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 MV-105*	90°C 105°C	Dry or wet locations	Thermoplastic or thermosetting	Jacket, sheath, or armor

*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						
	Without Jacket Insulation		With Jacket				Single Conductor						Multicondu Insulatic
			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

Conductor Size	2001–5000 Volts	5001–8000 Volts			8001–15,000
	100 Percent	100 Percent	133 Percent	173 Percent	100 Percent

(AWG or kcmil)	Insulation Level mm	Insulation Level mils	Insulation Level mm	Insulation Level mils	Insulation Level mm	Insulation Level mils	Insulation Level mm	Insulation Level mils	Insulation Level mm	Insulation Level 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	P 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.

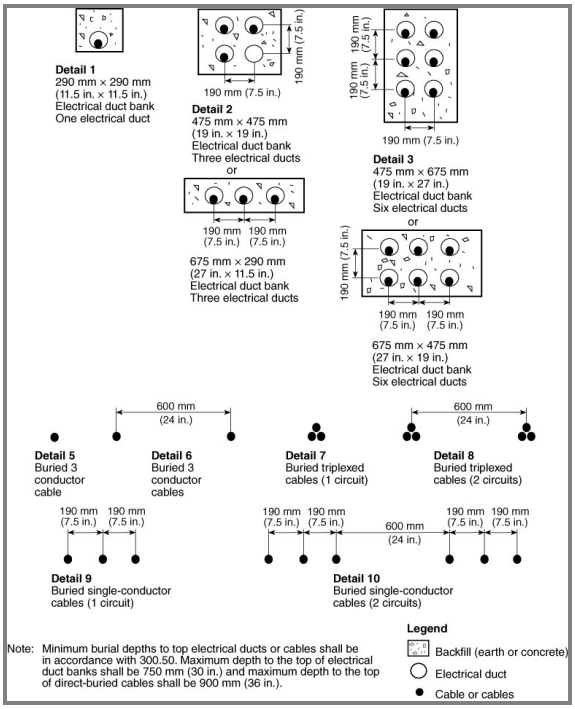
(a) Where burial depths are increased in part(s) of an electrical duct run, a decrease in ampacity of the conductors shall not be required, provided the total length of parts of the duct run increased in depth is less than 25 percent of the total run length.

(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:

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[311.60(D)(4}$$

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

Submitter Full Name: Paul Knapp
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 26 13:58:15 EDT 2020
Committee: NEC-P06

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:
State:
Zip:
Submittal Date: Wed Sep 09 15:23:41 EDT 2020
Committee: NEC-P06

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. <u>This article does not cover cables used above 2500 V for direct-current (dc) circuits.</u>

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

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

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 **Initiated by:** AAS-100	**AC No:** 150/5345-7F **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

This page intentionally left blank.

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

This page intentionally left blank.

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 **Initiated by:** AAS-100	**AC No:** 150/5345-7F **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

This page intentionally left blank.

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

This page intentionally left blank.

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

Prysmian Group
4 Tesseneer Drive | Highland Heights, KY 41076 | +1-859-572-8000 | website: na.prysmiangroup.com
Sales and Distribution:
One Tamaqua Blvd. | Schuylkill Haven PA 17972 | +1-570-385-4381

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.

© DRAKA - A Brand of The Prysmian Group. 2019 All Rights Reserved. The information contained within this document must not be copied, reprinted or reproduced in any form, either wholly or in part, without the written consent of Prysmian Group. The information is believed correct at the time of issue. Prysmian Group reserves the right to amend any specifications without notice. These specifications are not contractually valid unless authorized by Prysmian Group. Issued January 2019.

Prysmian Group

4 Tesseneer Drive | Highland Heights, KY 41076 | +1-859-572-8000 | website: na.prysmiangroup.com

Sales and Distribution:

One Tamaqua Blvd. | Schuylkill Haven PA 17972 | +1-570-385-4381

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.

Prysmian Group

4 Tesseneer Drive | Highland Heights, KY 41076 | +1-859-572-8000 | website: na.prysmiangroup.com

Sales and Distribution:

One Tamaqua Blvd. | Schuylkill Haven PA 17972 | +1-570-385-4381

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.

© DRAKA - A Brand of The Prysmian Group. 2019 All Rights Reserved. The information contained within this document must not be copied, reprinted or reproduced in any form, either wholly or in part, without the written consent of Prysmian Group. The information is believed correct at the time of issue. Prysmian Group reserves the right to amend any specifications without notice. These specifications are not contractually valid unless authorized by Prysmian Group. Issued January 2019.

Prysmian Group

4 Tesseneer Drive | Highland Heights, KY 41076 | +1-859-572-8000 | website: na.prysmiangroup.com

Sales and Distribution:

One Tamaqua Blvd. | Schuylkill Haven PA 17972 | +1-570-385-4381

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.

© DRAKA - A Brand of The Prysmian Group. 2019 All Rights Reserved. The information contained within this document must not be copied, reprinted or reproduced in any form, either wholly or in part, without the written consent of Prysmian Group. The information is believed correct at the time of issue. Prysmian Group reserves the right to amend any specifications without notice. These specifications are not contractually valid unless authorized by Prysmian Group. Issued January 2019.

