1.14 1.52	30 45 60	None	Thermoset	Pendant or portable	Damp loca-tions
Flexible stage and lighting power cable	SC [7,10]	600	8–250	1 or more	Thermoset	8–2 1–4/0 250	1.52 2.03 2.41	60 80 95				

Thermoset	Portable, extra-hard usage
SCE [7,10]	600
Thermoplastic elastomer	
Thermo-plastic elastomer	
SCT [7,10]	600
Thermoplastic	
Thermo-plastic	

Hard service cord	SE [7]	600	18–2	2 or more	Thermoplastic elastomer	18–15 14–9 8–2	0.76 1.14 1.52	30 45 60	None	Thermo- plastic elastomer	Pendant or portable	Damp loca- tions	Extra hard usag
SEW [7, 9]										600			
Damp and wet locations													
SEO [7]										600			
Oil- resistant thermo- plastic elastomer													
Damp locations													
SEOW [7,9]										600			
Damp and wet locations													
SEOO [7]										600			
Oil-resistant thermoplastic elastomer													
Damp locations													
SEOOW [7,9]										600			
Damp and wet locations													

Junior hard service cord	SJ	300	18–10	2–6	Thermoset	18–11 10	0.76 1.14	30 45	None	Thermoset	Pendant or portable	Damp loca- tions	Hard usage

SJE	300

Thermoplastic elastomer

			Thermo- plastic elastomer

SJEW [9]	300

							Damp and wet locations

SJEO	300

							Oil- resistant thermo- plastic elastomer

Damp locations

SJEOW [9]	300

							Damp and wet locations

SJEOO	300

Oil- resistant thermoplastic elastomer

Damp locations	
SJEOOW [9]	300
Damp and wet locations	
SJO	300
Thermoset	
Oil-resistant thermoset	
Damp locations	
SJOW [9]	300
Damp and wet locations	
SJOO	300
Oil-resistant thermoset	
Damp locations	
SJOOW [9]	300
Damp and wet locations	
SJT	300
Thermoplastic	
Thermo-	

				plastic									
	Damp locations												
SJTW [9]											300		
	Damp and wet locations												
	SJTO										300		
			18–12					0.76			30		
			10					1.14			45		
	Oil-resistant thermo-plastic												
	Damp locations												
SJTOW [9]											300		
	Damp and wet locations												
	SJTOO										300		
	Oil-resistant thermoplastic												
	Damp locations												
SJTOOW [9]											300		
	Damp and wet locations												
Hard service cord	SO [7]	600	18–2	2 or more	Thermoset	18–15	0.76	30	None	Oil-resistant	Pendant or portable	Damp loca-	Extra-hard usage

												thermoset	tions

SOW [7,9]		600
Damp and wet locations		
SOO [7]		600
Oil-resistant	14–9	1.14	45
thermoset	8–2	1.52	60
Damp locations			
SOOW [7,9]		600
Damp and wet locations		

All thermoset parallel cord	SP-1	300	20–18	2 or 3	Thermoset	20–18	0.76	30	None	None	Pendant or portable	Damp loca- tions	Not hard usage

SP-2	300	18–16
18–16	1.14	45
SP-3	300	18–10
18–16	1.52	60
15–14	2.03	80
12	2.41	95
10	2.80	110
Refrigera- tors, room air condi-		

	tioners, and as permitted in 422.16(B)												
All elastomer (thermo- plastic) parallel cord	SPE-1 [8]	300	20-18	2 or 3	Thermoplastic elastomer	20–18	0.76	30	None	None	Pendant or portable	Damp loca- tions	Not hard usag
	SPE-2 [8]	300	18–16										
	18–16	1.14	45										
	SPE-3 [8]	300	18–10										
	18–16	1.52	60										
	15–14	2.03	80										
	12	2.41	95										
	10	2.80	110										
	Refrigera- tors, room air condi- tioners, and as permitted in 422.16(B)												
All thermoplastic parallel cord	SPT-1	300	20–18	2 or 3	Thermoplastic	20–18	0.76	30	None	None	Pendant or portable	Damp loca- tions	Not har usa
	SPT-1W [9]	300											
	2												
	Damp and wet locations												

SPT-2	300	18–16	2 or 3									
	18–16	1.14	45									
	Damp locations											
SPT-2W [9]	300											
	2											
	Damp and wet locations											
SPT-3	300	18–10	2 or 3	18–16 15–14 12 10	1.52 2.03 2.41 2.80	60 80 95 110	Refrig-erators, room air condi-tioners, and as permitted in 422.16(B)	Damp loca-tions	Not hard usage			
Range, dryer cable	SRD	300	10–4	3 or 4	Thermoset	10–4	1.14	45	None	Thermoset	Portable	Damp loca-tions
SRDE	300	10–4	3 or 4	Thermoplastic elastomer								
	None	Thermo-plastic elastomer										
SRDT	300	10–4	3 or 4	Thermoplastic								
	None	Thermo-plastic										

Hard service cord	ST [7]	600	18–2	2 or more	Thermoplastic	18–15 14–9 8–2	0.76 1.14 1.52	30 45 60	None	Thermo-plastic	Pendant or portable	Damp loca-tions	Extra-hard usage
	STW [7,9]	600											
	Damp and wet locations												
	STO [7]	600											
	Oil-resistant thermo-plastic												
	Damp locations												
	STOW [7, 9]	600											
	Damp and wet locations												
	STOO [7]	600											
	Oil-resistant thermoplastic												
	Damp locations												
	STOOW [7]	600											
	Damp and wet locations												
Vacuum cleaner cord	SV	300	18–16	2 or 3	Thermoset	18–16	0.38	15	None	Thermoset	Pendant or portable	Damp loca-tions	Not hard usage

SVE	300
Thermoplastic elastomer	
Thermo- plastic elastomer	
SVEO	300
Oil-resistant thermo- plastic elastomer	
SVEOO	300
Oil-resistant thermoplastic elastomer	
SVO	300
Thermoset	
Oil-resistant thermoset	
SVOO	300
Oil-resistant thermoset	
Oil-resistant thermoset	
SVT	300

	Thermoplastic

				Thermoplastic

SVTO	300

	Thermoplastic

				Oil-resistant thermo-plastic

SVTOO	300

	Oil-resistant thermoplastic

Parallel tinsel cord	TPT [11]	300	27	2	Thermoplastic	27	0.76	30	None	Thermo-plastic	Attache to an applianc
Jacketed tinsel cord	TST [11]	300	27	2	Thermoplastic	27	0.38	15	None	Thermo-plastic	Attache to an applianc
Portable power cable	W [7]	2000	12–500 501–1000	1–6 1	Thermoset	12–2 1–4/0 250–500 501–1000	1.52 2.03 2.41 2.80	60 80 95 110			

Oil-resistant thermoset	Portable, extra-hard usage

Notes:

All types listed in Table 400.4 shall have individual conductors twisted together, except for Types HPN, SP-1, SP-2, SP-3, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, SPT-1W,

SPT-2W, TPT, NISP-1, NISP-2, NISPT-1, NISPT-2, NISPE-1, NISPE-2, and three-conductor parallel versions of SRD, SRDE, and SRDT.

The individual conductors of all cords, except those of heat-resistant cords, shall have a thermoset or thermoplastic insulation, except that the equipment grounding conductor, where used, shall be in accordance with 400.23(B).

[1]Rubber-filled or varnished cambric tapes shall be permitted as a substitute for the inner braids.

[2]Elevator traveling cables for operating control and signal circuits shall contain nonmetallic fillers as necessary to maintain concentricity. Cables shall have steel supporting members as required for suspension by 620.41. In locations subject to excessive moisture or corrosive vapors or gases, supporting members of other materials shall be permitted. Where steel supporting members are used, they shall run straight through the center of the cable assembly and shall not be cabled with the copper strands of any conductor.

In addition to conductors used for control and signaling circuits, Types E, EO, ETP, and ETT elevator cables shall be permitted to incorporate in the construction one or more 20 AWG telephone conductor pairs, one or more coaxial cables, or one or more optical fibers. The 20 AWG conductor pairs shall be permitted to be covered with suitable shielding for telephone, audio, or higher frequency communications circuits; the coaxial cables shall consist of a center conductor, insulation, and a shield for use in video or other radio frequency communications circuits. The optical fiber shall be suitably covered with flame-retardant thermoplastic. The insulation of the conductors shall be rubber or thermoplastic of a thickness not less than specified for the other conductors of the particular type of cable. Metallic shields shall have their own protective covering. Where used, these components shall be permitted to be incorporated in any layer of the cable assembly but shall not run straight through the center.

[3]Insulations and outer coverings that meet the requirements as flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the *Code* type designation.

[4]Elevator cables in sizes 20 AWG through 14 AWG are rated 300 volts, and sizes 10 AWG through 2 AWG are rated 600 volts. 12 AWG is rated 300 volts with a 0.76 mm (30 mil) insulation thickness and 600 volts with a 1.14 mm (45 mil) insulation thickness.

[5]Conductor size for Types EV, EVJ, EVE, EVJE, EVT, and EVJT cables apply to nonpower-limited circuits only. Conductors of power-limited (data, signal, or communications) circuits may extend beyond the stated AWG size range. All conductors shall be insulated for the same cable voltage rating.

[6]Insulation thickness for Types EV, EVJ, EVEJE, EVT, and EVJT cables of nylon construction is indicated in parentheses.

[7]Types G, G-GC, S, SC, SCE, SCT, SE, SEO, SEOO, SEW, SEOW, SEOOW, SO, SOO, SOW, SOOW, ST, STO, STOO, STW, STOW, STOOW, PPE, and W shall be permitted for use on theater stages, in garages, and elsewhere where flexible cords are permitted by this *Code*.

[8]The third conductor in Type HPN shall be used as an equipment grounding conductor only. The insulation of the equipment grounding conductor for Types SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, NISPT-1, NISPT-2, NISPE-1, and NISPE-2 shall be permitted to be thermoset polymer.

[9]Cords that comply with the requirements for outdoor cords and are so listed shall be permitted to be designated as weather and water resistant with the suffix “W” after the *Code* type designation. Cords with the “W” suffix are suitable for use in wet locations and are sunlight resistant.

[10]The required outer covering on some single-conductor cables may be integral with the insulation.

[11]Types TPT and TST shall be permitted in lengths not exceeding 2.5 m (8 ft) where attached directly, or by means of a special type of plug, to a portable appliance rated at 50 watts or less and of such nature that extreme flexibility of the cord is essential.

400.5 Ampacities for Flexible Cords and Flexible Cables.

(A) Ampacity Tables.

Table 400.5(A)(1) provides the ampacities, and Table 400.5(A)(2) provides the ampacities for flexible cords and flexible cables with not more than three current-carrying conductors. These tables shall be used in conjunction with applicable end-use product standards to ensure selection of the proper size and type. Where cords and cables are used in ambient temperatures other than 30°C (86°F), the temperature correction factors from Table 310.15(B)(1) that correspond to the temperature rating of the cord or cable shall be applied to the ampacity in Table 400.5(A)(1) and Table 400.5(A)(2). Cords and cables rated 105°C shall use correction factors in the 90°C column of Table 310.15(B)(1) for temperature correction. Where the number of current-carrying conductors exceeds three, the ampacity of each conductor shall be reduced from the three-conductor rating as shown in Table 400.5(A)(3).

Informational Note: See Informative Annex B, Table B.2(11), for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Table 400.5(A)(1) Ampacity for Flexible Cords and Flexible Cables

[Based on Ambient Temperature of 30°C (86°F). See 400.13 and Table 400.4.]

Copper Conductor				
Size (AWG)				
Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO, NISP-1, NISP-2				
Thermoplastic Types TPT, TST	Thermoplastic Types ETP, ETT, NISPE-1, NISPE-2, NISPT-1, NISPT-2, SE, SEW, SEO, SEOO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W, SPT-3, ST, STW, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVEOO, SVT, SVTO, SVTOO	Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW		
Column A [1]			Column B [2]	
27 [3]	0.5	—	—	—
20	—	5 [4]	5	—
18	—	7	10	10
17	—	9	12	13
16	—	10	13	15
15	—	12	16	17
14	—	15	18	20
13	—	17	21	—
12	—	20	25	30
11	—	23	27	—
10	—	25	30	35

9	—	29	34	—
8	—	35	40	—
7	—	40	47	—
6	—	45	55	—
5	—	52	62	—
4	—	60	70	—
3	—	70	82	—
2	—	80	95	—

[1]The currents under Column A apply to three-conductor cords and other multiconductor cords connected to utilization equipment so that only three-conductors are current-carrying.

[2]The currents under Column B apply to two-conductor cords and other multiconductor cords connected to utilization equipment so that only two conductors are current-carrying.

[3]Tinsel cord.

[4]Elevator cables only.

[5]7 amperes for elevator cables only; 2 amperes for other types.

Table 400.5(A)(2) Ampacity of Cable Types SC, SCE, SCT, PPE, G, G-GC, and W

[Based on Ambient Temperature of 30°C (86°F). See Table 400.4.]

Copper Conductor	Temperature Rating of Cable		
Size (AWG or kcmil)	60°C (140°F)		
	75°C (167°F)		
	90°C (194°F)		
D [1]	E [2]	F [3]	
D [1]	E [2]	F [3]	
D [1]	E [2]	F [3]	
12	—	31	26
—	37	31	
—	42	35	
10	—	44	37

	—	52	43
-			
	—	59	49
8	60	55	48
-			
	70	65	57
-			
	80	74	65
6	80	72	63
-			
	95	88	77
-			
	105	99	87
4	105	96	84
-			
	125	115	101
-			
	140	130	114
3	120	113	99
-			
	145	135	118
-			
	165	152	133
2	140	128	112
-			
	170	152	133
-			
	190	174	152
1	165	150	131
-			
	195	178	156
-			
	220	202	177
1/0	195	173	151
-			
	230	207	181
-			
	260	234	205
2/0	225	199	174
-			
	265	238	208
-			
	300	271	237

3/0	260	230	201
-			
	310	275	241
-			
	350	313	274
4/0	300	265	232
-			
	360	317	277
-			
	405	361	316
250	340	296	259
-			
	405	354	310
-			
	455	402	352
300	375	330	289
-			
	445	395	346
-			
	505	449	393
350	420	363	318
-			
	505	435	381
-			
	570	495	433
400	455	392	343
-			
	545	469	410
-			
	615	535	468
500	515	448	392
-			
	620	537	470
-			
	700	613	536
600	575	—	—
-			
	690	—	—
-			
	780	—	—
700	630	—	—
-			
	755	—	—
-			

	855		—	—	
750		655	—	—	
-					
	785		—	—	
-					
	885		—	—	
800		680	—	—	
-					
	815		—	—	
-					
	920		—	—	
900		730	—	—	
-					
	870		—	—	
-					
	985		—	—	
1000		780	—	—	
-					
	935		—	—	
-					
1055			—	—	

[1]The ampacities under subheading D shall be permitted for single-conductor Types SC, SCE, SCT, PPE, and W cable only where the individual conductors are not installed in raceways and are not in physical contact with each other except in lengths not to exceed 600 mm (24 in.) where passing through the wall of an enclosure.

[2]The ampacities under subheading E apply to two-conductor cables and other multiconductor cables connected to utilization equipment so that only two conductors are current-carrying.

[3]The ampacities under subheading F apply to three-conductor cables and other multiconductor cables connected to utilization equipment so that only three conductors are current-carrying.

Table 400.5(A)(3) Adjustment Factors for More Than Three Current-Carrying Conductors in a Flexible Cord or Flexible Cable

Number of Conductors	Percent of Value in Table 400.5(A)(1) and Table 400.5(A)(2)
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

A neutral conductor that carries only the unbalanced current from other conductors of the same

circuit shall not be required to meet the requirements of a current-carrying conductor.

In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, a common conductor carries approximately the same current as the line-to-neutral currents of the other conductors and shall be considered to be a current-carrying conductor.

On a 4-wire, 3-phase, wye circuit where more than 50 percent of the load consists of nonlinear loads, there are harmonic currents present in the neutral conductor and the neutral conductor shall be considered to be a current-carrying conductor.

An equipment grounding conductor shall not be considered a current-carrying conductor.

Where a single conductor is used for both equipment grounding and to carry unbalanced current from other conductors, as provided for in 250.140 for electric ranges and electric clothes dryers, it shall not be considered as a current-carrying conductor.

(B) Ultimate Insulation Temperature.

In no case shall conductors be associated together in such a way with respect to the kind of circuit, the wiring method used, or the number of conductors such that the limiting temperature of the conductors is exceeded.

(C) Engineering Supervision.

Under engineering supervision, conductor ampacities shall be permitted to be calculated in accordance with 310.14(B).

400.6 Markings.

(A) Standard Markings.

Flexible cords and flexible cables shall be marked by means of a printed tag attached to the coil reel or carton. The tag shall contain the information required in 310.8(A). Types S, SC, SCE, SCT, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, STOO, SEW, SEOW, SEOOW, SJEW, SJEOW, SJEOOW, SJOW, SJTW, SJTOW, SJTOOW, SOW, SOOW, STW, STOW, and STOOW flexible cords and G, G-GC, PPE, and W flexible cables shall be durably marked on the surface at intervals not exceeding 610 mm (24 in.) with the type designation, size, and number of conductors. Required markings on tags, cords, and cables shall also include the maximum operating temperature of the flexible cord or flexible cable.

(B) Optional Markings.

Flexible cords and cable types listed in Table 400.4 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistance, and so forth.

400.10 Uses Permitted.

(A) Uses.

Flexible cords and flexible cables shall be used only for the following:

(1) Pendants.

(2) Wiring of luminaires.

(3) Connection of portable luminaires, portable and mobile signs, or appliances.

(4) Elevator cables.

(5) Wiring of cranes and hoists.

(6) Connection of utilization equipment to facilitate frequent interchange.

(7) Prevention of the transmission of noise or vibration.

(8) Appliances where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance and repair, and the appliance is intended or identified for flexible cord connection.

(9) Connection of moving parts.

(10) Where specifically permitted elsewhere in this *Code*.

(11) Between an existing receptacle outlet and an inlet, where the inlet provides power to an additional single receptacle outlet. The wiring interconnecting the inlet to the single receptacle outlet shall be a Chapter 3 wiring method. The inlet, receptacle outlet, and Chapter 3 wiring method, including the flexible cord and fittings, shall be a listed assembly specific for this application.

(B) Attachment Plugs.

Where used as permitted in 400.10(A)(3), (A)(6), and (A)(8), each flexible cord shall be equipped with an attachment plug and shall be energized from a receptacle outlet or cord connector body.

Exception: As permitted in 368.56.

400.12 Uses Not Permitted.

Unless specifically permitted in 400.10, flexible cords, flexible cables, cord sets, and power supply cords shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

Exception to (4): Flexible cord and flexible cable shall be permitted to be attached to building surfaces in accordance with 368.56(B) and 590.4.

(5) Where concealed by walls, floors, or ceilings or located above suspended or dropped ceilings

Exception to (5): Flexible cords, flexible cables, and power supply cords shall be permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by 300.22(C)(3).

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: For proper application see UL 817, *Cord Sets and Power-Supply Cords*, and UL 62, *Flexible Cords and Cables*.

400.13 Splices.

Flexible cord shall be used only in continuous lengths without splice or tap where initially installed in applications permitted by 400.10(A). The repair of hard-service cord and junior hard-service cord (see Trade Name column in Table 400.4) 14 AWG and larger shall be permitted if conductors are spliced in accordance with 110.14(B) and the completed splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.

400.14 Pull at Joints and Terminals.

Flexible cords and flexible cables shall be connected to devices and to fittings so that tension is not transmitted to joints or terminals.

Exception: Listed portable single-pole devices that are intended to accommodate such tension at their terminals shall be permitted to be used with single-conductor flexible cable.

Informational Note: Some methods of preventing pull on a cord from being transmitted to joints or terminals include knotting the cord, winding with tape, and using support or strain-relief fittings.

400.15 In Show Windows and Showcases.

Flexible cords used in show windows and showcases shall be Types S, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJOO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, STOO, SEW, SEOW, SEOOW, SJEW, SJEOW, SJEOOW, SJOW, SJOOW, SJTW, SJTOW, SJTOOW, SOW, SOOW, STW, STOW, or STOOW.

Exception No. 1: For the wiring of chain-supported luminaires.

Exception No. 2: As supply cords for portable luminaires and other merchandise being displayed or exhibited.

400.16 Overcurrent Protection.

Flexible cords not smaller than 18 AWG, and tinsel cords or cords having equivalent characteristics of smaller size approved for use with specific appliances, shall be considered as protected against overcurrent in accordance with 240.5.

400.17 Protection from Damage.

Flexible cords and flexible cables shall be protected by bushings or fittings where passing through holes in covers, outlet boxes, or similar enclosures.

In industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation, flexible cords and flexible cables shall be permitted to be installed in aboveground raceways that are no longer than 15 m (50 ft) to protect the flexible cord or flexible cable from physical damage. Where more than three current-carrying conductors are installed within the raceway, the ampacity shall be adjusted in accordance with Table 400.5(A)(3).

Part II. Construction Specifications

400.20 Labels.

Flexible cords shall be examined and tested at the factory and labeled before shipment.

400.21 Construction.

(A) Conductors.

The individual conductors of a flexible cord or flexible cable shall have copper flexible stranding and shall not be smaller than the sizes specified in Table 400.4.

(B) Nominal Insulation Thickness.

The nominal thickness of insulation for conductors of flexible cords and flexible cables shall not be less than specified in Table 400.4.

400.22 Grounded-Conductor Identification.

One conductor of flexible cords that is intended to be used as a grounded circuit conductor shall have a continuous marker that readily distinguishes it from the other conductor or conductors. The identification shall consist of one of the methods indicated in 400.22(A) through (F).

(A) Colored Braid.

A braid finished to show a white or gray color and the braid on the other conductor or conductors finished to show a readily distinguishable solid color or colors.

(B) Tracer in Braid.

A tracer in a braid of any color contrasting with that of the braid and no tracer in the braid of the other conductor or conductors. No tracer shall be used in the braid of any conductor of a flexible cord that contains a conductor having a braid finished to show white or gray.

Exception: In the case of Types C and PD and cords having the braids on the individual conductors finished to show white or gray. In such cords, the identifying marker shall be permitted to consist of the solid white or gray finish on one conductor, provided there is a colored tracer in the braid of each other conductor.

(C) Colored Insulation.

A white or gray insulation on one conductor and insulation of a readily distinguishable color or colors on the other conductor or conductors for cords having no braids on the individual conductors.

For jacketed cords furnished with appliances, one conductor having its insulation colored light blue, with the other conductors having their insulation of a readily distinguishable color other than white or gray.

Exception: Cords that have insulation on the individual conductors integral with the jacket.

The insulation shall be permitted to be covered with an outer finish to provide the desired color.

(D) Colored Separator.

A white or gray separator on one conductor and a separator of a readily distinguishable solid color on the other conductor or conductors of cords having insulation on the individual conductors integral with the jacket.

(E) Tinned Conductors.

One conductor having the individual strands tinned and the other conductor or conductors having the individual strands untinned for cords having insulation on the individual conductors integral with the jacket.

(F) Surface Marking.

One or more ridges, grooves, or white stripes located on the exterior of the cord so as to identify one conductor for cords having insulation on the individual conductors integral with the jacket.

400.23 Equipment Grounding Conductor Identification.

A conductor intended to be used as an equipment grounding conductor shall have a continuous identifying marker readily distinguishing it from the other conductor or conductors. Conductors having a continuous green color or a continuous green color with one or more yellow stripes shall not be used for other than equipment grounding conductors. Cords or cables consisting of integral insulation and a jacket without a nonintegral equipment grounding conductor shall be permitted to be green. The identifying marker shall consist of one of the methods in 400.23(A) or (B).

(A) Colored Braid.