Prysmian Group

4 Tesseneer Drive | Highland Heights, KY 41076 | +1-859-572-8000 | website: na.prysmiangroup.com

Sales and Distribution:

One Tamaqua Blvd. | Schuylkill Haven PA 17972 | +1-570-385-4381

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.

-

.

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

Submitter Full Name:	L P
Organization:	{Note to Editorial staff: "L P" is a ;screen name', actual name is 'Leif Pihl'}
Affiliation:	Member, IBEW LU 292
Street Address:	
City:	
State:	

Zip:
Submittal Date: Wed Sep 09 21:24:48 EDT 2020
Committee: NEC-P06

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

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Tue Apr 21 13:07:37 EDT 2020
Committee: NEC-P06

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
Organization: AVCON, Inc.
Affiliation: none
Street Address:
City:
State:
Zip:
Submittal Date: Tue May 19 17:03:29 EDT 2020
Committee: NEC-P06

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
Organization: AVCON, Inc.
Affiliation: none
Street Address:
City:
State:
Zip:
Submittal Date: Tue May 05 17:27:21 EDT 2020
Committee: NEC-P06

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

Submitter Full Name: Agnieszka Golriz
Organization: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 05:46:09 EDT 2020
Committee: NEC-P06

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

Submitter Full Name: Carl Johnson II
Organization: AVCON, Inc.
Affiliation: none
Street Address:
City:
State:
Zip:
Submittal Date: Tue May 05 17:40:12 EDT 2020
Committee: NEC-P06

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
Organization: Fluor Enterprises, Inc.
Affiliation: Associated Builders and Contractors
Street Address:
City:
State:
Zip:
Submittal Date: Tue Nov 12 15:57:37 EST 2019
Committee: NEC-P06

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table of Contents

1.0 Introduction and Purpose 1
2.0 Testing Arrangement and Setup 2
3.0 Materials for Testing 6
4.0 Test Procedures 7
5.0 Test Results 11
6.0 Conclusions 16
7.0 Test Equipment and Calibration 17

Appendices

A – Photos ..... A1 – A12
B – Copper-Clad Aluminum Material Verification ..... B1 – B7
C – Static Heating Test Data
C1 – Static Heating Test at 100% Rated Current ..... C1-1 – C1-6
C2 – Static Heating Test at 135% Rated Current ..... C2-1 – C2-6
C3 – Static Heating Test at 150% Rated Current ..... C3-1 – C3-6
C4 – Static Heating Test at 200% Rated Current ..... C4-1 – C4-6
C5 – Static Heating Original 100% and 135% Trip Failure C5-1
D – Flexing Tests Data D1
E – Certificates of Calibration ..... E1 – E26

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.

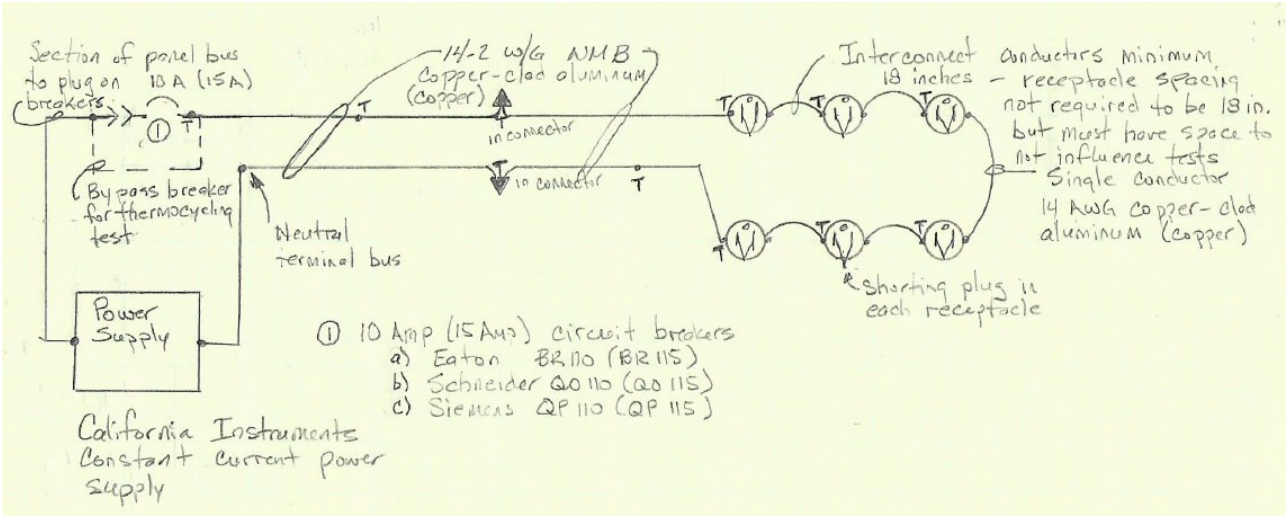


Figure 1 – Typical Test Circuit Diagram

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

Appendix A - Photos

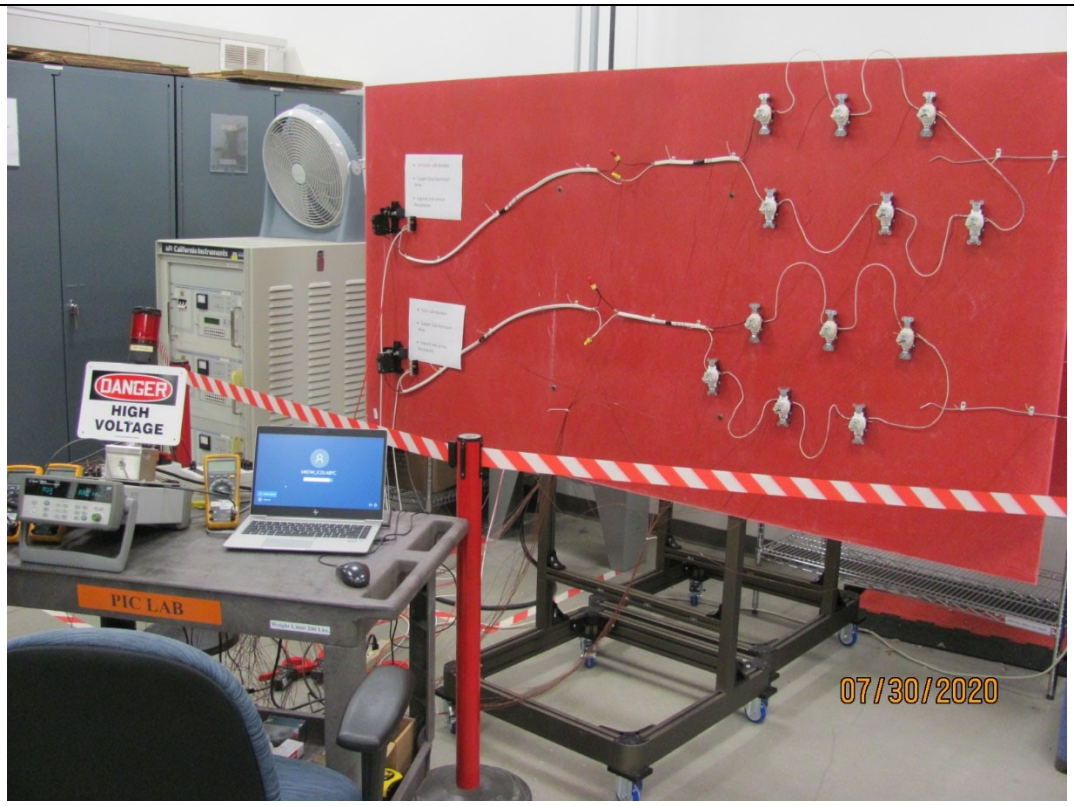


Photo 3 – Test Board and Test Equipment Arrangement