A braid finished to show a continuous green color or a continuous green color with one or more yellow stripes.

(B) Colored Insulation or Covering.

For cords having no braids on the individual conductors, an insulation of a continuous green color or a continuous green color with one or more yellow stripes.

400.24 Attachment Plugs.

Where a flexible cord is provided with an equipment grounding conductor and equipped with an attachment plug, the attachment plug shall comply with 250.138(A) and (B).

Part III. Portable Cables Over 600 Volts, Nominal

400.30 Scope.

Part III applies to single and multiconductor portable cables used to connect mobile equipment and machinery.

400.31 Construction.

(A) Conductors.

The conductors shall be 12 AWG copper or larger and shall employ flexible stranding.

(B) Equipment Grounding Conductor(s).

An equipment grounding conductor(s) shall be provided in cables with three or more conductors. The total area shall not be less than that of the size of the equipment grounding conductor required in 250.122.

400.32 Shielding.

All shields shall be connected to an equipment grounding conductor.

400.33 Equipment Grounding Conductors.

Equipment grounding conductors shall be connected in accordance with Parts VI and VII of Article 250.

400.34 Minimum Bending Radii.

The minimum bending radii for portable cables during installation and handling in service shall be adequate to prevent damage to the cable.

400.35 Fittings.

Connectors used to connect lengths of cable in a run shall be of a type that locks firmly together. Provisions shall be made to prevent opening or closing these connectors while energized. Suitable means shall be used to eliminate tension at connectors and terminations.

400.36 Splices and Terminations.

Portable cables shall not contain splices unless the splices are of the permanent molded, vulcanized types in accordance with 110.14(B). Terminations on portable cables rated over 600 volts, nominal, shall be accessible only to authorized and qualified personnel.

Statement of Problem and Substantiation for Public Input

This Article and other Articles throughout the code have provisions covering cord sets and power supply cords. Article 200 contains requirements for cords. Article 210 has provisions for cord-and-plug connected loads. Article 410 has provisions for cords and cables. Article 422 has provisions for appliance power supply cords. Article 590 has provisions for flexible cords, flexible cables and extension cords. And so on, and so forth. Cord sets and power supply cords need to be included in the title, scope and reference to other Articles in Article 400.

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Committee: NEC-P06

Committee Statement

Resolution: The informational note after 400.12 provides the information for reference to applications for “Cord sets and Power-Supply cords”.

Public Input No. 905-NFPA 70-2020 [Article 400]

Article 400 Flexible Cords and Flexible Cables

Part I. General

400.1 Scope.

This article covers general requirements, applications, and construction specifications for flexible cords and flexible cables.

400.2 Other Articles.

Flexible cords and flexible cables shall comply with this article and with the applicable provisions of other articles of this *Code* .

400.3 Suitability.

Flexible cords and flexible cables and their associated fittings shall be suitable for the conditions of use and location.

400.4 Types.

Flexible cords and flexible cables shall conform to the description in Table 400.4 . The use of flexible cords and flexible cables other than those in Table 400.4 shall require permission by the authority having jurisdiction.

Table 400.4 Flexible Cords and Flexible Cables

Trade

Name - - - - - - Nominal

Insulation

Thickness - - Use Type

Letter Voltage AWG

or

kcmil Number

of

Conductors Insulation AWG

or

kcmil mm mils Braid

on Each

Conduc-

tor Outer

Covering Lamp cord C 300

600 18–16

15–10 2 or more Thermoset or thermoplastic 18–16

15–10 0.76

1.14 30

45 Cotton None Pendant or portable Dry loca-

tions Not hard usage Elevator cable E 1,2,3,4 300 or

600 20–2 2 or more Thermoset 20–16

15–12

12–10

8–2 0.51

0.76

1.14

1.52 20

30

45

60 Cotton Three cotton; outer one flame-

retardant and

moisture-

resistant Elevator lighting and control Unclassified locations - - - - - - 20–16

15–12

12–10

8–2 0.51

0.76

1.14

1.52 20

30

45

60 Flexible nylon jacket - - - - Elevator

cable EO [1,2,4] 300 or

600 20–2 2 or more Thermoset 20–16

15–12

12–10

8–2 0.51

0.76

1.14

1.52 20

30

45

60 Cotton Three cotton; outer one flame-

retardant and

moisture-

resistant Elevator lighting and control Unclassified locations - - - - - - - - - - One cotton and a neoprene jacket - Hazardous (classified) locations Elevator cable ETP [2,4] 300 or

600 - - - - - - Rayon Thermo-

plastic Hazardous (classified) locations - ETT [2,4] 300 or

600 - - - - - - None One cotton or equivalent and a thermo-

plastic

jacket - Electric vehicle

cable EV [5,6] 1000 18–500 2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica-

tions, and optical fiber cables Thermoset with optional nylon 18–15 0.76

(0.51) 30

(20) Optional Oil-resistant thermoset Electric vehicle charging Wet locations Extra-hard usage 14–10 1.14

(0.76) 45

(30) 8–2 1.52

(1.14) 60

(45) 1–4/0 2.03

(1.52) 80

(60) 250–500 2.41

(1.90) 95

(75) EVJ 5.6 300 18–12 18–12 0.76

(0.51) 30

(20)

Hard usage - EVE 5.6 1000 18–500 2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica-

tions, and optical fiber cables Thermoplastic elastomer with optional nylon 18–15 0.76

(0.51) 30

(20) Oil-resistant thermo-

plastic elastomer Extra-hard

usage - 14–10 1.14

(0.76) 45

(30) - 8–2 1.52

(1.14) 60

(45) - 1–4/0 2.03

(1.52) 80

(60) - 250–500 2.41

(1.90) 95

(75) - EVJE 5.6 300 18–12 18–12 0.76

(0.51) 30

(20) Hard usage - EVT 5.6 1000 18–500 2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica-

tions, and optical fiber cables Thermoplastic with optional nylon 18–15 0.76

(0.51) 30

(20) Optional Oil-resistant thermo-

plastic Electric vehicle charging Wet Locations Extra-hard usage - 14–10 1.14

(0.76) 45

(30) - - 8–2 1.52

(1.14) 60

(45) - - 1–4/0 2.03

(1.52) 80

(60) - - 250–500 2.41

(1.90) 95

(75) - - EVJT 5.6

300 18–12 18–12 0.76

(0.51) 30

(20) Hard usage Portable

power

cable G 2000 12–500 2–6 plus equipment grounding conductor(s) Thermoset 12–2

1–4/0 250–500 1.52

2.03

2.41 60

80

95 - Oil-resistant

thermoset Portable and extra-hard usage - G-GC 7 2000 12–500 3–6 plus equipment grounding conductors and 1 ground check conductor Thermoset 12–2

1–4/0

250–500 1.52

2.03

2.41 60

80

95 - Oil-resistant thermoset - Heater

cord HPD 300 18–12 2, 3, or 4 Thermoset 18–16

15–12 -0.38

0.76 -15

30 None Cotton or rayon Portable heaters Dry loca-

tions Not hard usage Parallel

heater

cord HPN [8] 300 18–12 2 or 3 Oil-resistant thermoset -18–16

15

14

12 -1.14

1.52

2.41 -45

60

95 None Oil-resistant thermoset Portable Damp locations Not hard usage Thermoset

jacketed

heater

cords HSJ 300 18–12 2, 3, or 4 Thermoset -18–16

15–12 -0.76

1.14 -30

45 None Cotton and thermoset Portable or portable heater Damp loca-

tions Hard usage HSJW 300 18–12 - Thermoset - - - - Cotton and thermoset - Damp loca-
tions HSJO 300 18–12 - - - - - - Cotton and oil-resistant thermoset - Damp and wet
locations - HSJOW [9] 300 18–12 - - - - - - - - Damp locations - HSJOO 300 18–12 - Oil-
resistant thermoset - - - - - - - HSJOOW [9] 300 18–12 - - - - - - - - Damp and wet
locations - Non-integral

parallel

cords NISP-1 300 20–18 2 or 3 Thermoset 20–18 -0.38 15 None Thermoset Pendant or
portable Damp loca-

tions Not hard usage NISP-2 300 18–16 18–16 0.76 30 NISPE-
1 [8] 300 20–18 Thermoplastic elastomer 20–18 0.38 15 Thermo-

plastic

elastomer NISPE-2 [8] 300 18–16 18–16 0.76 30 NISPT-1 [8] 300 20–18 Thermoplastic 20–18 0.38 15 Thermoplastic NISPT-2 [8] 300 18–16 18–16 0.76 30 Twisted portable cord PD 300 600 18–16 14–10 2 or more Thermoset or thermoplastic 18–16 15–10 0.76 1.14 30 45 Cotton Cotton or rayon Pendant or portable Dry locations Not hard-usage Portable power cable PPE [7] 2000 12–500 1–6 plus optional equipment grounding conductor(s) Thermoplastic elastomer 12–2 1–4/0 250–500 1.52 2.03 2.41 60 80 95 - Oil-resistant thermoplastic elastomer Portable, extra-hard-usage Hard service cord S [7] 600 18–2 2 or more Thermoset 18–15 14–10 8–2 0.76 1.14 1.52 30 45

60 None Thermoset Pendant or portable Damp loca-

tions Extra-hard usage Flexible

stage and lighting power cable SC 7,10 600 8–250 1 or more Thermoset 8–2

1–4/0

250 1.52

2.03

2.41 60

80

95 - Thermoset Portable, extra-hard usage - SCE 7,10 600 - - Thermoplastic elastomer - - - - Thermo-

plastic

elastomer - - SCT 7,10 600 - - Thermoplastic - - - - Thermo-

plastic - Hard service cord SE 7 600 18–2 2 or more Thermoplastic elastomer 18–15

14–9

8–2 0.76

1.14

1.52 30

45

60 None Thermo-

plastic

elastomer Pendant or portable Damp loca-

tions Extra-hard usage - SEW 7, 9 600 - - - - - - - - - Damp and wet locations - - SEO 7 600 - - - - - - - Oil-

resistant

thermo-

plastic

elastomer - Damp locations - - SEOW 7,9 600 - - - - - - - - - Damp and wet locations - - SEOO 7 600 - - Oil-resistant thermoplastic elastomer - - - - - - Damp locations - - SEOOW 7,9 600 - - - - - - - - Damp and wet locations - Junior hard

service cord SJ 300 18–10 2–6 Thermoset 18–11

10 0.76

1.14 30

45 None Thermoset Pendant or portable Damp loca-

tions Hard usage - SJE 300 - - Thermoplastic elastomer - - - - Thermo-

plastic elastomer - - - - SJEW [9] 300 - - - - - - - - - Damp and wet
locations - - SJEO 300 - - - - - - - Oil-

resistant

thermo-

plastic

elastomer - Damp locations - - SJEOW [9] 300 - - - - - - - - - Damp and wet
locations - - SJEOO 300 - - Oil-

resistant thermoplastic elastomer - - - - - - Damp
locations - - SJEOOW [9] 300 - - - - - - - - - Damp and wet
locations - - SJO 300 - - Thermoset - - - - Oil-

resistant

thermoset - Damp locations - - SJOW [9] 300 - - - - - - - - - Damp and wet
locations - - SJOO 300 - - Oil-resistant thermoset - - - - - - Damp
locations - - SJOOW [9] 300 - - - - - - - - - Damp and wet
locations - - SJT 300 - - Thermoplastic - - - - Thermo-

plastic - Damp locations - - SJTW [9] 300 - - - - - - - - - Damp and wet
locations - - SJTO 300 - - - 18–12

10 0.76

1.14 30

45 - Oil-resistant

thermo-

plastic - Damp locations - - SJTOW [9] 300 - - - - - - - - Damp and wet
locations - - SJTOO 300 - Oil-resistant thermoplastic - - - - - - Damp
locations - - SJTOOW [9] 300 - - - - - - - - - Damp and wet locations - Hard service
cord SO [7] 600 18–2 2 or more Thermoset 18–15 0.76 30 None Oil-resistant

thermoset Pendant or portable Damp loca-

tions Extra-hard usage - SOW [7,9] 600 - - - - - - - - - Damp and wet
locations - - SOO [7] 600 - - Oil-resistant

thermoset 14–9

8–2 1.14

1.52 45

60 - - - Damp locations - - SOOW 7,9 600 - - - - - - - - - Damp and wet locations - All thermoset parallel cord SP-1 300 20–18 2 or 3 Thermoset 20–18 0.76 30 None None Pendant or portable Damp locations Not hard usage - SP-2 300 18–16 - - 18–16 1.14 45 - - - - - - SP-3 300 18–10 - - 18–16

15–14

12

10 1.52

2.03

2.41

2.80 60

80

95

110 - - Refrigerators, room air conditioners, and as permitted in 422.16(B) - - All elastomer (thermoplastic) parallel cord SPE-1 8 300 20-18 2 or 3 Thermoplastic elastomer 20–18 0.76 30 None None Pendant or portable Damp locations Not hard usage - SPE-2 8 300 18–16 - - 18–16 1.14 45 - - - - - - SPE-3 8 300 18–10 - - 18–16

15–14

12

10 1.52

2.03

2.41

2.80 60

80

~~95~~

~~110 - - Refrigera-~~

~~tors, room air condi-~~

~~tioners, and as permitted in 422.16(B) - - All thermoplastic parallel cord SPT-1 300 20–18 2 or 3 Thermoplastic 20–18 0.76 30 None None Pendant or portable Damp loca-~~

~~tions Not hard usage - SPT-1W [9] 300 - 2 - - - - - - - Damp and wet locations - - SPT-2 300 18–16 2 or 3 - 18–16 1.14 45 - - - Damp locations - - SPT-2W [9] 300 - 2 - - - - Damp and wet locations - - SPT-3 300 18–10 2 or 3 18–16~~

~~15 14~~

~~12~~

~~10 1.52~~

~~2.03~~

~~2.41~~

~~2.80 60~~

~~80~~

~~95~~

~~110 Refrig-erators, room~~

~~air condi-~~

~~tioners, and as permitted in 422.16(B) Damp loca-~~

~~tions Not hard usage Range, dryer cable SRD 300 10–4 3 or 4 Thermoset 10–4 1.14 45 None Thermoset Portable Damp loca-~~

~~tions Ranges, dryers - SRDE 300 10–4 3 or 4 Thermoplastic elastomer - - - None Thermo-~~

~~plastic elastomer - - - - SRDT 300 10–4 3 or 4 Thermoplastic - - - None Thermo-~~

~~plastic - - - Hard service cord ST [7] 600 18–2 2 or more Thermoplastic 18–15~~

~~14–9~~

~~8–2 0.76~~

~~1.14~~

~~1.52 30~~

45

60 None Thermo-

plastic Pendant or portable Damp loca-

tions Extra-hard usage - STW [7,9] 600 - - - - - - - - - Damp and wet
locations - - STO [7] 600 - - - - - - - Oil-resistant

thermo-

plastic - Damp locations - - STOW [7, 9] 600 - - - - - - - - - Damp and wet
locations - - STOO [7] 600 - - Oil-resistant thermoplastic - - - - - - Damp
locations - - STOOW [7] 600 - - - - - - - - - Damp and wet
locations - Vacuum cleaner cord SV 300 18–16 2 or
3 Thermoset 18–16 0.38 15 None Thermoset Pendant or
portable Damp loca-

tions Not hard usage - SVE 300 - - Thermoplastic
elastomer - - - - Thermo-

plastic elastomer - - - - SVEO 300 - - - - - - - Oil-resistant

thermo-

plastic

elastomer - - - - SVEOO 300 - - Oil-resistant thermoplastic
elastomer - - - - - - - - - SVO 300 - - Thermoset - - - - Oil-resistant

thermoset - - - - SVOO 300 - - Oil-resistant thermoset - - - - Oil-resistant

thermoset - - - - SVT 300 - - Thermoplastic - - - - Thermoplastic - - - - SVTO 300 - - Thermoplastic - - - - Oil
resistant

thermo-

plastic - - - - SVTOO 300 - - Oil-resistant thermoplastic - - - - - - - - Parallel
tinsel cord TPT [11] 300 27 2 Thermoplastic 27 0.76 30 None Thermo-

plastic Attached to an appliance Damp loca-

tions Not hard usage Jacketed tinsel

cord TST [11] 300 27 2 Thermoplastic 27 0.38 15 None Thermo-

plastic Attached to an appliance Damp loca-

tions Not hard usage Portable power

cable W [7] 2000 12–500

501–1000 1–6

1 Thermoset 12–2

1–4/0

250–500

501–1000 1.52

2.03

2.41

2.80 60

80

95

110 - Oil-resistant

thermoset Portable, extra-hard usage

Notes:

All types listed in Table 400.4 shall have individual conductors twisted together, except for Types HPN, SP-1, SP-2, SP-3, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, SPT-1W, SPT-2W, TPT, NISP-1, NISP-2, NISPT-1, NISPT-2, NISPE-1, NISPE-2, and three-conductor parallel versions of SRD, SRDE, and SRDT.

The individual conductors of all cords, except those of heat-resistant cords, shall have a thermoset or thermoplastic insulation, except that the equipment grounding conductor, where used, shall be in accordance with 400.23(B).

1 Rubber-filled or varnished cambric tapes shall be permitted as a substitute for the inner braids.

2 Elevator traveling cables for operating control and signal circuits shall contain nonmetallic fillers as necessary to maintain concentricity. Cables shall have steel supporting members as required for suspension by 620.41. In locations subject to excessive moisture or corrosive vapors or gases, supporting members of other materials shall be permitted. Where steel supporting members are used, they shall run straight through the center of the cable assembly and shall not be cabled with the copper strands of any conductor.

In addition to conductors used for control and signaling circuits, Types E, EO, ETP, and ETT elevator cables shall be permitted to incorporate in the construction one or more 20 AWG telephone conductor pairs, one or more coaxial cables, or one or more optical fibers. The 20 AWG conductor pairs shall be permitted to be covered with suitable shielding for telephone, audio, or higher frequency communications circuits; the coaxial cables shall consist of a center conductor, insulation, and a shield for use in video or other radio frequency communications circuits. The optical fiber shall be suitably covered with flame-retardant thermoplastic. The insulation of the conductors shall be rubber or thermoplastic of a thickness not less than specified for the other conductors of the particular type of cable. Metallic shields shall have their own protective covering. Where used, these components shall be permitted to be incorporated in any layer of the cable assembly but shall not run straight through the center.

3 Insulations and outer coverings that meet the requirements as flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the *Code* -type designation.

4 Elevator cables in sizes 20 AWG through 14 AWG are rated 300 volts, and sizes 10 AWG through 2 AWG are rated 600 volts. 12 AWG is rated 300 volts with a 0.76 mm (30 mil) insulation

thickness and 600 volts with a 1.14 mm (45 mil) insulation thickness.

5 Conductor size for Types EV, EVJ, EVE, EVJE, EVT, and EVJT cables apply to nonpower-limited circuits only. Conductors of power-limited (data, signal, or communications) circuits may extend beyond the stated AWG size range. All conductors shall be insulated for the same cable voltage rating.

6 Insulation thickness for Types EV, EVJ, EVEJE, EVT, and EVJT cables of nylon construction is indicated in parentheses.

7 Types G, G-GC, S, SC, SCE, SCT, SE, SEO, SEOO, SEW, SEOW, SEOOW, SO, SOO, SOW, SOOW, ST, STO, STOO, STW, STOW, STOOW, PPE, and W shall be permitted for use on theater stages, in garages, and elsewhere where flexible cords are permitted by this *Code* .

8 The third conductor in Type HPN shall be used as an equipment grounding conductor only. The insulation of the equipment grounding conductor for Types SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, NISPT-1, NISPT-2, NISPE-1, and NISPE-2 shall be permitted to be thermoset polymer.

9 Cords that comply with the requirements for outdoor cords and are so listed shall be permitted to be designated as weather and water resistant with the suffix "W" after the *Code* type designation. Cords with the "W" suffix are suitable for use in wet locations and are sunlight resistant.

10 The required outer covering on some single-conductor cables may be integral with the insulation.

11 Types TPT and TST shall be permitted in lengths not exceeding 2.5 m (8 ft) where attached directly, or by means of a special type of plug, to a portable appliance rated at 50 watts or less and of such nature that extreme flexibility of the cord is essential.

400.5 Ampacities for Flexible Cords and Flexible Cables.

(A) Ampacity Tables.

Table 400.5(A)(1) provides the ampacities, and Table 400.5(A)(2) provides the ampacities for flexible cords and flexible cables with not more than three current-carrying conductors. These tables shall be used in conjunction with applicable end-use product standards to ensure selection of the proper size and type. Where cords and cables are used in ambient temperatures other than 30°C (86°F), the temperature correction factors from Table 310.15(B)(1) that correspond to the temperature rating of the cord or cable shall be applied to the ampacity in Table 400.5(A)(1) and Table 400.5(A)(2) . Cords and cables rated 105°C shall use correction factors in the 90°C column of Table 310.15(B)(1) for temperature correction. Where the number of current-carrying conductors exceeds three, the ampacity of each conductor shall be reduced from the three-conductor rating as shown in Table 400.5(A)(3) .

> Informational Note: See Informative Annex B, Table B.2(11) , for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Table 400.5(A)(1) Ampacity for Flexible Cords and Flexible Cables

[Based on Ambient Temperature of 30°C (86°F). See 400.13 and Table 400.4.]

Copper Conductor

Size

(AWG) - Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO, NISP-1, NISP-2 - Thermoplastic Types TPT, TST Thermoplastic Types ETP, ETT, NISPE-1, NISPE-2, NISPT-1, NISPT-2, SE, SEW, SEO, SEOO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2,

SPT-2W, SPT-3, ST, STW, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVEOO, SVT, SVTO, SVTOO Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW - - **Column A** [1] **Column B** [2] - - 27 [3] 0.5 — — — 20 — 5 [4] [5] — 18 — 7 10 10 17 — 9 12 13 16 — 10 13 15 15 — 12 16 17 14 — 15 18 20 13 — 17 21 — 12 — 20 25 30 11 — 23 27 — 10 — 25 30 35 9 — 29 34 — 8 — 35 40 — 7 — 40 47 — 6 — 45 55 — 5 — 52 62 — 4 — 60 70 — 3 — 70 82 — 2 — 80 95 —

[1] The currents under Column A apply to three-conductor cords and other multiconductor cords connected to utilization equipment so that only three-conductors are current-carrying.

[2] The currents under Column B apply to two-conductor cords and other multiconductor cords connected to utilization equipment so that only two conductors are current-carrying.

[3] Tinsel cord.

[4] Elevator cables only.

[5] 7 amperes for elevator cables only; 2 amperes for other types.

Table 400.5(A)(2) Ampacity of Cable Types SC, SCE, SCT, PPE, G, G-GC, and W

[Based on Ambient Temperature of 30°C (86°F). See Table 400.4.]

- Temperature Rating of Cable Copper Conductor

Size

(AWG or kcmil) 60°C (140°F) - 75°C (167°F) - 90°C (194°F) D [1] E [2] F [3] - D [1] E [2] F [3] - D [1] E [2] F [3] 12 — 31 26 - — 37 31 - — 42 35 10 — 44 37 - — 52 4
/0 225 199 174 - 265 238 208 - 300 271 237 3
/0 260 230 201 - 310 275 241 - 350 313 274 4
/0 300 265 232 - 360 317 277 - 405 361 316 250 340 296 259 - 405 354 310 - 455 402 352 300 375 330

[1] The ampacities under subheading D shall be permitted for single-conductor Types SC, SCE, SCT, PPE, and W cable only where the individual conductors are not installed in raceways and are not in physical contact with each other except in lengths not to exceed 600 mm (24 in.) where passing through the wall of an enclosure.

[2] The ampacities under subheading E apply to two-conductor cables and other multiconductor cables connected to utilization equipment so that only two conductors are current-carrying.