Photo 4 – Copper-Clad Aluminum with Eaton and Hubbell Receptacles

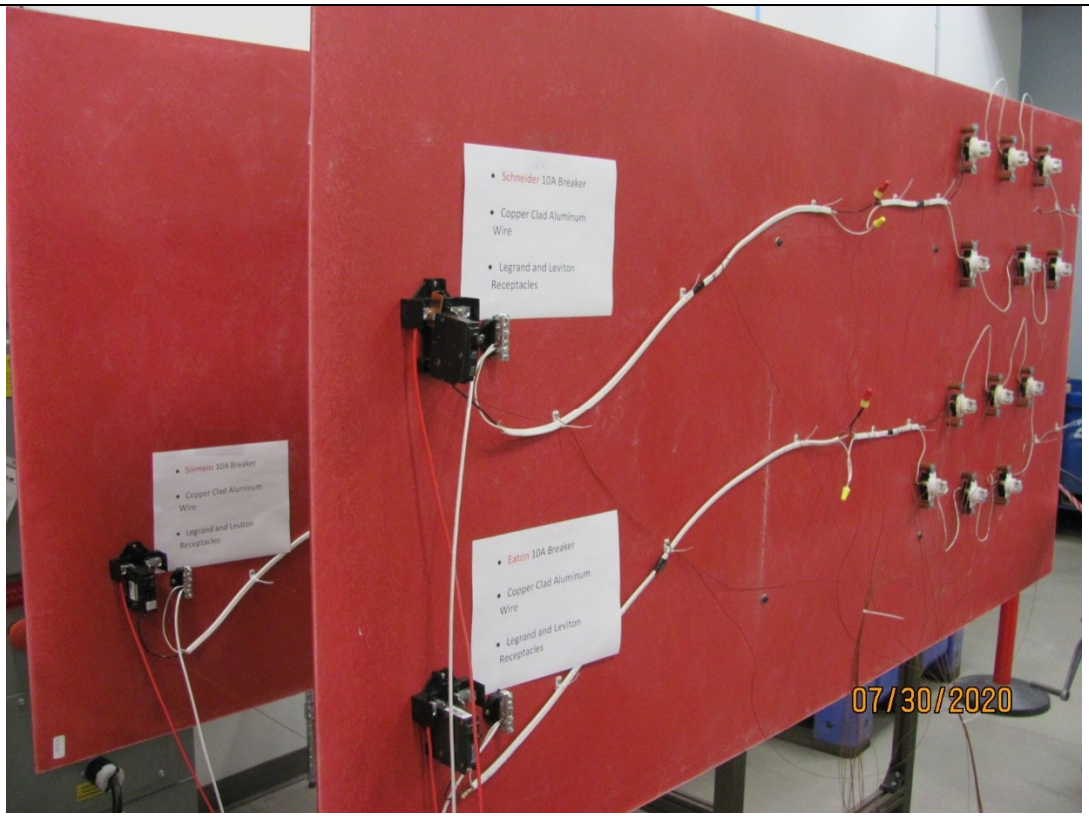


Photo 5 – Copper-Clad Aluminum with Legrand and Leviton Receptacles

Photo 6 – Copper with Eaton and Hubbell Receptacles

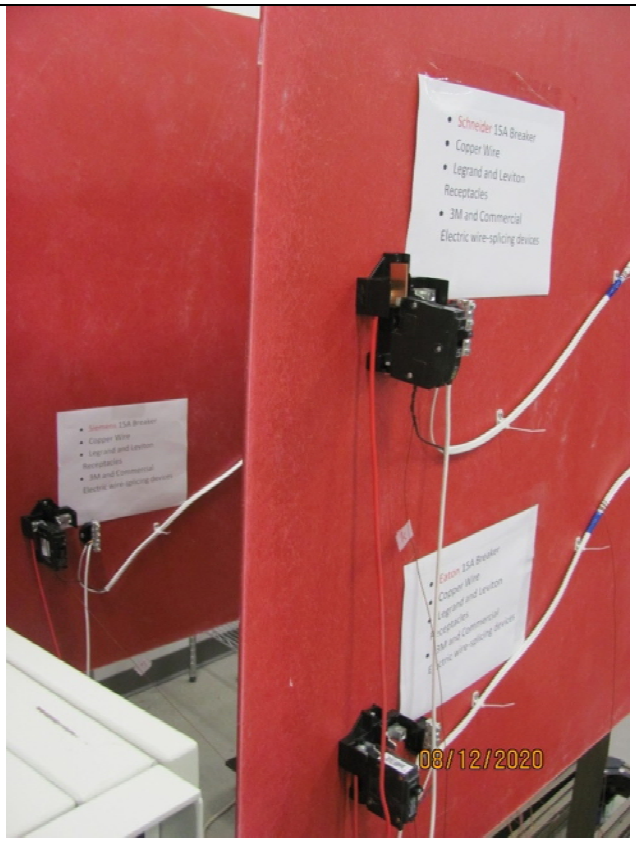


Photo 7 – Copper with Legrand and Leviton Receptacles

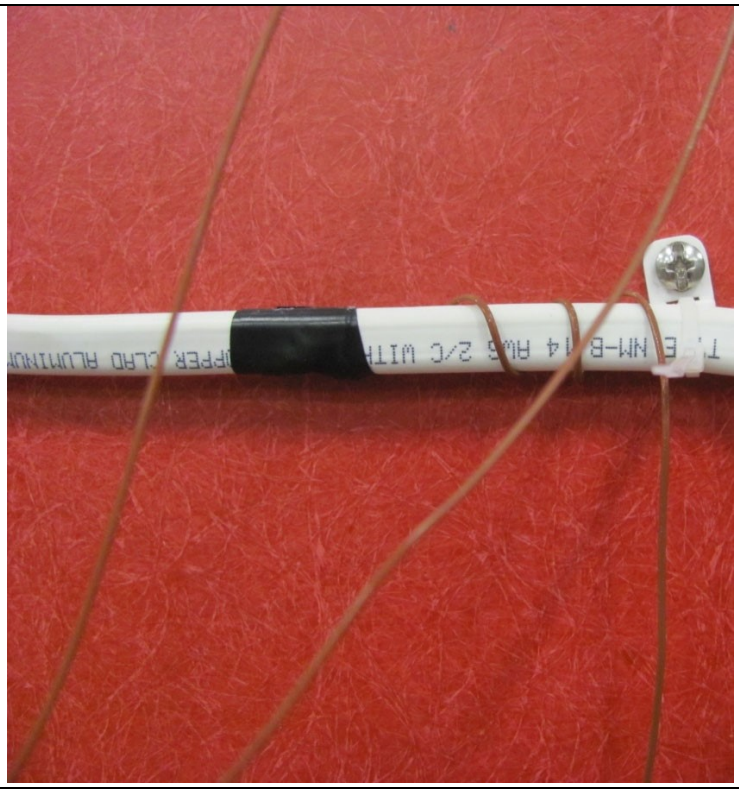


Photo 8 – Copper-Clad Aluminum NM-B Cable

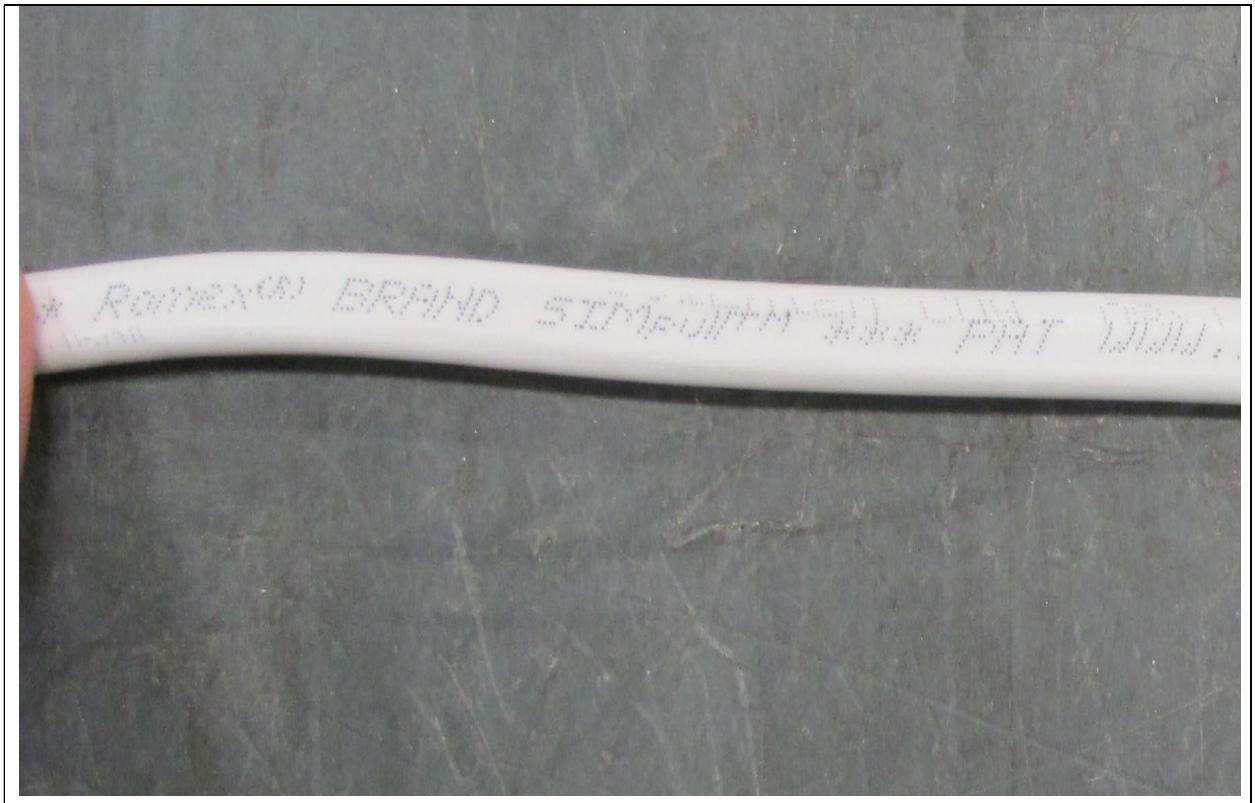


Photo 9 – Copper NM-B Cable