[3] The ampacities under subheading F apply to three-conductor cables and other multiconductor cables connected to utilization equipment so that only three conductors are current-carrying.

Table 400.5(A)(3) Adjustment Factors for More Than Three Current-Carrying Conductors in a Flexible Cord or Flexible Cable

Number of Conductors Percent of Value in

Table 400.5(A)(1) and

Table 400.5(A)
(2) 4–6 80 7–9 70 10–20 50 21–30 45 31–40 40 41 and above 35

A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to meet the requirements of a current-carrying conductor.

In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, a common conductor carries approximately the same current as the line-to-neutral currents of the other conductors and shall be considered to be a current-carrying conductor.

On a 4-wire, 3-phase, wye circuit where more than 50 percent of the load consists of nonlinear loads, there are harmonic currents present in the neutral conductor and the neutral conductor shall be considered to be a current-carrying conductor.

An equipment grounding conductor shall not be considered a current-carrying conductor.

Where a single conductor is used for both equipment grounding and to carry unbalanced current from other conductors, as provided for in 250.140 for electric ranges and electric clothes dryers, it shall not be considered as a current-carrying conductor.

(B) Ultimate Insulation Temperature.

In no case shall conductors be associated together in such a way with respect to the kind of circuit, the wiring method used, or the number of conductors such that the limiting temperature of the conductors is exceeded.

(C) Engineering Supervision.

Under engineering supervision, conductor ampacities shall be permitted to be calculated in accordance with 310.14(B) .

400.6 Markings.

(A) Standard Markings.

Flexible cords and flexible cables shall be marked by means of a printed tag attached to the coil reel or carton. The tag shall contain the information required in 310.8(A) . Types S, SC, SCE, SCT, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, STOO, SEW, SEOW, SEOOW, SJEW, SJEOW, SJEOOW, SJOW, SJTW, SJTOW, SJTOOW, SOW, SOOW, STW, STOW, and STOOW flexible cords and G, G-GC, PPE, and W flexible cables shall be durably marked on the surface at intervals not exceeding 610 mm (24 in.) with the type designation, size, and number of conductors. Required markings on tags, cords, and cables shall also include the maximum operating temperature of the flexible cord or flexible cable.

(B) Optional Markings.

Flexible cords and cable types listed in Table 400.4 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistance, and so forth.

400.10 Uses Permitted.

(A) Uses.

Flexible cords and flexible cables shall be used only for the following:

(1) Pendants.

(2) Wiring of luminaires.

(3) Connection of portable luminaires, portable and mobile signs, or appliances.

(4) Elevator cables.

(5) Wiring of cranes and hoists.

(6) Connection of utilization equipment to facilitate frequent interchange.

(7) Prevention of the transmission of noise or vibration.

(8) Appliances where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance and repair, and the appliance is intended or identified for flexible cord connection.

(9) Connection of moving parts.

(10) Where specifically permitted elsewhere in this *Code* .

(11) Between an existing receptacle outlet and an inlet, where the inlet provides power to an additional single receptacle outlet. The wiring interconnecting the inlet to the single receptacle outlet shall be a Chapter 3 wiring method. The inlet, receptacle outlet, and Chapter 3 wiring method, including the flexible cord and fittings, shall be a listed assembly specific for this application.

(B) Attachment Plugs.

Where used as permitted in 400.10(A)(3) , (A)(6), and (A)(8), each flexible cord shall be equipped with an attachment plug and shall be energized from a receptacle outlet or cord connector body.

Exception: *As permitted in 368.56* .

400.12 Uses Not Permitted.

Unless specifically permitted in 400.10 , flexible cords, flexible cables, cord sets, and power supply cords shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

Exception to (4): Flexible cord and flexible cable shall be permitted to be attached to building surfaces in accordance with 368.56(B) and 590.4 .

(5) Where concealed by walls, floors, or ceilings or located above suspended or dropped ceilings

Exception to (5): Flexible cords, flexible cables, and power supply cords shall be permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by 300.22(C)(3) .

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: For proper application see UL 817, *Cord Sets and Power-Supply Cords* , and UL 62, *Flexible Cords and Cables* .

400.13 Splices.

Flexible cord shall be used only in continuous lengths without splice or tap where initially installed in applications permitted by 400.10(A) . The repair of hard-service cord and junior hard-service cord (see Trade Name column in Table 400.4) 14 AWG and larger shall be permitted if conductors are spliced in accordance with 110.14(B) and the completed splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.

400.14 Pull at Joints and Terminals.

Flexible cords and flexible cables shall be connected to devices and to fittings so that tension is not transmitted to joints or terminals.

Exception: Listed portable single-pole devices that are intended to accommodate such tension at their terminals shall be permitted to be used with single-conductor flexible cable.

Informational Note: Some methods of preventing pull on a cord from being transmitted to joints or terminals include knotting the cord, winding with tape, and using support or strain-relief fittings.

400.15 In Show Windows and Showcases.

Flexible cords used in show windows and showcases shall be Types S, SE, SEO, SEOO, SJ, SJE, SJEO, SJEOO, SJO, SJOO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, STOO, SEW, SEOW, SEOOW, SJEW, SJEOW, SJEOOW, SJOW, SJOOW, SJTW, SJTOW, SJTOOW, SOW, SOOW, STW, STOW, or STOOW.

Exception No. 1: For the wiring of chain-supported luminaires.

Exception No. 2: As supply cords for portable luminaires and other merchandise being displayed or exhibited.

400.16 Overcurrent Protection.

Flexible cords not smaller than 18 AWG, and tinsel cords or cords having equivalent characteristics of smaller size approved for use with specific appliances, shall be considered as protected against overcurrent in accordance with 240.5 .

400.17 Protection from Damage.

Flexible cords and flexible cables shall be protected by bushings or fittings where passing through holes in covers, outlet boxes, or similar enclosures.

In industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation, flexible cords and flexible cables shall be permitted to be installed in aboveground raceways that are no longer than 15 m (50 ft) to protect the flexible cord or flexible cable from physical damage. Where more than three current-carrying conductors are installed within the raceway, the ampacity shall be adjusted in accordance with Table 400.5(A)(3) .

Part II. Construction Specifications

400.20 Labels.

Flexible cords shall be examined and tested at the factory and labeled before shipment.

400.21 Construction.

(A) Conductors.

The individual conductors of a flexible cord or flexible cable shall have copper flexible stranding and shall not be smaller than the sizes specified in Table 400.4 .

(B) Nominal Insulation Thickness.

The nominal thickness of insulation for conductors of flexible cords and flexible cables shall not be less than specified in Table 400.4 .

400.22 Grounded-Conductor Identification.

One conductor of flexible cords that is intended to be used as a grounded circuit conductor shall have a continuous marker that readily distinguishes it from the other conductor or conductors. The identification shall consist of one of the methods indicated in 400.22(A) through (F).

(A) Colored Braid.

A braid finished to show a white or gray color and the braid on the other conductor or conductors finished to show a readily distinguishable solid color or colors.

(B) Tracer in Braid.

A tracer in a braid of any color contrasting with that of the braid and no tracer in the braid of the other conductor or conductors. No tracer shall be used in the braid of any conductor of a flexible cord that contains a conductor having a braid finished to show white or gray.

Exception: *In the case of Types C and PD and cords having the braids on the individual conductors finished to show white or gray. In such cords, the identifying marker shall be permitted to consist of the solid white or gray finish on one conductor, provided there is a colored tracer in the braid of each other conductor.*

(C) Colored Insulation.

A white or gray insulation on one conductor and insulation of a readily distinguishable color or colors on the other conductor or conductors for cords having no braids on the individual conductors.

For jacketed cords furnished with appliances, one conductor having its insulation colored light blue, with the other conductors having their insulation of a readily distinguishable color other than white or gray.

Exception: *Cords that have insulation on the individual conductors integral with the jacket.*

The insulation shall be permitted to be covered with an outer finish to provide the desired color.

(D) Colored Separator.

A white or gray separator on one conductor and a separator of a readily distinguishable solid color on the other conductor or conductors of cords having insulation on the individual conductors integral with the jacket.

(E) Tinned Conductors.

One conductor having the individual strands tinned and the other conductor or conductors having the individual strands untinned for cords having insulation on the individual conductors integral with the jacket.

(F) Surface Marking.

One or more ridges, grooves, or white stripes located on the exterior of the cord so as to identify one conductor for cords having insulation on the individual conductors integral with the jacket.

400.23 Equipment Grounding Conductor Identification.

A conductor intended to be used as an equipment grounding conductor shall have a continuous identifying marker readily distinguishing it from the other conductor or conductors. Conductors having a continuous green color or a continuous green color with one or more yellow stripes shall not be used for other than equipment grounding conductors. Cords or cables consisting of integral insulation and a jacket without a nonintegral equipment grounding conductor shall be permitted to be green. The identifying marker shall consist of one of the methods in 400.23(A) or (B).

(A) Colored Braid.

A braid finished to show a continuous green color or a continuous green color with one or more yellow stripes.

(B) Colored Insulation or Covering.

For cords having no braids on the individual conductors, an insulation of a continuous green color or a continuous green color with one or more yellow stripes.

400.24 Attachment Plugs.

Where a flexible cord is provided with an equipment grounding conductor and equipped with an attachment plug, the attachment plug shall comply with 250.138(A) and (B).

Part III. Portable Cables Over 600 Volts, Nominal

400.30 Scope.

Part III applies to single and multiconductor portable cables used to connect mobile equipment and machinery.

400.31 Construction.

(A) Conductors.

The conductors shall be 12 AWG copper or larger and shall employ flexible stranding.

(B) Equipment Grounding Conductor(s).

An equipment grounding conductor(s) shall be provided in cables with three or more conductors. The total area shall not be less than that of the size of the equipment grounding conductor required in 250.122 .

400.32 Shielding.

All shields shall be connected to an equipment grounding conductor.

400.33 Equipment Grounding Conductors.

Equipment grounding conductors shall be connected in accordance with Parts VI and VII of Article 250.

~~**400.34** Minimum Bending Radii.~~

~~The minimum bending radii for portable cables during installation and handling in service shall be adequate to prevent damage to the cable.~~

~~**400.35** Fittings.~~

~~Connectors used to connect lengths of cable in a run shall be of a type that locks firmly together. Provisions shall be made to prevent opening or closing these connectors while energized. Suitable means shall be used to eliminate tension at connectors and terminations.~~

~~**400.36** Splices and Terminations.~~

~~Portable cables shall not contain splices unless the splices are of the permanent molded, vulcanized types in accordance with 110.14(B) . Terminations on portable cables rated over 600 volts, nominal, shall be accessible only to authorized and qualified personnel.~~

Statement of Problem and Substantiation for Public Input

Last code cycle the CMP state designers and installers are to dumb and would use this wiring method to wire houses. come on lets get real this flexible cord and calbe is a wiring method that is allowed to be permanently installed in various Article such as 410 and 525, we get it!! Flexible cord the worst wiring method available and has numerous limitations. however it is a wiring method and does not belong in chapter 4 as a piece of equipment. time to move forward and recognize this flexible cord for what it is.. a wiring method and let the article with all its restrictions speak for itself.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 906-NFPA 70-2020 [New Section after 314.72(F)]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
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Submittal Date: Sun Apr 26 10:51:39 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: There was no technical substantiation submitted that justifies the proposed changes for moving this to Chapter 3 for fixed wiring methods. Flexible cords and flexible cables are appropriately located in Chapter 4.

Public Input No. 1228-NFPA 70-2020 [New Section after 400.2]

Definitions

Add definitions to Article 400 or add additional definitions to Article 100 to cover terms that are used throughout Article 400. For example, define what is a “flexible cord”, a “flexible cable”, “flexible cord sets”, “power supply cords”, etc.

Statement of Problem and Substantiation for Public Input

A number of terms used in Article 400 are nuanced; lacking definition creates opportunity for confusion and misapplication. The NEC has improved significantly in large part due to improved clarity, formatting and readability. This change will continue the trend of making the NEC an easier to document for inspectors, installers and others.

Submitter Information Verification

Submitter Full Name: Gary Hein
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State:
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Submittal Date: Sat May 23 11:37:43 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8543-NFPA 70-2021
Statement: These terms are used throughout the code necessitating the need for definitions.

Public Input No. 3040-NFPA 70-2020 [Section No. 400.4]

400.4 Types.

Flexible cords and flexible cables shall conform to the description in Table 400.4. The use of flexible cords and flexible cables other than those in Table 400.4 shall require permission by the authority having jurisdiction.

Table 400.4 Flexible Cords and Flexible Cables

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
Lamp cord	C	300 600	18–16 15–10	2 or more	Thermoset or thermoplastic	18–16 15–10	0.7 1.1
Elevator cable	E 1,2,3,4	300 or 600	20–2	2 or more	Thermoset	~~20–16~~ 26–16 15–12 12–10 8–2	0.5 0.7 1.1 1.5
Elevator cable	EO 1,2,4	300 or 600	20–2	2 or more	Thermoset	~~20–16~~ 26–16 15–12 12–10 8–2	0.5 0.7 1.1 1.5

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
Elevator cable	ETP [2,4]	300 or 600	-	-	-	-	-
	-	ETT [2,4]	300 or 600	-	-	-	-
Electric vehicle cable	EV [5,6]	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	Thermoset with optional nylon	18–15	0.7 (0.5
						14–10	1.1 (0.7
						8–2	1.5 (1.1
						1–4/0	2.0 (1.5
						250–500	2.4 (1.9
	EVJ [5,6]	300	18–12			18–12	0.7 (0.5
	-	EVE [5,6]	1000	18–500	2 or more plus equipment	Thermoplastic elastomer with optional	18–

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
					grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	nylon	14–1
							8–2
							1–4/
							250–
		EVJE [5,6]	300	18–12			18–1
		EVT [5,6]	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	Thermoplastic with optional nylon	18–1
							14–1
							8–2
							1–4/
							250–
		EVJT [5,6]	300	18–12			18–1
Portable power	G	2000	12–500	2–6 plus equipment grounding conductor(s)	Thermoset	12–2 1–4/0 250–500	1.5 2.0

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
cable							2.4
	-	G-GC[7]	2000	12–500	3–6 plus equipment grounding conductors and 1 ground check conductor	Thermoset	12– 1–4/ 250–5
Heater cord	HPD	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.3 0.7
Parallel heater cord	HPN[8]	300	18–12	2 or 3	Oil-resistant thermoset	18–16 15 14 12	1.1 1.5 2.4
Thermoset jacketed heater cords	HSJ	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.7 1.1
	HSJW	300	18–12	-		Thermoset	-
	HSJO	300	18–12	-	-	-	-
	HSJOW[9]	300	18–12	-	-	-	-
	HSJOO	300	18–12	-		Oil-resistant thermoset	-
	HSJOOW [9]	300	18–12	-	-	-	-

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
Non-integral parallel cords	NISP-1	300	20–18	2 or 3	Thermoset	20–18	0.3
	NISP-2	300	18–16			18–16	0.7
	NISPE-1[8]	300	20–18		Thermoplastic elastomer	20–18	0.3
	NISPE-2[8]	300	18–16			18–16	0.7
	NISPT-1[8]	300	20–18		Thermoplastic	20–18	0.3
	NISPT-2[8]	300	18–16			18–16	0.7
Twisted portable cord	PD	300	18–16	2 or more	Thermoset or thermoplastic	18–16	0.7
		600	14–10			15–10	1.1
Portable power cable	PPE[7]	2000	12–500	1–6 plus optional equipment grounding conductor(s)	Thermoplastic elastomer	12–2	1.5
						1–4/0	2.0
						250–500	2.4
Hard service cord	S[7]	600	18–2	2 or more	Thermoset	18–15	0.7
						14–10	1.1
						8–2	1.5
Flexible stage and lighting power cable	SC[7,10]	600	8–250	1 or more	Thermoset	8–2	1.5
						1–4/0	2.0
						250	2.4
	-	SCE[7,10]	600	-	-		

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
	SCT[7,10]	600	-	-			Thermop
Hard service cord	SE[7]	600	18–2	2 or more	Thermoplastic elastomer	18–15 14–9 8–2	0.7 1.1 1.5
	-	SEW[7, 9]	600	-	-	-	-
	-	SEO[7]	600	-	-	-	-
	-	SEOW[7,9]	600	-	-	-	-
	SEOO[7]	600	-	-			Oil-resis thermop elastom
	SEOOW[7,9]	600	-	-	-	-	
Junior hard service cord	SJ	300	18–10	2–6	Thermoset	18–11 10	0.7 1.1
	-	SJE	300	-	-		
	SJEW[9]	300	-	-	-	-	-

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mn
	-	SJEO	300	-	-	-	-
	SJEOW[9]	300	-	-	-	-	-
	SJEOO	300	-	-			Oil- resistant thermop elastom
	SJEOOW[9]	300	-	-	-	-	-
	-	SJO	300	-	-		
	SJOW[9]	300	-	-	-	-	-
	SJOO	300	-	-			Oil-resis thermos
	SJOOW[9]	300	-	-	-	-	-
	SJT	300	-	-			Thermop
	SJTW[9]	300	-	-	-	-	-

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
	-	SJTO	300		-	-	
	-	SJTOW[9]	300		-	-	
	SJTOO	300	-			Oil-resistant thermoplastic	
	SJTOOW[9]	300	-	-	-	-	-
Hard service cord	SO[7]	600	18–2	2 or more	Thermoset	18–15	0.7
	-	SOW[7,9]	600	-	-	-	-
	-	SOO[7]	600	-	-		
	-	SOOW[7,9]	600	-	-	-	-
All thermoset parallel cord	SP-1	300	20–18	2 or 3	Thermoset	20–18	0.7
	-	SP-2	300	18–16	-	-	

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
	-	SP-3	300	18–10	-	-	
All elastomer (thermo-plastic) parallel cord	SPE-1[8]	300	20-18	2 or 3	Thermoplastic elastomer	20–18	0.7(
	-	SPE-2[8]	300	18–16	-	-	
	-	SPE-3[8]	300	18–10	-	-	
All thermoplastic parallel cord	SPT-1	300	20–18	2 or 3	Thermoplastic	20–18	0.7(
	-	SPT-1W[9]	300	-		2	-
	-	SPT-2	300	18–16	2 or 3		
	-	SPT-2W[9]	300	-		-	

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
	-	SPT-3	300	18–10	2 or 3		
Range, dryer cable	SRD	300	10–4	3 or 4	Thermoset	10–4	1.1
	-	SRDE	300	10–4	3 or 4	Thermoplastic elastomer	-
	SRDT	300	10–4	3 or 4	Thermoplastic	-	-
Hard service cord	ST[7]	600	18–2	2 or more	Thermoplastic	18–15 14–9 8–2	0.7 1.1 1.5
	-	STW[7,9]	600	-	-	-	-
	STO[7]	600	-	-	-	-	-
	STOW[7, 9]	600	-	-	-	-	-

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mn
	STOO[7]	600	-	-			Oil-resis thermop
	STOOW[7]	600	-	-	-	-	-
Vacuum cleaner cord	SV	300	18–16	2 or 3	Thermoset	18–16	0.3
	-	SVE	300	-	-		
	SVEO	300	-	-	-	-	-
	-	SVEOO	300	-	-		
	SVO	300	-	-			Thermos
	SVOO	300	-	-			Oil-resis thermos
	SVT	300	-	-			Thermop
	SVTO	300	-	-			Thermop
	SVTOO	300	-	-			Oil-resis thermop

Trade Name	Type Letter	Voltage	AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm
Parallel tinsel cord	TPT[11]	300	27	2	Thermoplastic	27	0.7
Jacketed tinsel cord	TST[11]	300	27	2	Thermoplastic	27	0.3
Portable power cable	W[7]	2000	12–500 501–1000	1–6 1	Thermoset	12–2 1–4/0 250–500 501–1000	1.5 2.0 2.4 2.8

Notes:

All types listed in Table 400.4 shall have individual conductors twisted together, except for Types HPN, SP-1, SP-2, SP-3, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, SPT-1W, SPT-2W, TPT, NISP-1, NISP-2, NISPT-1, NISPT-2, NISPE-1, NISPE-2, and three-conductor parallel versions of SRD, SRDE, and SRDT.

The individual conductors of all cords, except those of heat-resistant cords, shall have a thermoset or thermoplastic insulation, except that the equipment grounding conductor, where used, shall be in accordance with 400.23(B).

[1]Rubber-filled or varnished cambric tapes shall be permitted as a substitute for the inner braids.

[2]Elevator traveling cables for operating control and signal circuits shall contain nonmetallic fillers as necessary to maintain concentricity. Cables shall have steel supporting members as required for suspension by 620.41. In locations subject to excessive moisture or corrosive vapors or gases, supporting members of other materials shall be permitted. Where steel supporting members are used, they shall run straight through the center of the cable assembly and shall not be cabled with the copper strands of any conductor.

In addition to conductors used for control and signaling circuits, Types E, EO, ETP, and ETT elevator cables shall be permitted to incorporate in the construction one or more 20 AWG telephone conductor pairs, one or more coaxial cables, one or more optical fibers, or one or more ~~optical fibers~~ Ethernet cables . The 20 AWG conductor pairs shall be permitted to be covered with suitable shielding for telephone, audio, data transfer, or higher frequency communications circuits; the coaxial cables shall consist of a center conductor, insulation, and a shield for use in video or other radio frequency communications circuits. The optical fiber shall be suitably covered with flame-retardant thermoplastic. The insulation of the conductors shall be rubber or thermoplastic of a thickness not less than specified for the other conductors of the

particular type of cable. Metallic shields shall have their own protective covering. Where used, these components shall be permitted to be incorporated in any layer of the cable assembly but shall not run straight through the center.

[3]Insulations and outer coverings that meet the requirements as flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the *Code* type designation.

[4]Elevator cables in sizes 20 AWG through 14 AWG are rated 300 volts, and sizes 10 AWG through 2 AWG are rated 600 volts. 12 AWG is rated 300 volts with a 0.76 mm (30 mil) insulation thickness and 600 volts with a 1.14 mm (45 mil) insulation thickness.

[5]Conductor size for Types EV, EVJ, EVE, EVJE, EVT, and EVJT cables apply to nonpower-limited circuits only. Conductors of power-limited (data, signal, or communications) circuits may extend beyond the stated AWG size range. All conductors shall be insulated for the same cable voltage rating.

[6]Insulation thickness for Types EV, EVJ, EVEJE, EVT, and EVJT cables of nylon construction is indicated in parentheses.

[7]Types G, G-GC, S, SC, SCE, SCT, SE, SEO, SEOO, SEW, SEOW, SEOOW, SO, SOO, SOW, SOOW, ST, STO, STOO, STW, STOW, STOOW, PPE, and W shall be permitted for use on theater stages, in garages, and elsewhere where flexible cords are permitted by this *Code*.

[8]The third conductor in Type HPN shall be used as an equipment grounding conductor only. The insulation of the equipment grounding conductor for Types SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, NISPT-1, NISPT-2, NISPE-1, and NISPE-2 shall be permitted to be thermoset polymer.

[9]Cords that comply with the requirements for outdoor cords and are so listed shall be permitted to be designated as weather and water resistant with the suffix “W” after the *Code* type designation. Cords with the “W” suffix are suitable for use in wet locations and are sunlight resistant.

[10]The required outer covering on some single-conductor cables may be integral with the insulation.

[11]Types TPT and TST shall be permitted in lengths not exceeding 2.5 m (8 ft) where attached directly, or by means of a special type of plug, to a portable appliance rated at 50 watts or less and of such nature that extreme flexibility of the cord is essential.

Statement of Problem and Substantiation for Public Input

To allow for Ethernet cables to be included in elevator traveling cables. Requirements for Ethernet communications to elevator cars are becoming commonplace.
In addition, Ethernet in elevator travel cables are needed in order to provide the bandwidth needed to comply with the two-way video requirements specified in the IBC-2018 and ASME A17.1-2019

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3041-NFPA 70-2020 [Section No. 620.12(A)(2)]	
Public Input No. 3043-NFPA 70-2020 [Section No. 620.36]	

Submitter Information Verification

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Committee: NEC-P06

Committee Statement

Resolution: FR-8612-NFPA 70-2021
Statement: This change is found in the notes of the table. To address the need for data transfer in elevator installations an allowance for communications cable was added and the term data transfer was added to the note below the table.

Public Input No. 655-NFPA 70-2020 [Section No. 400.4]

400. 4–21 Types.

Flexible cords and flexible cables shall conform to the description in Table 400.4 21 . The use of flexible cords and flexible cables other than those in Table 400.4 21 shall require permission by the authority having jurisdiction.

Table 400.4 ~~Flexible~~ 21 Flexible Cords and Flexible Cables Construction and Application

Trade Name											
						Nominal Insulation Thickness					
Type Letter	Voltage	Use			AWG or kcmil	Number of Conductors	Insulation	AWG or kcmil	mm	mi	
Lamp cord	C	300 600	18–16 15–10	2 or more	Thermoset or thermoplastic	18–16 15–10	0.76 1.14	30 45	Cotton	None	
Elevator cable	E 1,2,3,4	300 or 600	20–2	2 or more	Thermoset	20–16 15–12 12–10 8–2	0.51 0.76 1.14 1.52	20 30 45 60	Cotton	Three cotton outer one flame retard and moist resist	
			20–16 15–12				0.51 0.76	20 30	Flexible nylon jacket		

						12–10	1.14	45					
						8–2	1.52	60					
Elevator cable	EO 1,2,4	300 or 600	20–2	2 or more	Thermoset	20–16	0.51	20	Cotton	Three cotton; outer one flame-retardant and moisture-resistant	Elevator lighting and control	Unclassified locations	
						15–12	0.76	30					
						12–10	1.14	45					
						8–2	1.52	60					
					One cotton and a neoprene jacket								
					Hazardous (classified) locations								
Elevator cable					ETP 2,4							300 or 600	
					ETT 2,4							300 or 600	
					Rayon	Thermo-plastic	Hazardous (classified) locations						
					None	One cotton or equivalent and a thermo-plastic jacket							
Electric vehicle	EV 5,6	1000	18–500	2 or more plus equipment grounding	Thermoset with optional nylon	18–15	0.76 (0.51)	30 (20)	Optional	Oil-resistant thermoset		Elec vehi char	

cable				conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables		14–10	1.14 (0.76)	45 (30)		
						8–2	1.52 (1.14)	60 (45)		
						1–4/0	2.03 (1.52)	80 (60)		
						250–500	2.41 (1.90)	95 (75)		
	EVJ 5,6	300	18–12			18–12	0.76 (0.51)	30 (20)		
EVE 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	Thermoplastic elastomer with optional nylon		18–15	0.76 (0.51)	30 (20)	Oil-resistant thermo- plastic elastomer	Extra-hard usage
						14–10	1.14 (0.76)	45 (30)		
						8–2	1.52 (1.14)	60 (45)		
						1–4/0	2.03 (1.52)	80 (60)		
						250– 500	2.41	95		

						(1.90)		(75)			
EVJE	5,6	300	18–12	18–12	0.76 (0.51)	30 (20)	Hard usage				
EVT 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica- tions, and optical fiber cables	Thermoplastic with optional nylon	18–15	0.76 (0.51)	30 (20)	Optional	Oil-resistant thermo- plastic	Electric vehicle charging	We Lo
					14–10	1.14 (0.76)	45 (30)				
					8–2	1.52 (1.14)	60 (45)				
					1–4/0	2.03 (1.52)	80 (60)				
					250– 500	2.41 (1.90)	95 (75)				
	EVJT 5,6	300	18–12	18–12	0.76 (0.51)	30 (20)	Hard usage				
Portable power	G	2000	12–500	2–6 plus equipment grounding conductor(s)	Thermoset	12–2 1–4/0	1.52 2.03	60 80			

cable							250–500	2.41	95		

Oil-resistant thermoset	Portable and extra-hard usage

G-GC [7]	2000	12–500	3–6 plus equipment grounding conductors and 1 ground check conductor	Thermoset	12–2 1–4/0 250–500	1.52 2.03 2.41	60 80 95	

Oil-resistant thermoset

Heater cord	HPD	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.38 0.76	15 30	None	Cotton or rayon	Portable heaters	Dry loca- tions
Parallel heater cord	HPN [8]	300	18–12	2 or 3	Oil-resistant thermoset	18–16 15 14 12	1.14 1.52 2.41	45 60 95	None	Oil-resistant thermoset	Portable	Damp locations
Thermoset jacketed heater cords	HSJ	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.76 1.14	30 45	None	Cotton and thermoset	Portable or portable heater	Damp loca- tions
	HSJW	300	18–12									

Thermoset

Cotton and thermoset

HSJO	Damp loca- tions 300	18–12

	Cotton and oil-resistant thermoset								
	Damp and wet locations								
	HSJOW [9]	300	18–12						
	Damp locations								
	HSJOO	300	18–12						
	Oil-resistant thermoset								
	HSJOOW [9]	300	18–12						
	Damp and wet locations								
Non-integral parallel cords	NISP-1	300	20–18	2 or 3	Thermoset	20–18	0.38	15	None	Thermos
	NISP-2	300	18–16			18–16	0.76	30		
	NISPE-1 [8]	300	20–18		Thermoplastic elastomer	20–18	0.38	15		Thermo-plastic elastome
	NISPE-2 [8]	300	18–16			18–16	0.76	30		
	NISPT-1 [8]	300	20–18		Thermoplastic	20–18	0.38	15		Thermo-plastic
	NISPT-2 [8]	300	18–16			18–16	0.76	30		
Twisted portable cord	PD	300 600	18–16 14–10	2 or more	Thermoset or thermoplastic	18–16 15–10	0.76 1.14	30 45	Cotton	Cotton o rayon
Portable power cable	PPE [7]	2000	12–500	1–6 plus optional equipment grounding conductor(s)	Thermoplastic elastomer	12–2 1–4/0 250–500	1.52 2.03 2.41	60 80 95		
	Oil-resistant thermo-	Portable, extra-hard usage								

	plastic elastomer											
Hard service cord	S [7]	600	18–2	2 or more	Thermoset	18–15 14–10 8–2	0.76 1.14 1.52	30 45 60	None	Thermoset	Pendant or portable	Damp loca-tions
Flexible stage and lighting power cable	SC [7,10]	600	8–250	1 or more	Thermoset	8–2 1–4/0 250	1.52 2.03 2.41	60 80 95				
-												
Thermoset	Portable, extra-hard usage											
-												
SCE [7,10]	600											
- -												
Thermoplastic elastomer												
- - - -												
Thermo-plastic elastomer												
- -												
SCT [7,10]	600											
- -												
Thermoplastic												
- - - -												
Thermo-plastic												
-												

Hard service cord	SE [7]	600	18–2	2 or more	Thermoplastic elastomer	18–15 14–9 8–2	0.76 1.14 1.52	30 45 60	None	Thermo- plastic elastomer	Pendant or portable	Damp loca- tions	Extra hard usag
SEW [7, 9]	600											
Damp and wet locations												
SEO [7]	600											
Oil- resistant thermo- plastic elastomer												
Damp locations												
SEOW [7,9]	600											
Damp and wet locations												
SEOO [7]	600											
Oil-resistant thermoplastic elastomer												
Damp locations												
SEOOW [7,9]	600											
Damp and wet locations												

Junior hard service cord	SJ	300	18–10	2–6	Thermoset	18–11 10	0.76 1.14	30 45	None	Thermoset	Pendant or portable	Damp loca- tions	Hard usage
SJE													300
Thermoplastic elastomer													
Thermo- plastic elastomer													
SJEW [9]													300
Damp and wet locations													
SJEO													300
Oil- resistant thermo- plastic elastomer													
Damp locations													
SJEOW [9]													300
Damp and wet locations													
SJEOO													300
Oil-													

resistant thermoplastic elastomer	
Damp locations	
SJEOOW [9]	300
Damp and wet locations	
SJO	300
Thermoset	
Oil-resistant thermoset	
Damp locations	
SJOW [9]	300
Damp and wet locations	
SJOO	300
Oil-resistant thermoset	
Damp locations	
SJOOW [9]	300
Damp and wet locations	
SJT	300
Thermoplastic	
Thermo-	

				plastic									
	Damp locations												
SJTW [9]					300								
	Damp and wet locations												
	SJTO				300								
		18–12			0.76			30					
		10			1.14			45					
	Oil-resistant thermo-plastic												
	Damp locations												
SJTOW [9]					300								
	Damp and wet locations												
	SJTOO				300								
	Oil-resistant thermoplastic												
	Damp locations												
SJTOOW [9]					300								
	Damp and wet locations												
Hard service cord	SO [7]	600	18–2	2 or more	Thermoset	18–15	0.76	30	None	Oil-resistant	Pendant or portable	Damp loca-	Extra-hard usage

											thermoset		tions

SOW 7,9		600
Damp and wet locations		
SOO 7		600
Oil-resistant	14–9	1.14	45
thermoset	8–2	1.52	60
Damp locations			
SOOW 7,9		600
Damp and wet locations			

All thermoset parallel cord	SP-1	300	20–18	2 or 3	Thermoset	20–18	0.76	30	None	None	Pendant or portable	Damp loca- tions	Not hard usage

SP-2	300	18–16
18–16	1.14	45
SP-3	300	18–10
18–16	1.52	60
15–14	2.03	80
12	2.41	95
10	2.80	110
Refrigera-		

tors, room air condi- tioners, and as permitted in 422.16(B)													
All elastomer (thermo- plastic) parallel cord	SPE-1 [8]	300	20-18	2 or 3	Thermoplastic elastomer	20–18	0.76	30	None	None	Pendant or portable	Damp loca- tions	Not hard usag
SPE-2 [8]		300		18–16									
		18–16		1.14			45						
SPE-3 [8]		300		18–10									
		18–16		1.52			60						
		15–14		2.03			80						
		12		2.41			95						
		10		2.80			110						
Refrigera- tors, room air condi- tioners, and as permitted in 422.16(B)													
All thermoplastic parallel cord	SPT-1	300	20–18	2 or 3	Thermoplastic	20–18	0.76	30	None	None	Pendant or portable	Damp loca- tions	Not har usa
SPT-1W [9]		300											
		2											

								Damp and wet locations			
SPT-2	300	18–16	2 or 3	18–16	1.14	45					
							Damp locations				
SPT-2W [9]	300	2									
							Damp and wet locations				
SPT-3	300	18–16 15–14 12 10	2 or 3	18–16 15–14 12 10	1.52 2.03 2.41 2.80	60 80 95 110	Refrig-erators, room air condi-tioners, and as permitted in 422.16(B)	Damp loca-tions	Not hard usage		
Range, dryer cable	SRD	300	10–4	3 or 4	Thermoset	10–4	1.14	45	None	Thermoset	Portable	D lo tic
SRDE	300	10–4	3 or 4	Thermoplastic elastomer							
							None	Thermo-plastic elastomer			
SRDT	300	10–4	3 or 4	Thermoplastic							
							None	Thermo-plastic			

Hard service cord	ST [7]	600	18–2	2 or more	Thermoplastic	18–15 14–9 8–2	0.76 1.14 1.52	30 45 60	None	Thermo-plastic	Pendant or portable	Damp loca-tions	Extra-hard usage
	STW [7,9]	600											
	Damp and wet locations												
	STO [7]	600											
	Oil-resistant thermo-plastic												
	Damp locations												
	STOW [7, 9]	600											
	Damp and wet locations												
	STOO [7]	600											
	Oil-resistant thermoplastic												
	Damp locations												
	STOOW [7]	600											
	Damp and wet locations												
Vacuum cleaner cord	SV	300	18–16	2 or 3	Thermoset	18–16	0.38	15	None	Thermoset	Pendant or portable	Damp loca-tions	Not hard usage

SVE	300

Thermoplastic elastomer

Thermo-

plastic elastomer

SVEO	300

Oil-resistant

thermo-

plastic

elastomer

SVEOO	300

Oil-resistant thermoplastic elastomer

SVO	300

Thermoset

Oil-resistant

thermoset

SVOO	300

Oil-resistant thermoset

Oil-resistant

thermoset

SVT	300

--

	Thermoplastic

				Thermoplastic

SVTO	300

--

	Thermoplastic

				Oil-resistant thermo-plastic

SVTOO	300

--

	Oil-resistant thermoplastic

Parallel tinsel cord	TPT [11]	300	27	2	Thermoplastic	27	0.76	30	None	Thermo-plastic	Attache to an applianc
Jacketed tinsel cord	TST [11]	300	27	2	Thermoplastic	27	0.38	15	None	Thermo-plastic	Attache to an applianc
Portable power cable	W [7]	2000	12–500 501–1000	1–6 1	Thermoset	12–2 1–4/0 250–500 501–1000	1.52 2.03 2.41 2.80	60 80 95 110			

-

Oil-resistant thermoset	Portable, extra-hard usage

Notes:

All types listed in Table 400.4 shall have individual conductors twisted together, except for Types HPN, SP-1, SP-2, SP-3, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, SPT-1W, SPT-2W, TPT, NISP-1, NISP-2, NISPT-1, NISPT-2, NISPE-1, NISPE-2, and three-conductor parallel versions of SRD, SRDE, and SRDT.

The individual conductors of all cords, except those of heat-resistant cords, shall have a thermoset or thermoplastic insulation, except that the equipment grounding conductor, where used, shall be in accordance with 400.23(B).

[1]Rubber-filled or varnished cambric tapes shall be permitted as a substitute for the inner braids.

[2]Elevator traveling cables for operating control and signal circuits shall contain nonmetallic fillers as necessary to maintain concentricity. Cables shall have steel supporting members as required for suspension by 620.41. In locations subject to excessive moisture or corrosive vapors or gases, supporting members of other materials shall be permitted. Where steel supporting members are used, they shall run straight through the center of the cable assembly and shall not be cabled with the copper strands of any conductor.

In addition to conductors used for control and signaling circuits, Types E, EO, ETP, and ETT elevator cables shall be permitted to incorporate in the construction one or more 20 AWG telephone conductor pairs, one or more coaxial cables, or one or more optical fibers. The 20 AWG conductor pairs shall be permitted to be covered with suitable shielding for telephone, audio, or higher frequency communications circuits; the coaxial cables shall consist of a center conductor, insulation, and a shield for use in video or other radio frequency communications circuits. The optical fiber shall be suitably covered with flame-retardant thermoplastic. The insulation of the conductors shall be rubber or thermoplastic of a thickness not less than specified for the other conductors of the particular type of cable. Metallic shields shall have their own protective covering. Where used, these components shall be permitted to be incorporated in any layer of the cable assembly but shall not run straight through the center.

[3]Insulations and outer coverings that meet the requirements as flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the *Code* type designation.

[4]Elevator cables in sizes 20 AWG through 14 AWG are rated 300 volts, and sizes 10 AWG through 2 AWG are rated 600 volts. 12 AWG is rated 300 volts with a 0.76 mm (30 mil) insulation thickness and 600 volts with a 1.14 mm (45 mil) insulation thickness.

[5]Conductor size for Types EV, EVJ, EVE, EVJE, EVT, and EVJT cables apply to nonpower-limited circuits only. Conductors of power-limited (data, signal, or communications) circuits may extend beyond the stated AWG size range. All conductors shall be insulated for the same cable voltage rating.

[6]Insulation thickness for Types EV, EVJ, EVEJE, EVT, and EVJT cables of nylon construction is indicated in parentheses.

[7]Types G, G-GC, S, SC, SCE, SCT, SE, SEO, SEOO, SEW, SEOW, SEOOW, SO, SOO, SOW, SOOW, ST, STO, STOO, STW, STOW, STOOW, PPE, and W shall be permitted for use on theater stages, in garages, and elsewhere where flexible cords are permitted by this *Code*.

[8]The third conductor in Type HPN shall be used as an equipment grounding conductor only. The insulation of the equipment grounding conductor for Types SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, NISPT-1, NISPT-2, NISPE-1, and NISPE-2 shall be permitted to be thermoset polymer.

[9]Cords that comply with the requirements for outdoor cords and are so listed shall be permitted to be designated as weather and water resistant with the suffix “W” after the *Code* type designation. Cords with the “W” suffix are suitable for use in wet locations and are sunlight resistant.

[10]The required outer covering on some single-conductor cables may be integral with the insulation.

[11]Types TPT and TST shall be permitted in lengths not exceeding 2.5 m (8 ft) where attached

directly, or by means of a special type of plug, to a portable appliance rated at 50 watts or less and of such nature that extreme flexibility of the cord is essential.

Statement of Problem and Substantiation for Public Input

Table 400.4 should be located in Part II Construction Specifications. This is the proper location for the Construction specification and Application Table and follows other article formatting. This revision provides continuity of 400.5 Ampacity of Flexible cords and Flexible cables. By relocating this Table it will improve usability of the article.

Submitter Information Verification

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Submittal Date: Sun Mar 15 17:31:27 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Moving this table will not improve usability of the code.

Public Input No. 1788-NFPA 70-2020 [Section No. 400.5(A)]

(A) Ampacity Tables.

Table 400.5(A)(1) provides the ampacities for flexible cords and flexible cables , and Table 400.5(A)(2) provides the ampacities for flexible cords and flexible cables with not more than three current-carrying conductors. These tables shall be used in conjunction with applicable end-use product standards to ensure selection of the proper size and type. Where cords and cables are used in ambient temperatures other than 30°C (86°F), the temperature correction factors from Table 310.15(B)(1) that correspond to the temperature rating of the cord or cable shall be applied to the ampacity in Table 400.5(A)(1) and Table 400.5(A)(2). Cords and cables rated 105°C shall use correction factors in the 90°C column of Table 310.15(B)(1) for temperature correction. Where the number of current-carrying conductors exceeds three, the ampacity of each conductor shall be reduced from the three-conductor rating as shown in Table 400.5(A)(3).

Informational Note: See Informative Annex B, Table B.2(11), for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Table 400.5(A)(1) Ampacity for Flexible Cords and Flexible Cables

[Based on Ambient Temperature of 30°C (86°F). See 400.13 and Table 400.4.]

Copper Conductor Size (AWG)	Thermoplastic Types TPT, TST	Thermoplastic Types ETP, ETT, NISPE-1, NISPE-2, NISPT-1, NISPT-2, SE, SEW, SEO, SEOO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, SPE-1, SPE-2, SPE-3, SPT-1, SPT-1W, SPT-2, SPT-2W, SPT-3, ST, STW, SRDE, SRDT, STO, STOW, STOO, STOOW, SVE, SVEO, SVEOO, SVT, SVTO, SVTOO	Thermoset Types C, E, EO, PD, S, SJ, SJO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW, SP-1, SP-2, SP-3, SRD, SV, SVO, SVOO, NISP-1, NISP-2	Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW	
				Column A[1]	Column B[2]
27[3]	0.5	—	—	—	
20	—	5[4]	5	—	
18	—	7	10	10	
17	—	9	12	13	
16	—	10	13	15	
15	—	12	16	17	
14	—	15	18	20	
13	—	17	21	—	
12	—	20	25	30	
11	—	23	27	—	
10	—	25	30	35	
9	—	29	34	—	
8	—	35	40	—	
7	—	40	47	—	

6	—	45	55	—
5	—	52	62	—
4	—	60	70	—
3	—	70	82	—
2	—	80	95	—

[1]The currents under Column A apply to three-conductor cords and other multiconductor cords connected to utilization equipment so that only three-conductors are current-carrying.

[2]The currents under Column B apply to two-conductor cords and other multiconductor cords connected to utilization equipment so that only two conductors are current-carrying.

[3]Tinsel cord.

[4]Elevator cables only.

[5]7 amperes for elevator cables only; 2 amperes for other types.

Table 400.5(A)(2) Ampacity of Cable Types SC, SCE, SCT, PPE, G, G-GC, and W

[Based on Ambient Temperature of 30°C (86°F). See Table 400.4.]

Copper Conductor Size (AWG or kcmil)	Temperature Rating of Cable								
	60°C (140°F)			75°C (167°F)			90°C (194°F)		
	D[1]	E[2]	F[3]	D[1]	E[2]	F[3]	D[1]	E[2]	F[3]
12	—	31	26	—	37	31	—	42	35
10	—	44	37	—	52	43	—	59	49
8	60	55	48	70	65	57	80	74	65
6	80	72	63	95	88	77	105	99	87
4	105	96	84	125	115	101	140	130	114
3	120	113	99	145	135	118	165	152	133
2	140	128	112	170	152	133	190	174	152
1	165	150	131	195	178	156	220	202	177
1/0	195	173	151	230	207	181	260	234	205
2/0	225	199	174	265	238	208	300	271	237
3/0	260	230	201	310	275	241	350	313	274
4/0	300	265	232	360	317	277	405	361	316
250	340	296	259	405	354	310	455	402	352
300	375	330	289	445	395	346	505	449	393
350	420	363	318	505	435	381	570	495	433
400	455	392	343	545	469	410	615	535	468
500	515	448	392	620	537	470	700	613	536
600	575	—	—	690	—	—	780	—	—
700	630	—	—	755	—	—	855	—	—
750	655	—	—	785	—	—	885	—	—
800	680	—	—	815	—	—	920	—	—
900	730	—	—	870	—	—	985	—	—

Copper Conductor Size (AWG or kcmil)	Temperature Rating of Cable								
	60°C (140°F)			75°C (167°F)			90°C (194°F)		
	D[1]	E[2]	F[3]	D[1]	E[2]	F[3]	D[1]	E[2]	F[3]
1000	780	—	—	935	—	—	1055	—	—

[1]The ampacities under subheading D shall be permitted for single-conductor Types SC, SCE, SCT, PPE, and W cable only where the individual conductors are not installed in raceways and are not in physical contact with each other except in lengths not to exceed 600 mm (24 in.) where passing through the wall of an enclosure.

[2]The ampacities under subheading E apply to two-conductor cables and other multiconductor cables connected to utilization equipment so that only two conductors are current-carrying.

[3]The ampacities under subheading F apply to three-conductor cables and other multiconductor cables connected to utilization equipment so that only three conductors are current-carrying.

Table 400.5(A)(3) Adjustment Factors for More Than Three Current-Carrying Conductors in a Flexible Cord or Flexible Cable

Number of Conductors	Percent of Value in Table 400.5(A)(1) and Table 400.5(A)(2)
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to meet the requirements of a current-carrying conductor.

In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, a common conductor carries approximately the same current as the line-to-neutral currents of the other conductors and shall be considered to be a current-carrying conductor.

On a 4-wire, 3-phase, wye circuit where more than 50 percent of the load consists of nonlinear loads, there are harmonic currents present in the neutral conductor and the neutral conductor shall be considered to be a current-carrying conductor.

An equipment grounding conductor shall not be considered a current-carrying conductor.

Where a single conductor is used for both equipment grounding and to carry unbalanced current from other conductors, as provided for in 250.140 for electric ranges and electric clothes dryers, it shall not be considered as a current-carrying conductor.

Statement of Problem and Substantiation for Public Input

Without stating that Table 400.5(A)(1) is for flexible cords and flexible cables the reference to ampacities makes no sense.

Submitter Information Verification

Submitter Full Name: Roger Zieg
Organization: Zieg Electric
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 03 10:02:06 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8471-NFPA 70-2021
Statement: The proposed “for flexible cords and flexible cables” addition clarifies what the ampacity is for and coincides with the table title.

Public Input No. 280-NFPA 70-2020 [Section No. 400.10(A)]

(A) Uses.

Flexible cords and flexible cables shall be used only for the following:

(1) Pendants.

(2) Wiring of luminaires.

(3) Connection of portable luminaires, portable and mobile signs, or appliances.