Photo 10 – Copper NM-B Cable Packaging

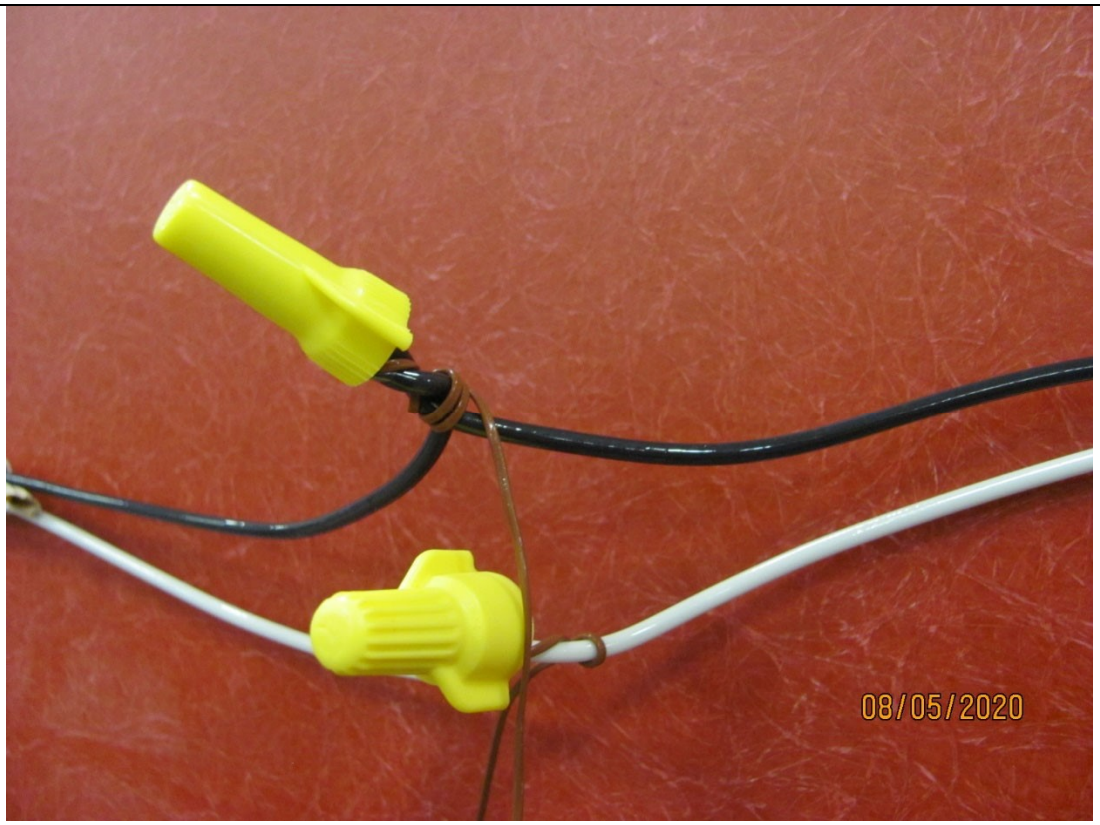


Photo 11 – Typical Installation of Wire Splicing Devices with Thermocouple

Photo 12 – Typical Installation of Receptacle using Wire Binding Screw