(4) Elevator cables.

(5) Wiring of cranes and hoists.

(6) Connection of utilization equipment to facilitate frequent interchange

(7) For a control attachment plug means for servicing equipment .

(8) Prevention of the transmission of noise or vibration.

(9) Appliances where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance and repair, and the appliance is intended or identified for flexible cord connection.

(10) Connection of moving parts.

(11) Where specifically permitted elsewhere in this *Code*.

(12) Between an existing receptacle outlet and an inlet, where the inlet provides power to an additional single receptacle outlet. The wiring interconnecting the inlet to the single receptacle outlet shall be a Chapter 3 wiring method. The inlet, receptacle outlet, and Chapter 3 wiring method, including the flexible cord and fittings, shall be a listed assembly specific for this application.

Statement of Problem and Substantiation for Public Input

currently there is no allowance to install a cord with an attachment plug for the sole purpose of lock out or plug control practices. NFPA 70 E recognizes the method and a reference to the installation use for this purpose would make it clear.

350.10 Exception: At the discretion of the ESA, alternative methods of ensuring worker safety shall be permitted to be employed for the following conditions:

(3) Work on cord-and-plug-connected equipment for which exposure to the hazards of unexpected energization or start up is controlled by the following:
a. Unplugging the equipment from the energy source
b. The employee performing the work maintaining exclusive control of the plug

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 493-NFPA 70-2020 [Section No. 400.10(B)]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jan 13 14:27:56 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: It is unclear what the submitter is trying to accomplish. Cord and plug attachments are already permitted for equipment.

Public Input No. 493-NFPA 70-2020 [Section No. 400.10(B)]

(B) Attachment Plugs.

Where used as permitted in 400.10(A)(3), (A)(6), A(7) and (A)(8 9), each flexible cord shall be equipped with an attachment plug and shall be energized from a receptacle outlet or cord connector body.

Exception: As permitted in 368.56.

Statement of Problem and Substantiation for Public Input

If PI passes numbers need to be updated

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 280-NFPA 70-2020 [Section No. 400.10(A)]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
Street Address:
City:
State:
Zip:
Submittal Date: Wed Feb 19 14:31:22 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: Change is not necessary as PI 280 was not accepted.

Public Input No. 1137-NFPA 70-2020 [Section No. 400.12]

400.12 Uses Not Permitted.

Unless specifically permitted in 400.10, flexible cords, flexible cables, cord sets, and power supply cords shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

Exception to (4): Flexible cord and flexible cable shall be permitted to be attached to building surfaces in accordance with 368.56(B) and 590.4.

(5) Where concealed by walls, floors, or ceilings or located above suspended or dropped ceilings

Exception to (5): Flexible cords, flexible cables, and power supply cords shall be permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by 300.22(C)(3).

Exception to (5): Flexible cords, flexible cables, and power supply cords shall be permitted if rated at no more than 50 volts , and not exceeding 1.8 m (6 ft) in length

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: For proper application see UL 817, *Cord Sets and Power-Supply Cords*, and UL 62, *Flexible Cords and Cables*.

Statement of Problem and Substantiation for Public Input

As technology progresses and becomes smaller and slimmer designed there has been an increase in products that use flexible cords/cables from their low voltage power supplies. I feel that these low consumption short length cables should be classified as fixture wires, and allowed to be concealed in drop ceilings or behind walls.

Submitter Information Verification

Submitter Full Name: shane spirk
Organization: E Light Electrical Services Inc
Street Address:
City:
State:
Zip:
Submittal Date: Mon May 18 15:41:51 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: There was insufficient technical justification submitted to allow the change. Information on specific application would need to be submitted for consideration.

Public Input No. 896-NFPA 70-2020 [Section No. 400.12]

400.12 Uses Not Permitted.

Unless specifically permitted in 400.10, flexible cords, flexible cables, cord sets, and power supply cords shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

Exception to (4): Flexible cord and flexible cable shall be permitted to be attached to building surfaces in accordance with 368.56(B) and 590.4.

(5) Where concealed by walls, floors, or ceilings or located above suspended or dropped ceilings

Exception to (5): Flexible cords, flexible cables, and power supply cords shall be permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by 300.22(C)(3) or listed for such installations .

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: For proper application see UL 817, *Cord Sets and Power-Supply Cords*, and UL 62, *Flexible Cords and Cables*.

Statement of Problem and Substantiation for Public Input

The current prohibition of power supply cords being located within a concealed accessible ceiling that is NOT being used as “other spaces used for environmental air” would not permit the current use of power supply cords from wireless routers/repeaters/extenders where these products are certified to be used with these cords above an accessible ceiling.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Tue Apr 21 13:10:54 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Enclosures are readily available for these applications and are specifically evaluated and listed for the installation.

Public Input No. 994-NFPA 70-2020 [Section No. 400.30]

400.30 ~~Scope~~ General .

Part III applies to single and multiconductor portable cables used to connect mobile equipment and machinery.

Statement of Problem and Substantiation for Public Input

Section 2.2 of the NEC Style Manual provides guidance on Article Scope statements. The Scope shall be the first section of the Article. Part III of section 400.30 is not a scope and may be more appropriate if the section was titled "General".

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: IEC
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 07 12:19:03 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8473-NFPA 70-2021
Statement: Revised heading in accordance with the Style Manual.

Public Input No. 3046-NFPA 70-2020 [Section No. 400.35]

400.35 Fittings.

Connectors used to connect lengths of cable in a run shall be of a type that ~~locks~~ locks or latches firmly together. Provisions shall be made to prevent opening or closing these connectors while energized. Suitable means shall be used to eliminate tension at connectors and terminations.

Statement of Problem and Substantiation for Public Input

There are several manufacturers of large single-pole “latching” style connectors which are currently used for power distribution in the North American oil and shipping industry. These plug and receptacle style connectors do not lock together but rather are secured together with a rigid latching mechanism. The word “latching” is used to describe the securement means of these connectors in UL Outline of Investigation UL1691A and therefore should be added to the NEC in 400.35 along with their “locking” cousins.

Submitter Information Verification

Submitter Full Name: Megan Hayes
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 04 10:43:30 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8468-NFPA 70-2021
Statement: Addition of “latches” clarifies that it does not have to only “lock” together.

Public Input No. 2700-NFPA 70-2020 [New Section after 400.36]

Part IV. Portable Power Feeder Cables Over 2000 Volts, Nominal

400.40 Scope.

Part IV applies to single and multiconductor portable power feeder cables over 2000 Volts, nominal, used to connect mobile equipment and machinery.

400.41 General.

Portable power feeder cables rated greater than 2000 Volts shall comply with sections 400.14, 400.17, and 400.23 and with the following sections.

Informational Note. For information on construction, testing and marking of portable power feeder cables, see ANSI/NEMA WC 58 / ICEA S-75-381, *Portable and Power Feeder Cables for Use in Mines and Similar Applications* .

400.42 Uses Permitted.

Portable power feeder cables over 2000 Volts shall be used only for connection of mobile equipment and machinery, or for wiring cranes and hoists.

400.43 Uses Not Permitted.

Portable power feeder cables over 2000 Volts shall not be used for the following:

(1) As a substitute for fixed wiring of a structure

(2) Where run through holes in walls, ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

(5) Where concealed by walls, floors or ceilings

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

400.44 Construction.

(A) Conductors. The conductors shall be 6 AWG copper, or larger, and shall employ flexible stranding.

(B) Nominal Insulation Thickness. The nominal thickness of insulation for portable power feeder cables shall not be less than specified in Tables 400.44 (A) through (D).

(C) Equipment Grounding Conductor(s). An equipment grounding conductor(s) shall be provided in cables with three or more conductors. The total area shall not be less than that of the size of the equipment grounding conductor required in 250.122.

Table 400.44 (A) Thickness of Insulation for Three-Conductor Type G Portable Power Feeder Cables Rated 2001 to 5000 Volts and Equipment Grounding Conductor Size.

Copper Conductor Size (AWG) or kcmil	Nominal Insulation Thickness of Power Conductors		Equipment Grounding Conductor
	mils	mm	Size AWG
6	110	2.79	10
4 - 2	110	2.79	8
1	110	2.79	7

1/0	110	2.79	6
2/0	110	2.79	5
3/0	110	2.79	4
4/0	110	2.79	3

Table 400.44 (B) Thickness of Insulation for Single Conductor Type SH Portable Power Feeder Cables Rated 2001 to 25000 Volts for 100% Insulation Level.

Copper Conductor Size (AWG) or kcmil	Nominal Insulation Thickness of Power Conductors	
	mils	mm
2001 to 5000 Volts		
6 – 4/0	110	2.79
250 - 500	120	3.05
5001 to 8000 Volts		
4 - 500	150	3.81
8001 to 15000 Volts		
2 - 500	210	5.33
15001 to 25000 Volts		
1 - 500	295	7.49

Table 400.44 (C) Thickness of Insulation for Three-Conductor Type SHD and SHD-GC Portable Power Feeder Cables rated 2001 to 25000 Volts for 100% Insulation Level and Grounding Conductor Size

Copper Conductor Size (AWG) or kcmil	Nominal Insulation Thickness of Power Conductors		Grounding Conductor
	mils	mm	Size AWG
2001 to 5000 Volts			
6- 4/0	110	2.79	8
250 - 500	120	3.05	8
5001 to 8000 Volts			
4 - 500	150	3.81	8
8001 to 15000 Volts			
2 – 4/0	210	5.33	8
15001 to 25000 Volts			
1 – 4/0	295	7.49	8

Table 400.44 (D) Thickness of Insulation for Three-Conductor Type SHD-CGC Portable Power Feeder Cables rated 2001 to 5000 Volts for 100% Insulation Level and Grounding Conductor Size

Copper Conductor	Nominal Insulation Thickness of Power Conductors	Grounding Conductor

Size (AWG) or kcmil	mils	mm	Size AWG
2001 to 5000 Volts			
6	110	2.79	10
4 - 2	110	2.79	8
1	110	2.79	7
1/0	110	2.79	6
2/0	110	2.79	5
3/0	110	2.79	4
4/0	110	2.79	3
250	120	3.05	2
300 - 350	120	3.05	1
500	120	3.05	2/0

400.45 Shielding. All shields shall be grounded at least at one end of the cable.

Informational Note. It is recommended that the shield be grounded at cable terminations. All grounding connections should be made to the shield in such a way as to provide a permanent low resistance bond.

400.46 Equipment Grounding Conductors. Equipment grounding conductors shall be connected in accordance with parts VI and VII of Article 250.

400.47 Minimum Bending Radius. The minimum bending radius for portable power feeder cables from 2000 to 5000 Volts shall not exceed 6 times the overall cable outer diameter. The minimum bending radius for portable power feeder cables from 5001 to 25000 Volts shall not exceed 8 times the overall cable outer diameter.

400.48 Fittings. The use of connectors and couplers to connect lengths of cable together in a run shall not be permitted.

400.49 Splices and Terminations. Portable power feeder cables shall not contain splices. Connectors, couplers, lugs, elbows and terminations for portable power feeder cables rated over 2000 Volts, nominal, shall be accessible only to authorized and qualified personnel. Suitable means shall be used to eliminate tension at connectors, couplers, lugs, elbows and terminations.

400.50 Portable Power Feeder Cable Types. Portable power feeder cables rated greater than 2000 Volts, nominal, shall conform to the descriptions in Table 400.50. Types G, SHD-PCG and SHD-CGC shall be used only from 2000 to 5000 Volts. Types SH, SHD and SHD-GC shall be used from 2000 to 25000 Volts. Where a type designation for portable power feeder cables over 2000 Volts conflicts with a designation description in Table 400.4 the description in Table 400.50 shall apply. The use of portable power feeder cables other than those in Table 400.50 shall require permission by the authority having jurisdiction.

Table 400.50 Portable Power Feeder Cables

Trade Name	Type Letter	Voltage	AWG or kcmil	Insulation	Outer Covering	Ground Check Conductor	Grounding Conductor	

		G	2001– 5000	8 -4/0	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	Yes	
		SHD-PCG	2001 – 5000	3-4/0	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	Yes	
	Portable Power Feeder Cables	**SH**	2001-25000	6-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	No	
		SHD	2001-25000	6-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	Yes	
		SHD-GC	2001-25000	6-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	Yes	Yes	

	SHD-CGC	2001-5000	8-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	Yes	Yes	

400.51 Ampacities for Portable Power Feeder Cables Rated Greater Than 2000 Volts.

400.51(A) Ampacity Tables. Table 400.51(A) provides the ampacities for single and three conductor portable power feeder cables rated greater than 2000 Volts. Where portable power feeder cables are used in ambient temperatures other than 30 °C (86°F), the temperature correction factors from Table 400.51(B) that correspond to the differing ambient temperature shall be applied the the ampacity in Table 400.51(A). Where the cable will not be completely unwound from the cord reel the ampacity correction factor based on the number of layers remaining wound on a reel shall be applied as shown in Table 400.51(C).

400.51(B) Engineering Supervision. Under engineering supervision, conductor ampacities shall be permitted to be calculated in accordance with 310.14(B).

Table 400.51(A) Ampacities for Portable Power Feeder Cables over 2000 Volts [Based on Ambient Temperature of 30°C(86°F) [2]

Copper Conductor Size (AWG) or kcmil	Single Conductor [1]			Three Conductor			Copper Conductor Size (AWG) or kcmil
	2001 – 8000 Volts Shielded	8001 – 15000 Volts Shielded	15001 – 25000 Volts Shielded	2001 – 8000 Volts Shielded	8001 – 15000 Volts Shielded	8001 – 15000 Volts Shielded	
6	123	-	-	102	-	-	**6**
4	163	-	-	134	-	-	**4**
3	188	-	-	154	-	-	**3**
2	214	214	-	175	180	196	**2**
1	247	247	244	202	205	210	**1**
1/0	286	285	280	232	236	240	**1/0**

2/0	329	328	322	267	270	274	**2/0**
3/0	379	377	371	307	311	315	**3/0**
4/0	440	437	428	353	357	360	**4/0**
250	488	484	473	390	395	396	**250**
300	545	540	528	438	-	-	**300**
350	604	597	582	478	-	-	**350**
400	656	649	629	470	-	-	**400**
450	704	696	676	503	-	-	**450**
500	757	746	725	536	-	-	**500**

[1] Ampacities are based on single isolated cable in air operated with open-circuited shield

[2] Ampacities are based on a conductor temperature of 90 ° C (104 °F) and an ambient air temperature of 30°C (86°F)

Table 400.51 (B) Adjustment Factors for Different Ambient Temperatures

Ambient Temperature, Degrees °C (°F)	Multiplying Correction Factor
10 (50)	1.26
20 (68)	1.18
30 (86)	1.10
40 (104)	1.00
50 (122)	.90

Table 400.51 (C) Adjustment Factors for Number of Layers of Cable Wound on a Reel

Number of Layers	Multiplying Correction Factor
1	0.85
2	0.65
3	0.45
4 [1]	0.35

[1] If more than four layers of cable are wound on the reel ampacity derating should be calculated using engineering supervision

400.52 Markings

(A) Required Markings. Portable power feeder cables shall be marked by means of a printed tag attached to the coil, reel or carton. The tag shall contain the information required in 310.8(A). Types G, SHD-PCG, SH, SHD, SHD-GC and SHD-CGC portable power feeder cables shall be durably marked on the surface at intervals not exceeding 610 mm (24 in) with the following:

(1) The maximum rated phase-to-phase or phase-to-ground Voltage.

(2) The proper type letter or letters for the type of portable power feeder cable as specified elsewhere in this *Code.*

(3) The manufacturers name, trademark, or other distictive marking by which the organization responsible for the product can be readily identified.

(4) The AWG size or circular mil area.

(5) The maximum conductor operating temperature

400.52 (B) Optional Markings. Portable power feeder cables listed in Table 400.50 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These

markings include, but are not limited to, markings for limited smoke, sunlight resistance and so forth.

Additional Proposed Changes

File Name	Description	Approved
Article_400_Part_IV_NEW_For_Submission.docx	Word Document with proposed PI for Article 400 part IV.	

Statement of Problem and Substantiation for Public Input

Part III of Article 400 covers Portable cables over 600 Volts, nominal, but there are no requirements that are specific to portable cables that are rated more than 2000 Volts. Tables 402.3 and 402.5 do not include any details regarding cables rated over 2000 V. Cranes, hoists, and mobile equipment and machinery that operate above 2000 Volts exist and are in use, and requirements for the cabling of this equipment should be included in the Code. This proposal adds the necessary information to properly apply portable cables rated above 2000 Volts. The ampacity and construction requirements referenced in this proposal are the same as those in ANSI/NEMA WC 58-2017/ ICEA No. S-75-381-2017, Standard for “Portable and Power Feeder Cables for Use in Mines and Similar Applications”.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3438-NFPA 70-2020 [Section No. 610.11(E)]	Companion
Public Input No. 2659-NFPA 70-2020 [Part III.]	
Public Input No. 3438-NFPA 70-2020 [Section No. 610.11(E)]	

Submitter Information Verification

Submitter Full Name: Paul Knapp
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 28 16:19:51 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8465-NFPA 70-2021
Statement: A new Part is being added to address portable power feeder cables for voltages 2000 Volts and up. This will provide clear guidance in using flexible cords above 2000 volts.

Article 400 Part IV NEW

Substantiation for the proposal: Part III of Article 400 covers Portable cables over 600 Volts, nominal, but there are no requirements that are specific to portable cables that are rated more than 2000 Volts. Tables 402.3 and 402.5 do not include any details regarding cables rated over 2000 V. Cranes, hoists, and mobile equipment and machinery that operate above 2000 Volts exist and are in use, and requirements for the cabling of this equipment should be included in the Code. This proposal adds the necessary information to properly apply portable cables rated above 2000 Volts. The ampacity and construction requirements referenced in this proposal are the same as those in ANSI/NEMA WC 58-2017/ ICEA No. S-75-381-2017, Standard for "Portable and Power Feeder Cables for Use in Mines and Similar Applications".

Part III. Portable Cables Over 600 Volts, up to 2000 Volts, Nominal

Part IV. Portable Power Feeder Cables Over 2000 Volts, Nominal

400.40 Scope.

Part IV applies to single and multiconductor portable power feeder cables over 2000 Volts nominal used to connect mobile equipment and machinery.

400.41 General. Portable power feeder cables rated greater than 2000 Volts shall comply with sections 400.14, 400.17 and 400.23 and with the following sections.

> Informational Note: For information on construction, testing, and marking of portable power feeder cables, see ANSI/NEMA WC 58/ ICEA S-75-381, Portable and Power Feeder Cables for Use in Mines and Similar Applications.

400.42 Uses Permitted. Portable power feeder cables over 2000 V shall be used only for connection of mobile equipment and machinery, or for wiring of cranes and hoists.

400.43 Uses Not Permitted. Portable power feeder cables over 2000 V shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

(5) Where concealed by walls, floors or ceilings

(6) Where installed in raceways, except as otherwise permitted in this Code

(7) Where subject to physical damage

400.44 Construction.

(A) Conductors. The conductors shall be 6 AWG copper or larger and shall employ flexible stranding.

(B) Nominal Insulation Thickness. The nominal thickness of insulation for portable power feeder cables shall not be less than specified in Tables 400.44 (A) through (D).

(C) Equipment Grounding Conductor(s). An equipment grounding conductor(s) shall be provided in cables with three or more conductors. The total area shall not be less than that of the size of the equipment grounding conductor required in 250.122.

Table 400.44 (A) Thickness of insulation for Three-Conductor Type G Portable Power Feeder Cables Rated 2000 to 5,000 Volts and Equipment Grounding Conductor Size

Copper Conductor Size (AWG) or kcmil	Nominal Insulation Thickness of Power Conductors		Equipment Grounding Conductor
	mils	mm	Size AWG
6	110	2.79	10
4 - 2	110	2.79	8
1	110	2.79	7
1/0	110	2.79	6
2/0	110	2.79	5
3/0	110	2.79	4
4/0	110	2.79	3

Table 400.44 (B) Thickness of insulation for Single Conductor Type SH Portable Power Feeder Cables Rated 2000 to 25000 Volts for 100% Insulation Level

Copper Conductor Size (AWG) or kcmil	Nominal Insulation Thickness of Power Conductors	
	mils	mm
2001 to 5000 Volts		
6 – 4/0	110	2.79
250 - 500	120	3.05
5001 to 8000 Volts		
4 - 500	150	3.81
8001 to 15000 Volts		
2 - 500	210	5.33
15001 to 25000 Volts		
1 - 500	295	7.49

Table 400.44(C) Thickness of insulation for Three-Conductor Type SHD and SHD-GC Portable Power Feeder Cables Rated 2000 to 25000 Volts for 100% Insulation Level and grounding conductor size

	Nominal Insulation Thickness of Power Conductors	Grounding Conductor

Copper Conductor Size (AWG) or kcmil	mils	mm	Size AWG
2000 to 5000 Volts			
6- 4/0	110	2.79	8
250 - 500	120	3.05	8
5001 to 8000 Volts			
4 - 500	150	3.81	8
8001 to 15000 Volts			
2 – 4/0	210	5.33	8
15001 to 25000 Volts			
1 – 4/0	295	7.49	8

Table 400.44(D) Thickness of insulation for Three-Conductor Type SHD-CGC Portable Power Feeder Cables Rated 2000 to 5000 Volts for 100% Insulation Level and grounding conductor size

Copper Conductor Size (AWG) or kcmil	Nominal Insulation Thickness of Power Conductors		Grounding Conductor
	mils	mm	Size AWG
2000 to 5000 Volts			
6	110	2.79	10
4 - 2	110	2.79	8
1	110	2.79	7
1/0	110	2.79	6
2/0	110	2.79	5
3/0	110	2.79	4
4/0	110	2.79	3
250	120	3.05	2
300 - 350	120	3.05	1
500	120	3.05	2/0

400.45 Shielding. All shields shall be grounded at least at one end.

> Informational Note. It is recommended that the shield be grounded at cable terminations. All grounding connections should be made to the shield in such a way as to provide a permanent low resistance bond.

400.46 Equipment grounding conductors. Equipment grounding conductors shall be connected in accordance with Parts VI and VII of Article 250.

400.47 Minimum Bending Radii. The minimum bending radii for portable power feeder cables from 2000 Volts to 5000 Volts shall not exceed 6 times the overall cable outer diameter. The minimum bending radii for portable cables from 5001 Volts to 25000 Volts shall not exceed 8 times the overall cable outer diameter.

400.48 Fittings. The use of connectors and couplers to connect lengths of cable together in a run shall not be permitted

400.49 Splices and Terminations. Portable power feeder cables shall not contain splices. Connectors, couplers, lugs, elbows and terminations for portable power feeder cables rated over 2000 volts, nominal, shall be accessible only to authorized and qualified personnel. Suitable means shall be used to eliminate tension at connectors, couplers, lugs, elbows and terminations.

400.50 Types. Portable power feeder cables rated greater than 2000 Volts shall conform to the description in Table 400.50. Types G, SHD-PCG and SHD-CGC shall be used only from 2000 volts to 5,000 Volts. Types SH, SHD and SHD-GC shall be used from 2000 volts to 25,000 Volts. Where a Type designation for portable power feeder cables over 2000 Volts conflicts with a designation description in table 400.4 the description in Table 400.50 shall apply. The use of portable power feeder cables other than those in Table 400.50 shall require permission by the authority having jurisdiction.

Table 400.50 Portable Power Feeder Cables

Trade Name	Type Letter	Voltage	AWG or kcmil	Insulation	Outer Covering	Ground Check Conductor	Grounding Conductor	Shielded	Multiconductor Configuration
Portable Power Feeder Cables	**G**	2001 – 5000	8 - 4/0	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	Yes	Yes	Two parallel power conductors with a single grounding conductor
	SHD-PCG	2001 – 5000	3-4/0	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	Yes	individually shielded power conductors	Round three power conductors, which are separately covered with insulation, a tape and a metallic shield, grounding

									conductor, and one or more control conductors under a unit jacket.
	SH	2001-25000	6-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	No	Yes	N/A
	SHD	2001-25000	6-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	No	Yes	individually shielded power conductors and grounding conductors	Round three power conductors that are separately covered with insulation, a tape and a shield, and three grounding conductors, one in each interstice.
	SHD-GC	2001-25000	6-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	Yes	Yes	Individually shielded power and grounding conductors	Round three power conductors that are separately covered with insulation, a tape, and a shield, and two grounding conductors and one

									ground-check conductor
	SHD-CGC	2001-5000	8-500	Thermoset	Heavy Duty or extra heavy duty Thermoset	Yes	Yes	individually shielded power conductors, grounding conductors, and one ground-check conductor in center	Round three power conductors that are separately covered with insulation , a tape, and metal shield, three grounding conductors , and one center ground-check conductor.

400.51 Ampacities for Portable Power Feeder Cables Rated Greater Than 2000 Volts.

400.51(A) Ampacity Tables. Table 400.51(A) provides the ampacities for single and three conductor portable power feeder cables rated greater than 2000 Volts, Where portable power feeder cables are used in ambient temperatures other than 30°C (86°F), the temperature correction factors from Table 400.51(B) that correspond to the differing ambient temperature shall be applied to the ampacity in Table 400.51(A). Where the cable will not be completely unwound from the cord reel the ampacity correction factor based on the number of layers remaining wound on a reel shall be applied as shown in Table 400.51(C).

400.51 (B) Engineering Supervision. Under engineering supervision, conductor ampacities shall be permitted to be calculated in accordance with 310.14(B).

Table 400.51 (A) Ampacity for portable power feeder cables over 2,000 Volts [Based on Ambient Temperature of 30°C (86°F)[2].

Copper Conductor Size (AWG) or kcmil	Single Conductor[1]			Three Conductor			Copper Conductor Size (AWG) or kcmil
	2,001 – 8,000 Volts Shielded	8,001 – 15,000 Volts Shielded	15,001 – 25,000 Volts Shielded	2,001 – 8,000 Volts Shielded	8,001 – 15,000 Volts Shielded	8,001 – 15,000 Volts Shielded	
6	123	-	-	102	-	-	**6**

4	163	-	-	134	-	-	**4**
3	188	-	-	154	-	-	**3**
2	214	214	-	175	180	196	**2**
1	247	247	244	202	205	210	**1**
1/0	286	285	280	232	236	240	**1/0**
2/0	329	328	322	267	270	274	**2/0**
3/0	379	377	371	307	311	315	**3/0**
4/0	440	437	428	353	357	360	**4/0**
250	488	484	473	390	395	396	**250**
300	545	540	528	438	-	-	**300**
350	604	597	582	478	-	-	**350**
400	656	649	629	470	-	-	**400**
450	704	696	676	503	-	-	**450**
500	757	746	725	536	-	-	**500**

[1]Ampacities are based on single isolated cable in air operated with open-circuited shield.

[2]NOTE—Ampacities are based on a conductor temperature of 90°C (194°F) and an ambient air temperature of 30°C (86°F).

Table 400.51 (B) Adjustment Factors for Different Ambient Temperatures

Ambient Temperature, Degrees °C (°F)	Multiplying Correction Factor
10 (50)	1.26
20 (68)	1.18
30 (86)	1.10
40 (104)	1.00
50 (122)	.90

Table 400.51 (C) Adjustment Factors for Number of Layers of cable Wound on a Reel

Number of Layers	Multiplying Correction Factor
1	0.85
2	0.65
3	0.45
4[1]	0.35

[1]If more than four layers of cable are wound on the reel ampacity derating should be calculated using engineering supervision

400.52 Markings

(A) Required Markings. Portable power feeder cables shall be marked by means of a printed tag attached to the coil reel or carton. The tag shall contain the information required in 310.8(A). Types G, SHD-PCG, SH, SHD, SHD-GC, and SHD-CGC portable power feeder cables shall be durably marked on the surface at intervals not exceeding 610 mm (24 in.) with the following:

(1) The maximum rated voltage

(2) The proper type letter or letters for the type of portable power feeder cable as specified elsewhere in this *Code*

(3) The manufacturer's name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified

(4) The AWG size or circular mil area

(5) maximum operating temperature

400.52 (B) Optional Markings. Portable power feeder cables listed in Table 400.50 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistance, and so forth**.**

Public Input No. 281-NFPA 70-2020 [Article 402]

Article 402 Fixture Wires

402.1 Scope.

This article covers general requirements and construction specifications for fixture wires.

402.2 Other Articles.

Fixture wires shall comply with this article and also with the applicable provisions of other articles of this *Code* .

Informational Note: For application in luminaires, see Article 410.

402.3 Types.

Fixture wires shall be of a type listed in Table 402.3 , and they shall comply with all requirements of that table. The fixture wires listed in Table 402.3 are all suitable for service at 600 volts, nominal, unless otherwise specified.

Informational Note: Thermoplastic insulation may stiffen at temperatures lower than -10°C (+14°F). Thermoplastic insulation may also be deformed at normal temperatures where subjected to pressure, such as at points of support.

Table 402.3 Fixture Wires

Name - - - Thickness of Insulation - - - Type

Letter Insulation AWG mm mils Outer

Covering Maximum

Operating

Temperature Application

Provisions Heat-resistant rubber-covered fixture wire — flexible stranding FFH-2 Heat-resistant rubber or cross-linked synthetic polymer 18–16 0.76 30 Nonmetallic covering 75°C Fixture wiring (167°F) FFHH-2 - 90°C

(194°F) - ECTFE — solid or 7-strand HF Ethylene

chloro-

trifluoroethylene 18–14 0.38 15 None 150°C Fixture wiring (302°F) ECTFE — flexible stranding HFF Ethylene

chlorotrifluo-

roethylene 18–14 0.38 15 None 150°C Fixture wiring (302°F) Tape insulated fixture wire — solid or 7-strand KF-1 Aromatic

polyimide

tape 18–10 0.14 5.5 None 200°C Fixture wiring

— limited to

~~300 volts (392°F) KF-2 Aromatic polyimide tape 18–10 0.21 8.4 None 200°C Fixture wiring (392°F) Tape insulated fixture wire — flexible stranding KFF-1 Aromatic~~

~~polyimide~~

~~tape 18–10 0.14 5.5 None 200°C Fixture wiring~~

~~— limited to~~

~~300 volts (392°F) KFF-2 Aromatic~~

~~polyimide~~

~~tape 18–10 0.21 8.4 None 200°C Fixture wiring (392°F) Perfluoro-alkoxy — solid or 7-strand (nickel or nickel-coated copper) PAF Perfluoro-~~

~~alkoxy 18–14 0.51 20 None 250°C~~

~~Fixture wiring~~

~~(nickel or~~

~~nickel-coated~~

~~copper) (482°F) Perfluoro-alkoxy — flexible stranding PAFF Perfluoro-~~

~~alkoxy 18–14 0.51 20 None 150°C Fixture wiring (302°F) Fluorinated ethylene propylene fixture wire — solid or 7-strand PF Fluorinated~~

~~ethylene~~

~~propylene 18–14 0.51 20 None 200°C Fixture wiring (392°F) Fluorinated ethylene propylene fixture wire — flexible stranding PFF Fluorinated~~

~~ethylene~~

~~propylene 18–14 0.51 20 None 150°C Fixture wiring (302°F) Fluorinated ethylene propylene fixture wire — solid or 7-strand PGF Fluorinated~~

~~ethylene~~

~~propylene 18–14 0.36 14 Glass braid 200°C Fixture wiring (392°F) Fluorinated ethylene propylene fixture wire — flexible stranding PGFF Fluorinated~~

~~ethylene~~

~~propylene 18–14 0.36 14 Glass braid 150°C Fixture wiring (302°F) Extruded polytetrafluoroethylene — solid or 7-strand (nickel or nickel-coated copper) PTF Extruded~~

~~polytetrafluo-~~

~~roethylene 18–14 0.51 20 None 250°C Fixture wiring~~

~~(nickel or~~

nickel-coated

copper) (482°F) Extruded polytetrafluoroethylene — flexible stranding 26-36 (AWG silver or nickel-coated copper) PTFF Extruded

polytetrafluo-

roethylene 18–14 0.51 20 None 150°C Fixture wiring

(silver or

nickel-coated

copper) (302°F) Heat-resistant rubber-covered fixture wire — solid or 7-strand RFH-1 Heat-resistant

rubber 18 0.38 15 Nonmetallic

covering 75°C Fixture wiring

— limited to

300 volts (167°F) RFH-2 Heat-resistant

rubber

Cross-linked

synthetic

polymer 18–16 0.76 30 None or non-

metallic

covering 75°C Fixture wiring (167°F) Heat-resistant cross-linked synthetic polymer-insulated fixture wire — solid or 7-strand RFHH-2* Cross-linked

synthetic

polymer 18–16 0.76 30 None or non-

metallic

covering 90°C Fixture wiring RFHH-3* 18–16 1.14 45 (194°F) Silicone insulated fixture wire — solid or 7-strand SF-1 Silicone

rubber 18 0.38 15 Nonmetallic

covering 200°C Fixture wiring

— limited to

300 volts (392°F) SF-2 Silicone

rubber 18–12 0.76 30 Nonmetallic

covering 200°C Fixture wiring 10 1.14 45 (392°F) Silicone insulated fixture wire — flexible stranding SFF-1 Silicone

rubber 18 0.38 15 Nonmetallic

covering 150°C Fixture wiring

— limited to

300 volts (302°F) SFF-2 Silicone

rubber 18–12 0.76 30 Nonmetallic

covering 150°C Fixture wiring 10 1.14 45 (302°F) Thermoplastic covered fixture wire — solid or 7-strand TF* Thermoplastic 18–16 0.76 30 None 60°C Fixture wiring (140°F) Thermoplastic covered fixture wire — flexible stranding TFF* Thermoplastic 18–16 0.76 30 None 60°C Fixture wiring (140°F) Heat-resistant thermoplastic covered fixture wire — solid or 7-strand TFN* Thermoplastic 18–16 0.38 15 Nylon-

jacket-

ed or

equivalent 90°C Fixture wiring (194°F) Heat-resistant thermoplastic covered fixture wire — flexible stranded TFFN* Thermoplastic 18–16 0.38 15 Nylon-

jacket-

ed or

equivalent 90°C Fixture wiring (194°F) Cross-linked polyolefin insulated fixture wire — solid or 7-strand XF* Cross-linked

polyolefin 18–14 0.76 30 None 150°C Fixture wiring

— limited to

300 volts 12-10 1.14 45 (302°F) Cross-linked polyolefin insulated fixture wire — flexible stranded XFF* Cross-linked

polyolefin 18–14 0.76 30 None 150°C Fixture wiring

— limited to

300 volts 12–10 1.14 45 (302°F) Modified ETFE — solid or 7-strand ZF Modified

ethylene

tetrafluoro-

ethylene 18–14 0.38 15 None 150°C Fixture wiring (302°F) Modified ETFE — flexible stranding ZFF Modified

ethylene

tetrafluoro-

ethylene 18–14 0.38 15 None 150°C Fixture wiring (302°F) High temp. modified ETFE— solid or 7-strand ZHF Modified

ethylene

tetrafluoro-

ethylene 18–14 0.38 15 None 200°C Fixture wiring (392°F)

*Insulations and outer coverings that meet the requirements of flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the *Code* type designation.

402.5 Ampacities for Fixture Wires.

The ampacity of fixture wire shall be as specified in Table 402.5 .

No conductor shall be used under such conditions that its operating temperature exceeds the temperature specified in Table 402.3 for the type of insulation involved.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Table 402.5 Ampacity for Fixture Wires

Size (AWG) Ampacity 18 6 16 8 14 17 12 23 10 28

402.6 Minimum Size.

Fixture wires shall not be smaller than 18 AWG.

402.7 Number of Conductors in Conduit or Tubing.

The number of fixture wires permitted in a single conduit or tubing shall not exceed the percentage fill specified in Table 1, Chapter 9.

402.8 Grounded Conductor Identification.

Fixture wires that are intended to be used as grounded conductors shall be identified by one or more continuous white stripes on other than green insulation or by the means described in 400.22(A) through (E).

402.9 Marking.

(A) Method of Marking.

Thermoplastic insulated fixture wire shall be durably marked on the surface at intervals not exceeding 610 mm (24 in.). All other fixture wire shall be marked by means of a printed tag attached to the coil, reel, or carton.

(B) Optional Marking.

Fixture wire types listed in Table 402.3 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistance, and so forth.

402.10 Uses Permitted.

Fixture wires shall be permitted (1) for installation in luminaires and in similar equipment where enclosed or protected and not subject to bending or twisting in use, or (2) for connecting luminaires to the branch-circuit conductors supplying the luminaires.

402.12 Uses Not Permitted.

Fixture wires shall not be used as branch-circuit conductors except as permitted elsewhere in this *Code* .

402.14 Overcurrent Protection.

Overcurrent protection for fixture wires shall be as specified in 240.5 .

Delete entire Article and move to NEW Article 309

Statement of Problem and Substantiation for Public Input

This article is located in Chapter 4 for equipment and is misleading and confusing. Obviously this is a conductor with an Insulation and conductor ampacity table. The article itself states is a conductor several times! The title in Chapter three States WIRING methods, Fixture wire is a wiring method, you primarily wire fixtures. it is clear from the article of it's limitation. A wire is a conductor, a conductor is a wire. let not confuse this any longer by keeping this conductor a piece of equipment.

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
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Submittal Date: Mon Jan 13 15:12:59 EST 2020
Committee: NEC-P06

Committee Statement

Resolution: Fixture wiring is not generally permitted as a branch circuit and therefore does not fit within Chapter 3.

Public Input No. 998-NFPA 70-2020 [Article 402]

Article 402 ~~Fixture~~ Luminaire Wires

402.1 Scope.

This article covers general requirements and construction specifications for ~~fixture~~ luminaire wires.

402.2 Other Articles.

Fixture wires shall comply with this article and also with the applicable provisions of other articles of this *Code*.

Informational Note: For application in luminaires, see Article 410.

402.3 Types.

~~Fixture~~ Luminaire wires shall be of a type listed in Table 402.3, and they shall comply with all requirements of that table. The ~~fixture~~ luminaire wires listed in Table 402.3 are all suitable for service at 600 volts, nominal, unless otherwise specified.

Informational Note: Thermoplastic insulation may stiffen at temperatures lower than -10°C (+14°F). Thermoplastic insulation may also be deformed at normal temperatures where subjected to pressure, such as at points of support.

Table 402.~~3 Fixture~~ 3 Luminaire Wires

Name	Type Letter	Insulation	AWG	Thickness of Insulation mm	Thickness of Insulation mils	Outer Covering	Maximum Operating Temperature	Application Provisions
Heat-resistant rubber-covered fixture wire — flexible stranding	FFH-2 FFHH-2	Heat-resistant rubber or cross-linked synthetic polymer	18–16	0.76	30	Nonmetallic covering	75°C (167°F)	Fixtu wirin (1
ECTFE — solid or 7-strand	HF	Ethylene chloro-trifluoroethylene	18–14	0.38	15	None	150°C (302°F)	Fixtu wirin
ECTFE — flexible stranding	HFF	Ethylene chlorotrifluo-roethylene	18–14	0.38	15	None	150°C (302°F)	Fixtu wirin
Tape insulated fixture wire — solid or 7-strand	KF-1	Aromatic polyimide tape	18–10	0.14	5.5	None	200°C (392°F)	Fixtu wirin — li 300
	KF-2	Aromatic polyimide tape	18–10	0.21	8.4	None	200°C (392°F)	Fixtu wirin
Tape insulated fixture wire — flexible stranding	KFF-1	Aromatic polyimide tape	18–10	0.14	5.5	None	200°C (392°F)	Fixtu wirin — li 300
	KFF-2	Aromatic polyimide tape	18–10	0.21	8.4	None	200°C (392°F)	Fixtu wirin

Name	Type Letter	Insulation	AWG	mm	mils	Outer Covering	Thickness of Ins	
							Maximum Operating Temperature	App Pro
Perfluoro-alkoxy — solid or 7-strand (nickel or nickel-coated copper)	PAF	Perfluoro-alkoxy	18–14	0.51	20	None	250°C (482°F)	Fixtu wirin (nick nick coat copp
Perfluoro-alkoxy — flexible stranding	PAFF	Perfluoro-alkoxy	18–14	0.51	20	None	150°C (302°F)	Fixtu wirin
Fluorinated ethylene propylene fixture wire — solid or 7-strand	PF	Fluorinated ethylene propylene	18–14	0.51	20	None	200°C (392°F)	Fixtu wirin
Fluorinated ethylene propylene fixture wire — flexible stranding	PFF	Fluorinated ethylene propylene	18–14	0.51	20	None	150°C (302°F)	Fixtu wirin
Fluorinated ethylene propylene fixture wire — solid or 7-strand	PGF	Fluorinated ethylene propylene	18–14	0.36	14	Glass braid	200°C (392°F)	Fixtu wirin
Fluorinated ethylene propylene fixture wire — flexible stranding	PGFF	Fluorinated ethylene propylene	18–14	0.36	14	Glass braid	150°C (302°F)	Fixtu wirin
Extruded polytetrafluoroethylene — solid or 7-strand (nickel or nickel-coated copper)	PTF	Extruded polytetrafluo-roethylene	18–14	0.51	20	None	250°C (482°F)	Fixtu wirin (nick nick coat copp
Extruded polytetrafluoroethylene — flexible stranding 26-36 (AWG silver or	PTFF	Extruded polytetrafluo-	18–14	0.51	20	None	150°C	Fixtu wirin (silv

Name	Type Letter	Insulation	AWG	Thickness of Insulation mm	Thickness of Insulation mils	Outer Covering	Maximum Operating Temperature	Application Provisions
nickel-coated copper)		roethylene					(302°F)	nicke coat copp
Heat-resistant rubber-covered fixture wire — solid or 7-strand	RFH-1	Heat-resistant rubber	18	0.38	15	Nonmetallic covering	75°C (167°F)	Fixtu wirin — li 300
	RFH-2	Heat-resistant rubber Cross-linked synthetic polymer	18–16	0.76	30	None or non-metallic covering	75°C (167°F)	Fixtu wirin
Heat-resistant cross-linked synthetic polymer-insulated fixture wire — solid or 7-strand	RFHH-2* RFHH-3*	Cross-linked synthetic polymer	18–16 18–16	0.76 1.14	30 45	None or non-metallic covering	90°C (194°F)	Fixtu wirin
Silicone insulated fixture wire — solid or 7-strand	SF-1	Silicone rubber	18	0.38	15	Nonmetallic covering	200°C (392°F)	Fixtu wirin — li 300
	SF-2	Silicone rubber	18–12 10	0.76 1.14	30 45	Nonmetallic covering	200°C (392°F)	Fixtu wirin
Silicone insulated fixture wire — flexible stranding	SFF-1	Silicone rubber	18	0.38	15	Nonmetallic covering	150°C (302°F)	Fixtu wirin — li 300
	SFF-2	Silicone rubber	18–12 10	0.76 1.14	30 45	Nonmetallic covering	150°C (302°F)	Fixtu wirin

Name	Type Letter	Insulation	AWG	mm	mils	Outer Covering	Thickness of Ins	
							Maximum Operating Temperature	App Pro
Thermoplastic covered fixture wire — solid or 7-strand	TF*	Thermoplastic	18–16	0.76	30	None	60°C (140°F)	Fixtu wirin
Thermoplastic covered fixture wire — flexible stranding	TFF*	Thermoplastic	18–16	0.76	30	None	60°C (140°F)	Fixtu wirin
Heat-resistant thermoplastic covered fixture wire — solid or 7-strand	TFN*	Thermoplastic	18–16	0.38	15	Nylon-jacket-ed or equivalent	90°C (194°F)	Fixtu wirin
Heat-resistant thermoplastic covered fixture wire — flexible stranded	TFFN*	Thermoplastic	18–16	0.38	15	Nylon-jacket-ed or equivalent	90°C (194°F)	Fixtu wirin
Cross-linked polyolefin insulated fixture wire — solid or 7-strand	XF*	Cross-linked polyolefin	18–14 12-10	0.76 1.14	30 45	None	150°C (302°F)	Fixtu wirin — lir 300
Cross-linked polyolefin insulated fixture wire — flexible stranded	XFF*	Cross-linked polyolefin	18–14 12–10	0.76 1.14	30 45	None	150°C (302°F)	Fixtu wirin — lir 300
Modified ETFE — solid or 7-strand	ZF	Modified ethylene tetrafluoro-ethylene	18–14	0.38	15	None	150°C (302°F)	Fixtu wirin
Modified ETFE — flexible stranding	ZFF	Modified ethylene	18–14	0.38	15	None	150°C	Fixtu wirin

Name	Type Letter	Insulation	AWG	mm	mils	Outer Covering	Thickness of Ins: Maximum Operating Temperature	Thickness of Ins: App Pro
		tetrafluoro-ethylene					(302°F)	
High temp. modified ETFE— solid or 7-strand	ZHF	Modified ethylene tetrafluoro-ethylene	18–14	0.38	15	None	200°C (392°F)	Fixtu wirin

*Insulations and outer coverings that meet the requirements of flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the *Code* type designation.

402.5 Ampacities for ~~Fixture~~ Luminaire Wires.

The ampacity of ~~fixture~~ luminaire wire shall be as specified in Table 402.5.

No conductor shall be used under such conditions that its operating temperature exceeds the temperature specified in Table 402.3 for the type of insulation involved.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Table 402.5 Ampacity for ~~Fixture~~ Luminaire Wires

Size (AWG)	Ampacity
18	6
16	8
14	17
12	23
10	28

402.6 Minimum Size.

~~Fixture~~ Luminaire wires shall not be smaller than 18 AWG.

402.7 Number of Conductors in Conduit or Tubing.

The number of ~~fixture~~ luminaire wires permitted in a single conduit or tubing shall not exceed the percentage fill specified in Table 1, Chapter 9.

402.8 Grounded Conductor Identification.

~~Fixture~~ Luminaire wires that are intended to be used as grounded conductors shall be identified by one or more continuous white stripes on other than green insulation or by the means described in 400.22(A) through (E).

402.9 Marking.

(A) Method of Marking.

Thermoplastic insulated fixture wire shall be durably marked on the surface at intervals not exceeding 610 mm (24 in.). All other fixture wire shall be marked by means of a printed tag attached to the coil, reel, or carton.

(B) Optional Marking.

~~Fixture~~ Luminaire wire types listed in Table 402.3 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistance, and so forth.

402.10 Uses Permitted.

~~Fixture~~ Luminaire wires shall be permitted (1) for installation in luminaires and in similar equipment where enclosed or protected and not subject to bending or twisting in use, or (2) for connecting luminaires to the branch-circuit conductors supplying the luminaires.

402.12 Uses Not Permitted.

~~Fixture~~ Luminaire wires shall not be used as branch-circuit conductors except as permitted elsewhere in this *Code*.

402.14 Overcurrent Protection.

Overcurrent protection for ~~fixture~~ luminaire wires shall be as specified in 240.5.

Statement of Problem and Substantiation for Public Input

Fixture was replaced throughout the NEC to Luminaire a while ago. The improvement would make the NEC more consistent. Also Fixture is not clearly defined in the NEC.

Submitter Information Verification

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City:
State:
Zip:
Submittal Date: Thu May 07 18:02:36 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Replacing “Fixture” with “Luminaire” is inconsistent with all the permitted uses. Fixture wire can be used for other wiring than Luminaires.