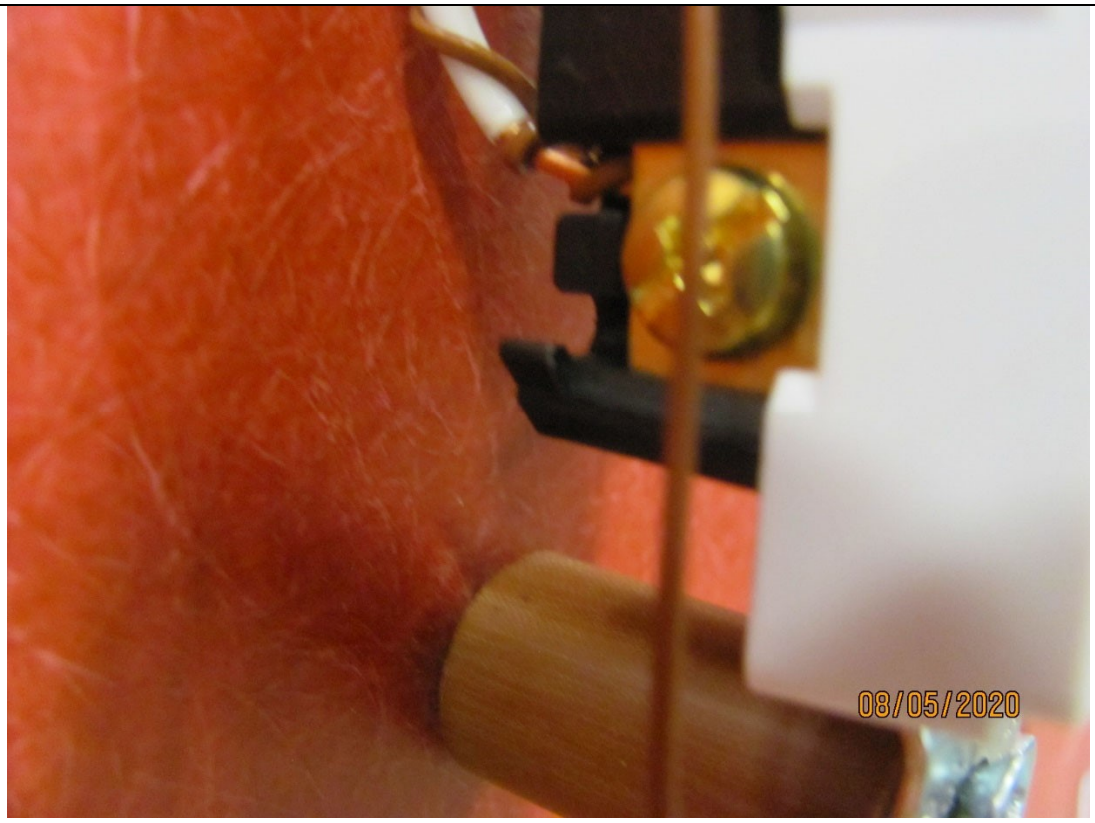


Photo 13 – Typical Installation of Receptacle Since Conductor Back Wired

Photo 14 – Typical Installation of Receptacle Two Conductors Back Wired

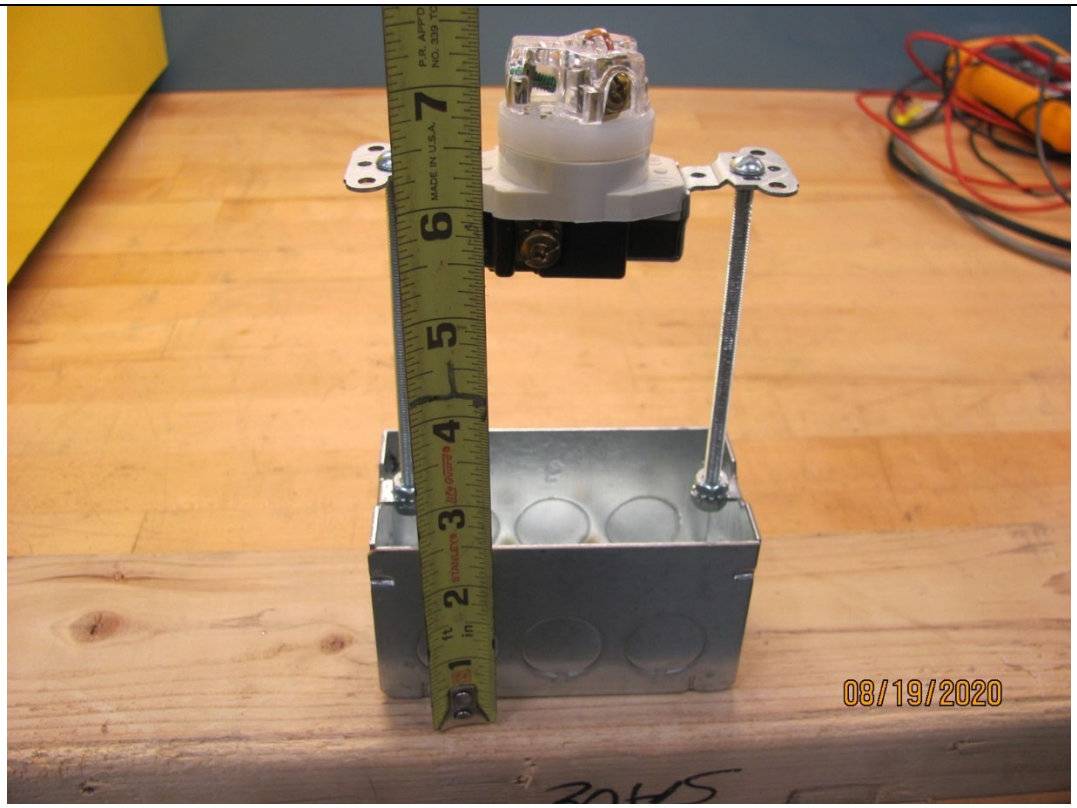


Photo 15 – Flexing Test Setup