Public Input No. 3877-NFPA 70-2020 [Section No. 402.2]

402.2 Other Articles.

Fixture wires shall comply with this article and also with the applicable provisions of other articles of this *Code*.

Informational Note: ~~For~~ See 410.1 f or application in luminaires~~, see Article 410~~ .

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to an entire article, other than Article 100. As such, it is proposed to revise this reference to the scope of the article and the informational note is reorganized in accordance with Section 4.1.3 of the NEC(r) Style Manual.

Submitter Information Verification

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Submittal Date: Wed Sep 09 14:37:24 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8478-NFPA 70-2021
Statement: A reference to Part VI of article 410 was added to the informational note since it is more specific to wiring luminaires.

Public Input No. 3339-NFPA 70-2020 [New Section after B.7]

TITLE OF NEW CONTENT

B8. Cable Aging Criteria

Informational Note: See "The In-Op Design of Electrical Distribution Systems Based on Microsystem Criteria" for information about including conductor age in the design of premise wiring systems. **IEEE Transactions on Industry Applications Volume: 54 , Issue: 1 , Jan.-Feb. 2018**

Statement of Problem and Substantiation for Public Input

The Terra System prohibits positioning this content an appropriate location so the committee may opt to locate the informational reference elsewhere. This research offers other approaches to building premise power distribution wiring; a consideration that may require further review in light of the expansion of DC wiring and power-over-ethernet wiring for equipment loads. The abstract of the paper speaks for itself; reproduced below:

ABSTRACT. This paper deals with an innovative design strategy of building power systems by introducing criteria based on both the “installation approach” and the “operating approach” applying plan-do-check-act (PDCA) cycle. The In-Op design of the electrical power systems takes care of the worst cases of configurations, adequate gaps on load in selecting the rating of components, the actual mean losses to evaluate their energetic operation, and to avoid excessive gaps on the lifetime of components. With this aim, the authors suggest consideration of the thermal aging model of Arrhenius to review the actual gap on load in selecting the rating of components. In reference to IEC standards, this paper underlines in the circuits design the cable steady and transient current densities, the load current torque density as “natural” parameters that allow applying a thumb rule in the classic sizing of the cross-sectional area of circuit conductors. Microsystem criteria in power systems design allow structuring their configuration with components of smaller size to reduce radically the volume of circuit conductors with more sensitive results in the branch distribution. The authors suggest why not reconsider the series of commercial cross section areas of power cables.

Authors: Giuseppe Parise + Luigi Parise (Sapienza University of Rome, Italy) & Michael A. Anthony + James R. Harvey (University of Michigan)

Link to the Abstract:

https://ieeexplore.ieee.org/document/8014496

Arrangements to obtain permission from IEEE to get copies of the full article to the committee are now underway and should be distributed to the appropriate person well ahead of the First Draft Meetings.

Submitter Information Verification

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Submittal Date: Tue Sep 08 08:21:53 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Including “Cable Aging Criteria” in Annex B does not prove to be beneficial to the average code user.

Public Input No. 4245-NFPA 70-2020 [Definition: With Required Temperature Correction Factor.]

With Required Temperature Correction Factor.

If a 175-ampere service rating is selected, a service conductor is then

175 amperes × 0.83 = 145.25 amperes per 310.12.

If the conductors are installed in an ambient temperature of 38°C (100°F), the conductor ampacity must be multiplied by the appropriate correction factor in Table 310.15(B)(1). In this case, we will use an XHHW-2 conductor, so we use a correction factor of 0.91 to find the minimum conductor ampacity and size:

145.25 ~~/~~ x .91 = ~~159~~ 132 .~~6~~ 2 amperes

In accordance with Table 310.16, a ~~2/0 AWG~~ 1 AWG Cu or a 4 1 /0 AWG Al would be required.

If no temperature correction or ampacity adjustment factors are required, the following table includes conductor sizes calculated using the requirements in 310.12. This table is based on 75°C terminations and without any adjustment or correction factors.

Service or Feeder Rating (Amperes)	Conductor (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum
100	4	2
110	3	1
125	2	1/0
150	1	2/0
175	1/0	3/0
200	2/0	4/0
225	3/0	250
250	4/0	300
300	250	350
350	350	500
400	400	600

Statement of Problem and Substantiation for Public Input

The text directs the user of the Code to multiply the appropriate correction factor. See below:

If the conductors are installed in an ambient temperature of 38°C (l00°F), the conductor ampacity must be multiplied by
the appropriate correction factor in Table 310.15(B) (1). In this case, we will use an XHHW-2 conductor, so we use a correction
factor of 0.91 to find the minimum conductor ampacity and size:

145.25/ .91 = 159.6 amperes

In accordance with Table 310.16, a 2/ 0 AWG Cu or a 4/ 0 AWG Al would be required

In the example, the formula is showing a division of 145.25 by .91. This is increasing the amperes instead of decreasing the amperage. Change formula to read as:

145.25 amperes x .91 = 132.2 amperes

This looks to also effect the wire size in this example. Consider revising as follows:

In accordance with Table 310.16, a 1 AWG Cu or a 1/ 0 AWG Al would be required.

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Submittal Date: Thu Sep 10 08:19:05 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The calculation in Annex D #7 was performed correctly. Any time an installation does not meet the parameters listed in the title of the table then correction or adjustment factors need to be applied. The intent of applying these factors is to increase the conductor size to compensate for the additional resistance caused by heat.

Public Input No. 948-NFPA 70-2020 [Annex E]

Informative Annex E Types of Construction

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Table E.1 Fire Resistance Ratings for Type I Through Type V Construction (hr)

	Type I		Type II		Type III			Type IV			Type V	
	442	332	222	111	000	211	200	2HH	111	000
Exterior Bearing Walls [a]										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0 [b]	2	2	2	1	0 [b]
Supporting one floor only	4	3	2	1	0 [b]	2	2	2	1	0 [b]
Supporting a roof only	4	3	1	1	0 [b]	2	2	2	1	0 [b]
Interior Bearing Walls										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting roofs only	3	2	1	1	0	1	0	1	1	0
Columns										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	3	2	2	1	0	1	0	H	1	0
Supporting roofs only	3	2	1	1	0	1	0	H	1	0
Beams, Girders, Trusses, and Arches										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	2	2	2	1	0	1	0	H	1	0
Supporting roofs only	2	2	1	1	0	1	0	H	1	0
Floor/Ceiling Assemblies	2	2	2	1	0	1	0	H	1	0
Roof/Ceiling Assemblies	2	1 1/2	1	1	0	1	0	H	1	0
Interior Nonbearing Walls	0	0	0	0	0	0	0	0	0	0
Exterior Nonbearing Walls [c]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]

Source: Table 7.2.1.1 from *NFPA 5000, Building Construction and Safety Code* , 2018 edition.

H: Heavy timber members.

[a] See 7.3.2.1 in *NFPA 5000* .

[b] See Section 7.3 in *NFPA 5000* .

[c] See 7.2.3.2.12, 7.2.4.2.3, and 7.2.5.6.8 in *NFPA 5000* .

Table E.1 contains the fire resistance rating, in hours, for Types I through V construction. The five different types of construction can be summarized briefly as follows (see also Table E.2):

Type I is a fire-resistive construction type. All structural elements and most interior elements are required to be noncombustible. Interior, nonbearing partitions are permitted to be 1 or 2 hour rated. For nearly all occupancy types, Type I construction can be of unlimited height.

Type II construction has three categories: fire-resistive, one-hour rated, and non-rated. The number of stories permitted for multifamily dwellings varies from two for non-rated and four for one-hour rated to 12 for fire-resistive construction.

Type III construction has two categories: one-hour rated and non-rated. Both categories require the structural framework and exterior walls to be of noncombustible material. One-hour rated construction requires all interior partitions to be one-hour rated. Non-rated construction allows nonbearing interior partitions to be of non-rated construction. The maximum permitted number of stories for multifamily dwellings and other structures is two for non-rated and four for one-hour rated.

Type IV is a single construction category that provides for heavy timber construction. Both the structural framework and the exterior walls are required to be noncombustible except that wood members of certain minimum sizes are allowed. This construction type is seldom used for multifamily dwellings but, if used, would be permitted to be four stories high.

Type V construction has two categories: one-hour rated and non-rated. One-hour rated construction requires a minimum of one-hour rated construction throughout the building. Non-rated construction allows non-rated interior partitions with certain restrictions. The maximum permitted number of stories for multifamily dwellings and other structures is two for non-rated and three for one-hour rated.

Table E.

~~2 Maximum Number of Stories for Types V, IV, and III Construction Construction Type Maximum Number of Stories Permitted V Non-rated 2 V Non-rated, Sprinklered 3 V One-Hour Rated 3 V One-Hour Rated, Sprinklered 4 IV Heavy Timber 4 IV Heavy Timber, Sprinklered 5 III Non-rated 2 III Non-rated, Sprinklered 3 III One-Hour Rated 4 III One-Hour Rated, Sprinklered 5~~

2 (Replaced with NFPA 5000 Table 7.4.1}

Note: See section 7.5.3 of NFPA 5000 for allowable increase in number of stories for mass timber construction.

In Table E.1 the system of designating types of construction also includes a specific breakdown of the types of construction through the use of arabic numbers. These arabic numbers follow the roman numeral notation where identifying a type of construction [for example, Type I(442), Type II(111), Type III(200)] and indicate the fire resistance rating requirements for certain structural elements as follows:

(1) First arabic number — exterior bearing walls

(2) Second arabic number — columns, beams, girders, trusses and arches, supporting bearing walls, columns, or loads from more than one floor

(3) Third arabic number — floor construction

Table E.3 provides a comparison of the types of construction for various model building codes. [***5000*** **:** A.7.2.1.1]

Table E.3 Cross-Reference of Building Construction Types

NFPA 5000	**I (442)**	**I (332)**	**II (222)**	**II (111)**	**II (000)**	**III (211)**	**III (200)**	**IV (2HH)**	**V (111)**	**V (000)**
UBC	—	I FR	II FR	II 1 hr	II N	III 1 hr	III N	IV HT	V 1 hr	V N
B/NBC	1A	1B	2A	2B	2C	3A	3B	4	5A	5B
SBC	I	II	—	IV 1 hr	IV UNP	V 1 hr	V UNP	III	VI 1 hr	VI UNP
IBC	—	IA	IB	IIA	IIB	IIIA	IIIB	IV HT	VA	VB

Source: Table A.7.2.1.1 from *NFPA 5000, Building Construction and Safety Code* , 2018 edition.

UBC: *Uniform Building Code* .

FR: Fire rated.

N: Nonsprinklered.

HT: Heavy timber.

B/NBC: *National Building Code* .

SBC: *Standard Building Code* .

UNP: Unprotected.

IBC: *International Building Code* .

Additional Proposed Changes

File Name	Description	Approved
Annex_E_2020_NEC.1588689677993_1_.docx	Word file is attached to clarify the revisions. Terra does not show the intended changes and has underlined text that has not been revised.	
Pages_from_NFPA_5000_Table_7.4.1.pdf	Pages from NFPA 5000 Table 7.4.1	

Statement of Problem and Substantiation for Public Input

A Correlating Committee Task Group reviewed Annex E for correlation with NFPA 5000 and the IBC 2018 for construction types. Task group members consisted of David Hittinger, David Williams and

David Kendall. Table E.2 was replaced with NFPA 5000 Table 7.4.1 to reflect the published NFPA Standard. Table E.3 was updated to correlate with the 2021 IBC for Type IV construction scheduled to be published in January 2021. A PDF is included with the complete Table from the 2018 edition of NFPA 5000. A note was added at the bottom of Table E-2 to see section 7.5.3 of NFPA 5000 for allowable increase in number of stories for mass timber construction.

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Submittal Date: Tue May 05 10:11:01 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: While this section needs to be revised to reflect changes in construction types, this PI appears to be incomplete. The description of Type IV is no longer accurate, as it does not discuss mass timber construction. Since NFPA 5000 does not differentiate mass timber from heavy timber in the name (as the IBC does, for instance, by labeling them Type IV-A, B, or C), but rather includes them in Type IV, they must be discussed here. The last sentence is not accurate, as Type IV is permitted to be taller than four stories (even without considering mass timber). Table E3 also needs further revision, because Type IV as described in NFPA 5000 includes more than just Type IV-HT, as the proposed table currently states.

Table E.2 Maximum Number of Stories for Types V, IV, and III Construction for One, Two, and Multi-family Dwellings

Construction Type	Maximum Number of Stories Permitted
V Non-rated	2
V Non-rated, Sprinklered	3
V One-Hour Rated	3
V One-Hour Rated, Sprinklered	4
IV Heavy Timber	4
IV Heavy Timber, Sprinklered	5
III Non-rated	2
III Non-rated, Sprinklered	3
III One-Hour Rated	4
III One-Hour Rated, Sprinklered	5

Source: IBC-2018 Table 504.4

Note: See section 7.5.3 of NFPA 5000 for allowable increase in number of stories for mass timber construction.

Table E.3 Cross-Reference of Building Construction Types

NFPA 5000	I (442)	I (332)	II (222)	II (111)	II (000)	III (211)	III (200)	IV (2HH)	V (111)	V (000)
UBC	—	I FR	II FR	II 1 hr	II N	III 1 hr	III N	IV HT	V 1 hr	V N
B/NBC	1A	1B	2A	2B	2C	3A	3B	4	5A	5B
SBC	I	II	—	IV 1 hr	IV UNP	V 1 hr	V UNP	III	VI 1 hr	VI UNP
IBC	—	IA	IB	IIA	IIB	IIIA	IIIB	IV HT	VA	VB

Source: Table A.7.2.1.1 from *NFPA 5000, Building Construction and Safety Code*, 2018 edition.

UBC: *Uniform Building Code*.

FR: Fire rated.

N: Nonsprinklered.

HT: Heavy timber.

B/NBC: *National Building Code*.

SBC: *Standard Building Code*.

UNP: Unprotected.

IBC: *International Building Code*.

SR-8025 Hide Deleted

The heights of buildings based on their type of construction classification, shall not exceed the allowable heights set forth in Table 7.4.1.

Table 7.4.1 Allowable Building Height and Area

	TYPE I				TYPE II						TYPE III				TYPE IV		TYPE V			
	442		332		222		111		000		211		200		2HH		111		000	
Construction Type	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N
Maximum building height (ft)	UL	UL	420	400	180	160	85	65	75	55	85	65	75	55	85	65	70	50	60	40
OCCUPANCY																				
Assembly >1000	UL	4	UL	4	12	4	3	2	1	NP	3	2	NP	NP	3	2	3	2	NP	NP
	UL		UL		UL		15,500		8,500		14,000		NP		15,000		11,500		NP	
Assembly > 300	UL	4	UL	4	12	4	4	3	2	1	4	2	1	1	4	2	4	2	1	1
	UL		UL		UL		15,500		8,500		14,000		8,500		15,000		11,500		5,500	
Assembly ≤300	UL	7	UL	7	12	7	4	3	2	1	4	3	2	1	4	3	4	3	2	1
	UL		UL		UL		15,500		8,500		14,000		8,500		15,000		11,500		5,500	
Assembly, outdoor	UL	UL	UL	UL	UL	UL	UL	UL	UL	UL	4	3	3	2	4	3	3	2	2	1
	UL		UL		UL		UL		UL		UL		UL		UL		UL		UL	
Business	UL	UL	UL	UL	12	11	6	5	5	4	6	5	5	4	6	5	4	3	3	2
	UL		UL		UL		37,500		23,000		28,500		19,000		36,000		18,000		9,000	
Board and care, large	UL	NP	UL	NP	12	NP	3	NP	2	NP	2	NP	1	NP	2	NP	2	NP	1	NP
	UL		UL		55,000		19,000		10,000		16,500		10,000		18,000		10,500		4,500	
Board and care, small	UL	UL	UL	UL	12	11	5	4	5	4	5	4	5	4	5	4	4	3	3	2
	UL		UL		UL		24,000		16,000		24,000		16,000		20,500		12,000		7,000	
Day care	UL	2	UL	2	12	2	6	1	4	1	4	1	2	1	2	1	4	1	2	1
	UL		UL		60,500		26,500		13,000		23,500		13,000		25,500		18,500		9,000	
Detention and correctional	UL	7	UL	7	12	7	2	2	2	NP	2	2	2	NP	2	2	2	2	2	NP
	UL		UL		UL		15,000		10,000		10,500		7,500		12,000		7,500		5,000	
Educational	UL	UL	UL	UL	12	5	4	3	3	2	4	3	3	2	4	3	2	1	2	1
	UL		UL		UL		26,500		14,500		23,500		14,500		25,500		18,500		9,500	
Health care	UL	NP	UL	NP	12	NP	3	NP	1	NP	1	NP	NP	NP	1	NP	1	NP	NP	NP
	UL		UL		UL		15,000		11,000		12,000		NP		12,000		9,500		NP	
Health care, ambulatory	UL	UL	UL	UL	12	11	6	5	5	1	6	5	5	1	6	5	4	3	3	1
	UL		UL		UL		37,500		23,000		28,500		19,000		36,000		18,000		9,000	
Industrial, ordinary hazard	UL	UL	UL	UL	12	11	5	4	3	2	4	3	3	2	5	4	3	2	2	1
	UL		UL		UL		25,000		15,500		19,000		12,000		33,500		14,000		8,500	
Industrial, low hazard	UL	UL	UL	UL	12	11	6	5	4	3	5	4	4	3	6	5	4	3	3	2
	UL		UL		UL		37,500		23,000		28,500		18,000		50,500		21,000		13,000	
Mercantile	UL	UL	UL	UL	12	11	5	4	5	4	5	4	5	4	5	4	4	3	2	1
	UL		UL		UL		21,500		12,500		18,500		12,500		20,500		14,000		9,000	
Residential	UL	UL	UL	UL	12	11	5	4	5	4	5	4	5	4	5	4	4	3	3	2
	UL		UL		UL		24,000		16,000		24,000		16,000		20,500		12,000		7,000	
Residential, 1- and 2-family	UL	UL	UL	UL	12	11	5	4	5	4	5	4	5	4	5	4	4	3	3	2
	UL		UL		UL		UL		UL		UL		UL		UL		UL		UL	
Storage, ordinary hazard	UL	UL	UL	UL	12	11	5	4	4	3	4	3	4	3	5	4	4	3	2	1
	UL		UL		48,000		26,000		17,500		26,000		17,500		25,500		14,000		9,000	
Storage, low hazard	UL	UL	UL	UL	12	11	6	5	5	4	5	4	5	4	6	5	5	4	3	2

	TYPE I				TYPE II						TYPE III				TYPE IV		TYPE V			
	442		332		222		111		000		211		200		2HH		111		000	
Construction Type	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N
Maximum building height (ft)	UL	UL	420	400	180	160	85	65	75	55	85	65	75	55	85	65	70	50	60	40
OCCUPANCY																				
	UL		UL		79,000		39,000		26,000		39,000		26,000		38,500		21,000		13,500	
HIGH HAZARD CONTENTS																				
High hazard contents not requiring Protection Level 1 through Protection Level 5	Use values for appropriate occupancy class. For industrial or storage occupancies, use values for ordinary hazard.																			
Protection Level 1	1	NP	1	NP	1	NP	1	NP	1	NP	1	NP	1	NP	1	NP	1	NP	NP	NP
	21,000		21,000		16,500		11,000		7,000		9,500		7,000		10,500		7,500		NP	
Protection Level 2	UL	NP	UL	NP	3	NP	2	NP	1	NP	2	NP	1	NP	2	NP	1	NP	1	NP
	21,000		21,000		16,500		11,000		7,000		9,500		7,000		10,500		7,500		3,000	
Protection Level 3	UL	NP	UL	NP	6	NP	4	NP	2	NP	4	NP	2	NP	4	NP	2	NP	1	NP
	UL		UL		60,000		26,500		14,000		17,500		13,000		25,500		10,000		5,000	
Protection Level 4	UL	NP	UL	NP	8	NP	6	NP	4	NP	6	NP	4	NP	6	NP	4	NP	3	NP
	UL		UL		UL		37,500		17,500		28,500		17,500		36,000		18,000		6,500	
Protection Level 5	4	NP	4	NP	4	NP	3	NP	3	NP	3	NP	3	NP	3	NP	3	NP	2	NP
	UL		UL		UL		37,500		23,000		28,500		19,000		36,000		18,000		9,000	

For SI units, 1 ft = 0.3048 m; 1 ft^2 = 0.093 m^2.

S: Allowable building height in feet and allowable number of stories in buildings protected with an automatic sprinkler system ~~as specified in 7.4.1~~ in accordance with 55.3.1.1(1) and electrically supervised in accordance with 55.3.2 .

N: Allowable building height in feet and allowable number of stories in buildings not protected with an automatic sprinkler system ~~as specified in 7.4.1~~ in accordance with 55.3.1.1(1) and electrically supervised in accordance with 55.3.2 .

UL: Unlimited.

NP: Not permitted.

Note: Within each occupancy category and protection level, the top row refers to the allowable number of stories, and the bottom row refers to the allowable area per story. *(See 3.3.444, Number of Stories.)*

7.4.1.1 Multiple Buildings.

Multiple buildings located on the same lot shall be permitted to be a single building where the height of each building and the aggregate area of the buildings are within the limitations of Table 7.4.1, as modified by Sections 7.4 through 7.6.

7.4.1.2 Multiple Occupancies.

In other than buildings containing high hazard contents requiring Protection Level 1, Protection Level 2, Protection Level 3, Protection Level 4, or Protection Level 5, where the building is occupied for two or more uses not included in the same occupancy, the building, or portion thereof, shall comply with 7.4.1.2.1, 7.4.1.2.2, or a combination thereof.

7.4.1.2.1 Mixed Occupancies.

Buildings with mixed occupancies complying with 6.2.3 shall have their required type of construction determined by applying the most restrictive type of construction to the entire building in accordance with Sections 7.4 through 7.6 for each of the occupancies.

7.4.1.2.2 Separated Occupancies.

Buildings with separated occupancies complying with 6.2.4 shall have their required type of construction determined in accordance with 7.4.1.2.2.1 and 7.4.1.2.2.2.

7.4.1.2.2.1

Each separated occupancy shall comply with the story and height limitations of Sections 7.4 through 7.6 based on the location of the occupancy in the building.

7.4.1.2.2.2

For each story in the building, the sum of the ratios of the per story area of each separated occupancy divided by the allowable area per story as determined by Table 7.4.1, and as modified by 7.6.2, shall not exceed 1.0.

7.4.1.3 Areas with High Hazard Contents.

The separation of areas containing high hazard contents requiring Protection Level 1, Protection Level 2, Protection Level 3, Protection Level 4, or Protection Level 5 shall be in accordance with Chapter 34.

7.4.1.4 Special Requirements.

Public Input No. 868-NFPA 70-2020 [New Part after I.]

Anti-Oxidant Compound

Compound that is applied to an aluminum conductor to prevent oxidation at its termination points.

Statement of Problem and Substantiation for Public Input

The use of Ani-oxidant on aluminum conductors is not a requirement by the NEC and should be.

Submitter Information Verification

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Zip:
Submittal Date: Tue Apr 14 10:09:35 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The submitter failed to provide the paragraph of the NFPA standard to which the Public Input is directed as required in the “Regulations Governing the Development of NFPA Standards”-4.3.4.1. For a definition to exist in the Code the term must be used in a requirement. The application of anti-oxidant compound is only required when specified by the mfg’s.

Public Input No. 2768-NFPA 70-2020 [Sections Part II., 310.4, 310.6, 310.8]

Sections Part II., 310.4, 310.6, 310.8

Part II. Construction Specifications

310.4 Conductor Constructions and Applications.

Insulated conductors shall comply with Table 310.4(A) and Table 310.4(B).

Informational Note: Thermoplastic insulation may stiffen at temperatures lower than −10°C (+14°F). Thermoplastic insulation may also be deformed at normal temperatures where subjected to pressure, such as at points of support.

Table 310.4(A) Conductor Applications and Insulations Rated 600 Volts [1]

Trade Name Type Letter Maximum Operating Temperature Application Provisions Insulation Thickness of Insulation - AWG or kcmil mm mils Outer Covering [2]

Fluorinated ethylene propylene FEP or FEPB 90°C Dry and damp locations Fluorinated ethylene propylene 14–10 0.51 20 None (194°F) 8–2 0.76 30 - 200°C Dry locations — special applications [3] Fluorinated ethylene propylene 14–8 0.36 14 Glass braid (392°F) 6–2 0.36 14 Glass or other suitable braid material Mineral insulation (metal sheathed) MI 90°C Dry and wet locations Magnesium oxide 18–16 [4] 0.58 23 Copper or alloy steel (194°F) 16–10 0.91 36 250°C For special applications [3] 9–4 1.27 50 (482°F) 3–500 1.40 55 Moisture-, heat-, and oil-resistant thermoplastic MTW 60°C Machine tool wiring in wet locations Flame-retardant, moisture-, heat-, and oil-resistant thermoplastic - (A) (B) (A) (B) (A) None (140°F) (B) Nylon jacket or equivalent 90°C Machine tool wiring in dry locations. 22–12 0.76 0.38 30 15 (194°F) 10 0.76 0.51 30 20 - 8 1.14 0.76 45 30 - Informational Note: See NFPA 79. 6 1.52 0.76 60 30 - 4–2 1.52 1.02 60 40 - 1–4/0 2.03 1.27 80 50 - 213–500 2.41 1.52 95 60 - 5 85°C For underground service conductors, or by special permission Paper - - - Lead sheath (185°F) Perfluoro-alkoxy PFA 90°C Dry and damp locations Perfluoro-alkoxy 14–10 0.51 20 None (194°F) 8–2 0.76 30 200°C Dry locations — special applications [3] 1–4/0 1.14 45 (392°F) - - - Perfluoro-alkoxy PFAH 250°C Dry locations only. Only for leads within apparatus or within raceways connected to apparatus (nickel or nickel-coated copper only) Perfluoro-alkoxy 14–10 0.51 20 None (482°F) 8–2 0.76 30 1–4/0 1.14 45 Thermoset RHH 90°C Dry and damp locations - 14-10 1.14 45 Moisture-resistant, flame-retardant, nonmetallic covering [2] (194°F) 8–2 1.52 60 1–4/0 2.03 80 213–500 2.41 95 501–1000 2.79 110 1001–2000 3.18 125 Moisture-resistant thermoset RHW 75°C Dry and wet locations Flame-retardant, moisture-resistant thermoset 14–10 1.14 45 Moisture-resistant, flame-retardant, nonmetallic covering (167°F) 8–2 1.52 60 1–4/0 2.03 80 RHW-2 90°C 213–500 2.41 95 (194°F) 501–1000 2.79 110 1001–2000 3.18 125 Silicone SA 90°C Dry and damp locations Silicone rubber 14–10 1.14 45 Glass or other suitable braid material (194°F) 8–2 1.52 60 1–4/0 2.03 80 200°C For special application [3] 213–500 2.41 95 (392°F) 501–1000 2.79 110 1001–2000 3.18 125 Thermoset SIS 90°C Switchboard and switchgear wiring only Flame-retardant thermoset 14–10 0.76 30 None (194°F) 8–2 1.14 45 1–4/0 1.40 55 Thermoplastic and fibrous outer braid TBS 90°C Switchboard and switchgear wiring only Thermoplastic 14–10 0.76 30 Flame-retardant, nonmetallic covering (194°F) 8 1.14 45 6–2 1.52 60 1–4/0 2.03 80 Extended polytetra-fluoro-ethylene TFE 250°C Dry locations only. Only for leads within apparatus or within raceways connected to apparatus, or as open wiring (nickel or nickel-coated copper only) Extruded polytetra-fluoroethylene 14–10 0.51 20 None (482°F) 8–2 0.76 30 1–4/0 1.14 45 Heat-resistant thermoplastic THHN 90°C Dry and damp locations Flame-retardant, heat-resistant

thermoplastic 14–12 0.38 15 Nylon jacket or equivalent (194°F) 10 0.51 20 8–6 0.76 30 4–2 1.02 40 1–4/0 1.27 50 250–500 1.52 60 501–1000 1.78 and heat-resistant thermoplastic THHW -75°C Wet location Flame-retardant, moisture- and heat-resistant thermoplastic 14–10 0.76 30 None (167°F) 8 1.14 45 6–2 1.52 60 -90°C Dry location 1–4/0 2.03 80 (194°F) 213–500 2.41 95 501–1000 2.79 110 1001–2000 3.18 125 Moisture- and heat-resistant thermoplastic THW -75°C Dry and wet locations Flame-retardant, moisture- and heat-resistant thermoplastic 14–10 0.76 30 None (167°F) 8 1.14 45 -90°C Special applications within electric discharge lighting equipment. Limited to 1000 open-circuit volts or less. (Size 14-8 only as permitted in 410.68.) 6–2 1.52 60 (194°F) 1–4/0 2.03 80 213–500 2.41 95 501–1000 2.79 110 1001–2000 3.18 125 90°C Dry and wet locations - - - - - (194°F) Moisture- and heat-resistant thermoplastic THWN 75°C Dry and wet locations Flame-retardant, moisture- and heat-resistant thermoplastic 14–12 0.38 15 Nylon jacket or equivalent (167°F) 10 0.51 20 8–6 0.76 30 4–2 1.02 40 THWN-2 90°C 1–4/0 1.27 50 (194°F) 250–500 1.52 60 501–1000 1.78 70 Moisture-resistant thermoplastic TW -60°C Dry and wet locations Flame-retardant, moisture-resistant thermoplastic 14–10 0.76 30 None (140°F) 8 1.14 45 6–2 1.52 60 1–4/0 2.03 80 213–500 2.41 95 501- feeder and branch-circuit cable — single conductor (for Type UF cable employing more than one conductor, see Article 340). UF -60°C See Article 340. Moisture-resistant 14–10 1.52 60 [6] Integral with insulation (140°F) 8–2 2.03 80 [6] 1–4/0 2.41 95 [6] 75°C Moisture- and heat-resistant (167°F) [5] Underground service-entrance cable — single conductor (for Type USE cable employing more than one conductor, see Article 338). USE 75°C See Article 338. Heat- and moisture-resistant 14–10 1.14 45 Moisture-resistant nonmetallic covering (See 338.2.) (167°F) [5] 8–2 1.52 60 1–4/0 2.03 80 213–500 2.41 95 [7] 501–1000 2.79 110 1001–2000 3.18 125 USE-2 -90°C Dry and wet locations (194°F) Thermoset XHH -90°C Dry and damp locations Flame-retardant thermoset 14–10 0.76 30 None (194°F) 8–2 1.14 45 1–4/0 1.40 55 213–500 1.65 65 501–1000 2.03 8 and damp locations Flame-retardant thermoset 14–12 0.38 15 Nylon jacket or equivalent (194°F) 10 0.51 20 8–6 0.76 30 4–2 1.02 40 1–4/0 1.27 50 250–500 1.52 60 501–1000 1.78 resistant thermoset XHHW -90°C Dry and damp locations Flame-retardant, moisture-resistant thermoset 14–10 0.76 30 None (194°F) 8–2 1.14 45 -75°C Wet locations 1–4/0 1.40 55 (167°F) 213–500 1.65 65 501–1000 2.03 80 1001–2000 2.41 95 Moisture-resistant thermoset XHHW-2 -90°C Dry and wet locations Flame-retardant, moisture-resistant thermoset 14–10 0.76 30 None (194°F) 8–2 1.14 45 1–4/0 1.40 55 213–500 1.65 65 501–1000 2.03 8 resistant thermoset XHWN 75°C Dry and wet locations Flame-retardant, moisture-resistant thermoset 14–12 0.38 15 Nylon jacket or equivalent (167°F) 10 0.51 20 8–6 0.76 30 XHWN-2 90°C 4–2 1.02 40 (194°F) 1–4/0 1.27 50 250–500 1.52 60 501–1000 1.78 70 Modified ethylene tetrafluoro-ethylene Z -90°C Dry and damp locations Modified ethylene tetrafluoro-ethylene 14–12 0.38 15 None (194°F) 10 0.51 20 150°C Dry locations — special applications [3] 8–4 0.64 25 (302°F) 3–1 0.89 35 1/0–4/0 1.14 45 Modified ethylene tetrafluoro-ethylene ZW -75°C Wet locations Modified ethylene tetrafluoro-ethylene 14–10 0.76 30 None (167°F) 8–2 1.14 45 90°C Dry and damp locations (194°F) 150°C Dry locations — special applications [3] (302°F) ZW-2 90°C Dry and wet locations (194°F)

[1] Conductors shall be permitted to be rated up to 1000 volts if listed and marked.

[2] Outer coverings shall not be required where listed without a covering.

[3] Higher temperature rated constructions shall be permitted where design conditions require maximum conductor operating temperatures above 90°C (194°F).

[4] Conductor sizes shall be permitted for signaling circuits permitting 300-volt insulation.

[5] The ampacity of Type UF cable shall be limited in accordance with 340.80.

[6] Type UF insulation thickness shall include the integral jacket.

[7] Insulation thickness shall be permitted to be 2.03 mm (80 mils) for listed Type USE conductors that have been subjected to special investigations. The nonmetallic covering over individual rubber-covered conductors of aluminum-sheathed cable and of lead-sheathed or multiconductor cable shall not be required to be flame retardant.

Table 310.4(B) Thickness of Insulation for Nonshielded Types RHH and RHW Solid Dielectric Insulated Conductors Rated 2000 Volts

Conductor Size

(AWG or kcmil) - Column A [1] - Column B [2] - mm mils - mm mils 14–10 - 2.03 80 - 1.52 60 8 - 2.03 80 - 1.78 70 6–2 - 2.41 95 - 1.78 70 1–2/0 - 2/0–4/0 - 2.79 110 - 2.29 90 213–500 - 3.18 125 - 2.67 105 501–1000 - 3.56 140 - 3.05 120 1001–2000 -

[1] Column A insulations shall be limited to natural, SBR, and butyl rubbers.

[2] Column B insulations shall be materials such as cross-linked polyethylene, ethylene propylene rubber, and composites thereof.

310.6 Conductor Identification.

(A) Grounded Conductors.

Insulated or covered grounded conductors shall be identified in accordance with 200.6 .

(B) Equipment Grounding Conductors.

Equipment grounding conductors shall be identified in accordance with 250.119 .

(C) Ungrounded Conductors.

Conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from grounded and equipment grounding conductors. Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1) . Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C) . Feeders shall be identified in accordance with 215.12 .

Exception: *Conductor identification shall be permitted in accordance with* *200.7* .

310.8 Marking.

(A) Required Information.

All conductors and cables shall be marked to indicate the following information, using the applicable method described in 310.8(B) :

(1) The maximum rated voltage.

(2) The proper type letter or letters for the type of wire or cable as specified elsewhere in this *Code* .

(3) The manufacturer's name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified.

(4) The AWG size or circular mil area.

Informational Note: See Chapter 9 , Table 8, Conductor Properties, for conductor area expressed in SI units for conductor sizes specified in AWG or circular mil area.

(5) Cable assemblies where the neutral conductor is smaller than the ungrounded conductors shall be so marked.

(B) Method of Marking.

(1) Surface Marking.

The following conductors and cables shall be durably marked on the surface:

(1) Single-conductor and multiconductor thermoset and thermoplastic-insulated wire and cable

(2) Nonmetallic-sheathed cable

(3) Service-entrance cable

(4) Underground feeder and branch-circuit cable

(5) Tray cable

(6) Irrigation cable

(7) Power-limited tray cable

(8) Instrumentation tray cable

The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).

(2) Marker Tape.

Metal-covered multiconductor cables shall employ a marker tape located within the cable and running for its complete length.

Exception No. 1: *Type MI cable shall not require a marker tape.*

Exception No. 2: *Type AC cable shall not require a marker tape.*

Exception No. 3: *The information required in 310.8(A) shall be permitted to be durably marked on the outer nonmetallic covering of Type MC, Type ITC, or Type PLTC cables at intervals not exceeding 1.0 m (40 in.).*

Exception No. 4: *The information required in 310.8(A) shall be permitted to be durably marked on a nonmetallic covering under the metallic sheath of Type ITC or Type PLTC cable at intervals not exceeding 1.0 m (40 in.).*

Informational Note: Included in the group of metal-covered cables are Type AC cable (Article 320), Type MC cable (Article 330), and lead-sheathed cable.

(3) Tag Marking.

The following conductors and cables shall be marked by means of a printed tag attached to the coil, reel, or carton:

(1) Type MI cable

(2) Switchboard wires

(3) Metal-covered, single-conductor cables

(4) Type AC cable

~~**(4)** Optional Marking of Wire Size.~~

~~The information required in 310.8(A)(4) shall be permitted to be marked on the surface of the individual insulated conductors for the following multiconductor cables:~~

(1) ~~Type MC cable~~

(2) ~~Tray cable~~

(3) ~~Irrigation cable~~

(4) ~~Power-limited tray cable~~

(5) ~~Power-limited fire alarm cable~~

(6) ~~Instrumentation tray cable~~

~~**(C)** Suffixes to Designate Number of Conductors.~~

~~A type letter or letters used alone shall indicate a single insulated conductor. The letter suffixes shall be indicated as follows:~~

(1) ~~D — For two insulated conductors laid parallel within an outer nonmetallic covering~~

(2) ~~M — For an assembly of two or more insulated conductors twisted spirally within an outer nonmetallic covering~~

~~**(D)** Optional Markings.~~

~~All conductors and cables contained in Chapter 3 shall be permitted to be surface marked to indicate special characteristics of the cable materials. These markings include, but are not limited to, markings for limited smoke, sunlight resistant, and so forth.~~

Statement of Problem and Substantiation for Public Input

In 2020 310.104 part III construction specifications was relocated to 310.4 Part II. This is an inconsistent with all other articles in chapter 3. In order to bring it back in compliance with the style manual and to create consistency in Chapter 3 Part II construction specifications needs to be relocated back to 310.104 and changes to Part III.
this was originally moved to 310.104 in the 2011 code cycle ROP# 70-A2010ROP Page 70.
The article parts should breakdown
Part I General
Part II Installation
Part III Construction Specification
this will make it consistent with all the wiring methods in chapter 3

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2769-NFPA 70-2020 [Part III.]	
Public Input No. 2770-NFPA 70-2020 [New Section after 310.21]	

Submitter Information Verification

Submitter Full Name: Jon Coulimore
Organization: JC Electric, Inc.
Street Address:
City:
State:

Zip:

Submittal Date: Mon Aug 31 14:36:32 EDT 2020

Committee: NEC-P06

Committee Statement

Resolution: Article 310 is unique in that it does not contain specific installation instructions, so it does not need to match the other articles.

Public Input No. 3254-NFPA 70-2020 [Sections Part II., 400.20, 400.21, 400.22, 400.23, 400.24]

~~Sections Part II., 400.20, 400.21, 400.22, 400.23, 400.24~~

~~Part II.~~ ~~Construction Specifications~~

~~400.20~~ ~~Labels.~~

~~Flexible cords shall be examined and tested at the factory and labeled before shipment.~~

~~400.21~~ ~~Construction.~~

~~(A)~~ ~~Conductors.~~

~~The individual conductors of a flexible cord or flexible cable shall have copper flexible stranding and shall not be smaller than the sizes specified in Table 400.4 .~~

~~(B)~~ ~~Nominal Insulation Thickness.~~

~~The nominal thickness of insulation for conductors of flexible cords and flexible cables shall not be less than specified in Table 400.4 .~~

~~400.22~~ ~~Grounded-Conductor Identification.~~

~~One conductor of flexible cords that is intended to be used as a grounded circuit conductor shall have a continuous marker that readily distinguishes it from the other conductor or conductors. The identification shall consist of one of the methods indicated in 400.22(A) through (F).~~

~~(A)~~ ~~Colored Braid.~~

~~A braid finished to show a white or gray color and the braid on the other conductor or conductors finished to show a readily distinguishable solid color or colors.~~

~~(B)~~ ~~Tracer in Braid.~~

~~A tracer in a braid of any color contrasting with that of the braid and no tracer in the braid of the other conductor or conductors. No tracer shall be used in the braid of any conductor of a flexible cord that contains a conductor having a braid finished to show white or gray.~~

~~Exception:~~ ~~In the case of Types C and PD and cords having the braids on the individual conductors finished to show white or gray. In such cords, the identifying marker shall be permitted to consist of the solid white or gray finish on one conductor, provided there is a colored tracer in the braid of each other conductor.~~

~~(C)~~ ~~Colored Insulation.~~

~~A white or gray insulation on one conductor and insulation of a readily distinguishable color or colors on the other conductor or conductors for cords having no braids on the individual conductors.~~

~~For jacketed cords furnished with appliances, one conductor having its insulation colored light blue, with the other conductors having their insulation of a readily distinguishable color other than white or gray.~~

~~Exception:~~ ~~Cords that have insulation on the individual conductors integral with the jacket.~~

~~The insulation shall be permitted to be covered with an outer finish to provide the desired color.~~

~~(D)~~ ~~Colored Separator.~~

~~A white or gray separator on one conductor and a separator of a readily distinguishable solid color on the other conductor or conductors of cords having insulation on the individual conductors integral with the jacket.~~

~~**(E)** Tinned Conductors.~~

~~One conductor having the individual strands tinned and the other conductor or conductors having the individual strands untinned for cords having insulation on the individual conductors integral with the jacket.~~

~~**(F)** Surface Marking.~~

~~One or more ridges, grooves, or white stripes located on the exterior of the cord so as to identify one conductor for cords having insulation on the individual conductors integral with the jacket.~~

~~**400.23** Equipment Grounding Conductor Identification.~~

~~A conductor intended to be used as an equipment grounding conductor shall have a continuous identifying marker readily distinguishing it from the other conductor or conductors. Conductors having a continuous green color or a continuous green color with one or more yellow stripes shall not be used for other than equipment grounding conductors. Cords or cables consisting of integral insulation and a jacket without a nonintegral equipment grounding conductor shall be permitted to be green. The identifying marker shall consist of one of the methods in 400.23(A) or (B).~~

~~**(A)** Colored Braid.~~

~~A braid finished to show a continuous green color or a continuous green color with one or more yellow stripes.~~

~~**(B)** Colored Insulation or Covering.~~

~~For cords having no braids on the individual conductors, an insulation of a continuous green color or a continuous green color with one or more yellow stripes.~~

~~**400.24** Attachment Plugs.~~

~~Where a flexible cord is provided with an equipment grounding conductor and equipped with an attachment plug, the attachment plug shall comply with 250.138(A) and (B).~~

Statement of Problem and Substantiation for Public Input

This is covered by product standard (UL 62) and does not need to be repeated in the CODE.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
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City:
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Submittal Date: Mon Sep 07 10:56:52 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: The NEC states minimum construction requirements that are used to develop product safety standards. Inclusion of construction requirements is consistent with other articles for wiring methods.

Public Input No. 2659-NFPA 70-2020 [Part III.]

Part III. Portable Cables Over 600 Volts, ~~Nominal~~ up to 2000 Volts, Nominal

Statement of Problem and Substantiation for Public Input

This is a companion PI to PI number 2700 Part IV for cables over 2000 Volts Nominal.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2700-NFPA 70-2020 [New Section after 400.36]	Companion

Submitter Information Verification

Submitter Full Name: Paul Knapp
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Submittal Date: Thu Aug 27 14:27:55 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: FR-8475-NFPA 70-2021
Statement: The title to Part III was revised in order to accommodate adding a new Part IV.

Public Input No. 2769-NFPA 70-2020 [Part III.]

Part ~~III.~~ II Installation

Statement of Problem and Substantiation for Public Input

See Public Input # 2768. Relocating Part II Construction Specification to Part III 310.104. Part II will then become Part II Installation.
this will comply with the style manual and provide consistency with other articles in chapter 3

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2768-NFPA 70-2020 [Sections Part II., 310.4, 310.6, 310.8]	

Submitter Information Verification

Submitter Full Name: Jon Coulimore
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Submittal Date: Mon Aug 31 14:53:55 EDT 2020
Committee: NEC-P06

Committee Statement

Resolution: Article 310 is unique in that it does not contain specific installation instructions, so it does not need to match the other articles.

Public Input No. 137-NFPA 70-2019 [Section No. Table]

Table 8

Table 8 Conductor Properties

Size (AWG or kcmil)	Conductors									
	Area		Stranding		Overall					
				Diameter		Diameter		Area		
	mm^2	Circular mils	Quantity	mm	in.	mm	in.	mm^2	$in.^2$
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219
250	127	— 250000	37	2.09	0.082	14.61	0.575	168	0.260
300	152	— 300000	37	2.29	0.090	16.00	0.630	201	0.312
350	177	— 350000	37	2.47	0.097	17.30	0.681	235	0.364
400	203	— 400000	37	2.64	0.104	18.49	0.728	268	0.416
500	253	— 500000	37	2.95	0.116	20.65	0.813	336	0.519
600	304	— 600000	61	2.52	0.099	22.68	0.893	404	0.626
700	355	— 700000	61	2.72	0.107	24.49	0.964	471	0.730
750	380	— 750000	61	2.82	0.111	25.35	0.998	505	0.782
800	405	— 800000	61	2.91	0.114	26.16	1.030	538	0.834
900	456	— 900000	61	3.09	0.122	27.79	1.094	606	0.940
1000	507	— 1000000	61	3.25	0.128	29.26	1.152	673	1.042
1250	633	— 1250000	91	2.98	0.117	32.74	1.289	842	1.305
1500	760	— 1500000	91	3.26	0.128	35.86	1.412	1011	1.566
1750	887	— 1750000	127	2.98	0.117	38.76	1.526	1180	1.829

Size	Conductors									
	Area			Stranding		Overall				
(AWG or kcmil)	mm^2	Circular mils	Quantity	Diameter mm	Diameter in.	Diameter mm	Diameter in.	Area mm^2	Area $in.^2$
2000	1013	200000	127	3.19	0.126	41.45	1.632	1349	2.092

Notes:

1. These resistance values are valid **only** for the parameters as given. Using conductors having coated strands, different stranding type, and,

especially, other temperatures changes the resistance.

2. Equation for temperature change: $R_2 = R_1$ [1 + a (T_2 - 75)], where α_{cu} = 0.00323, α_{AL} = 0.00330 at 75°C.

3. Conductors with compact and compressed stranding have about 9 percent and 3 percent, respectively,

smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.

4. The IACS conductivities used: bare copper = 100%, aluminum = 61%.

5. Class B stranding is listed as well as solid for some sizes. Its overall diameter and area are those of its circumscribing circle.

Informational Note: The construction information is in accordance with NEMA WC/70-2009 or ANSI/UL 1581-2017.

The resistance is calculated in accordance with *National Bureau of Standards Handbook 100*, dated 1966, and

Handbook 109, dated 1972.

Statement of Problem and Substantiation for Public Input

The circular mil area of the conductors needs to be shown. Otherwise, it appears from this table that the conductors in kcmil sizes have a mm squared area but not a kcmil area.
The present information can be confusing when using or teaching this Table. One has to explain that the table does indeed include the kcmil area of the noted conductors. You just need to look at the left column and add 1000 to the conductor size designation.

Submitter Information Verification

Submitter Full Name: Phil Simmons
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City:
State:
Zip:
Submittal Date: Thu Nov 21 13:59:55 EST 2019

Committee: NEC-P06

Committee Statement

Resolution: The table should remain as is. The first column designates either kcmil or awg and the third column designates circular mils. Adding the circular mill value to the table for values 250kcmil-2000kcmil is redundant. This table provides clarity in its current state and is not designed for the untrained code user.