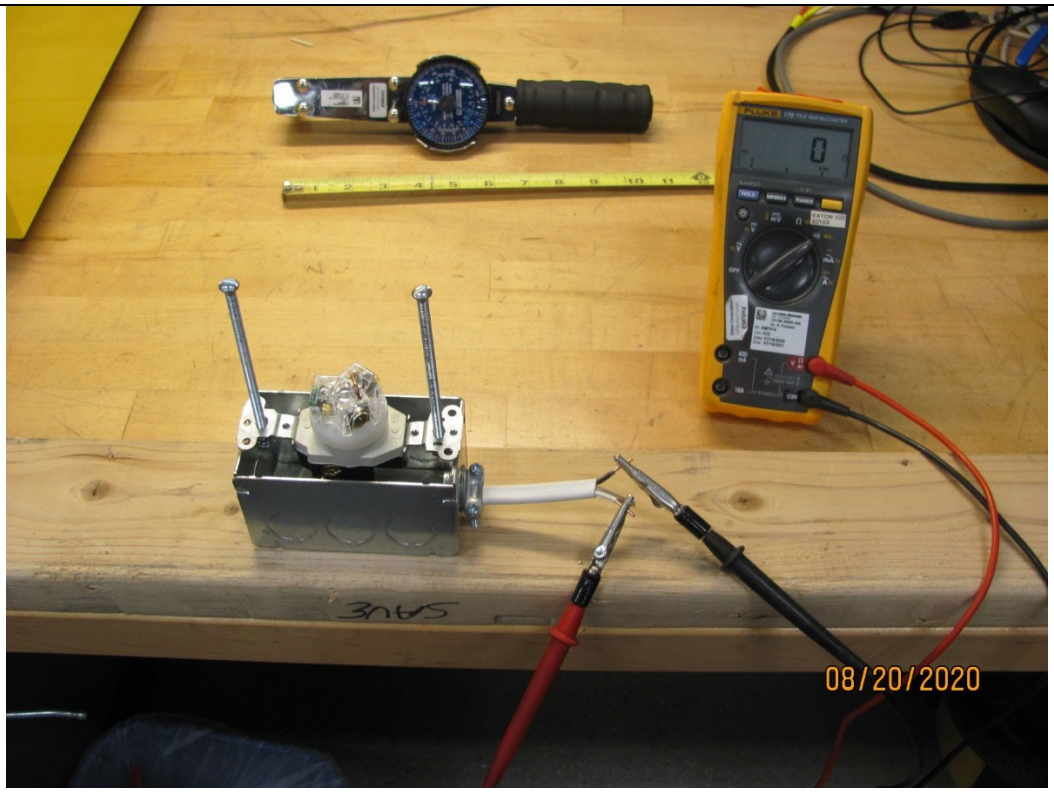


Photo 16 – Flexing Test Setup

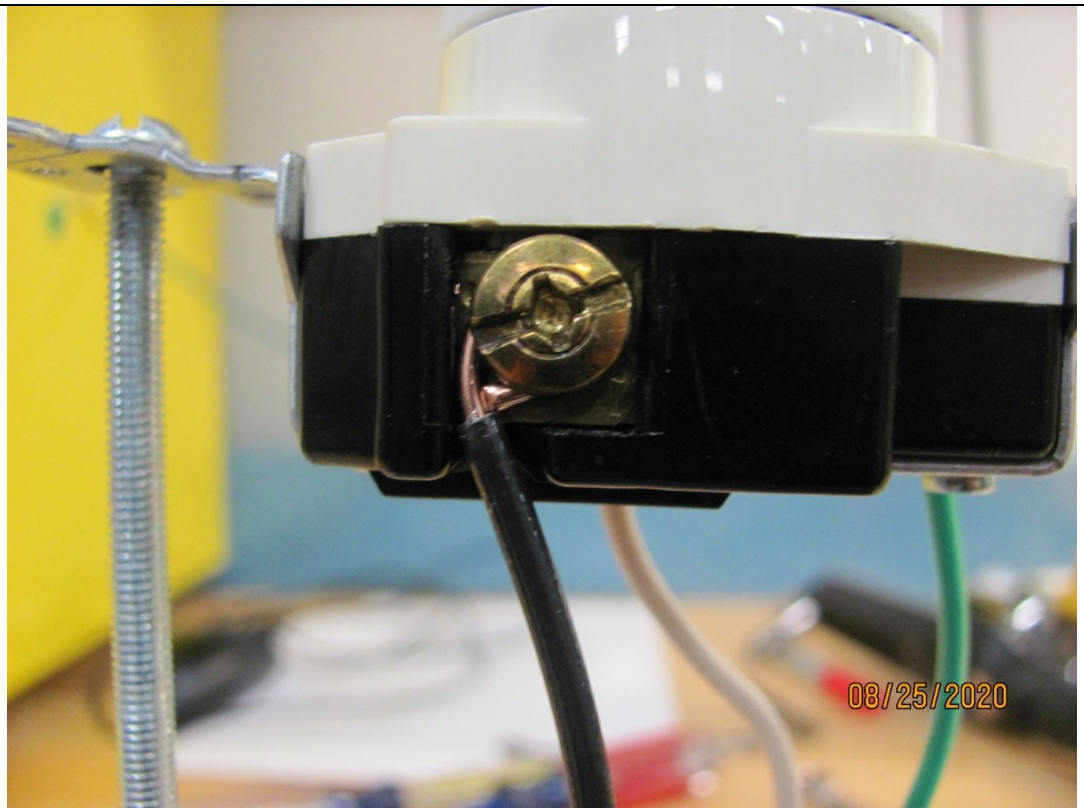


Photo 17 – Flexing Test Fully Extended

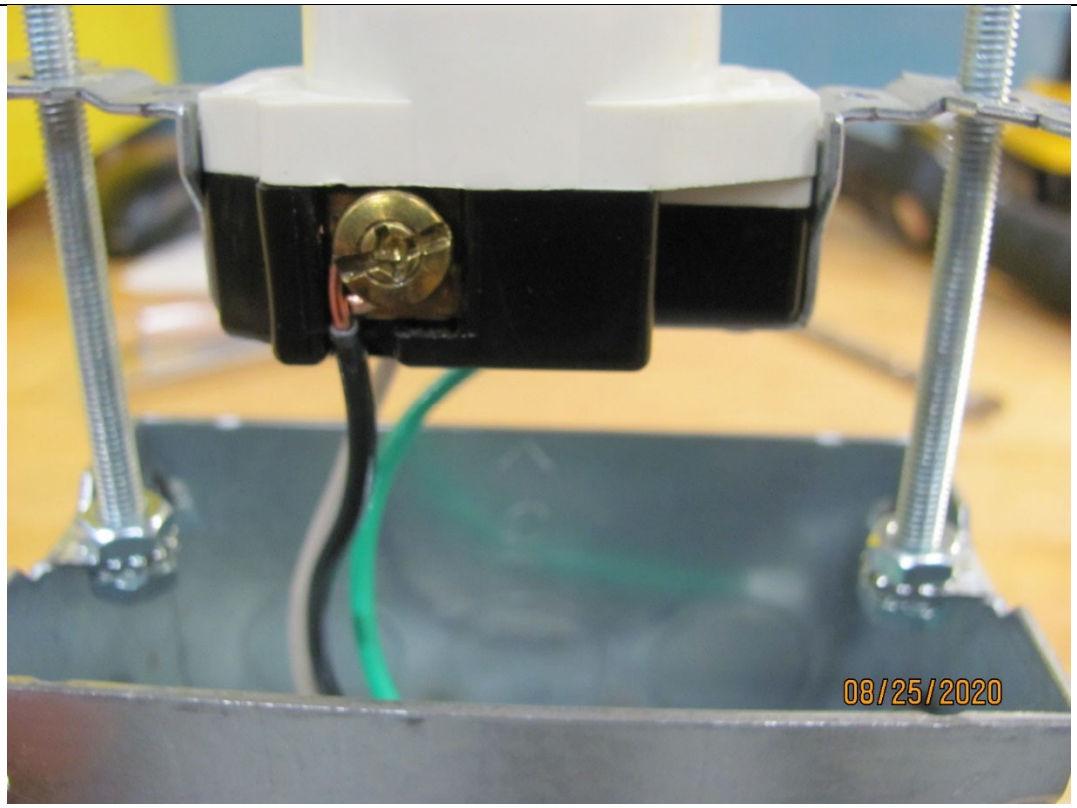


Photo 18 – Flexing Test Partial Insertion

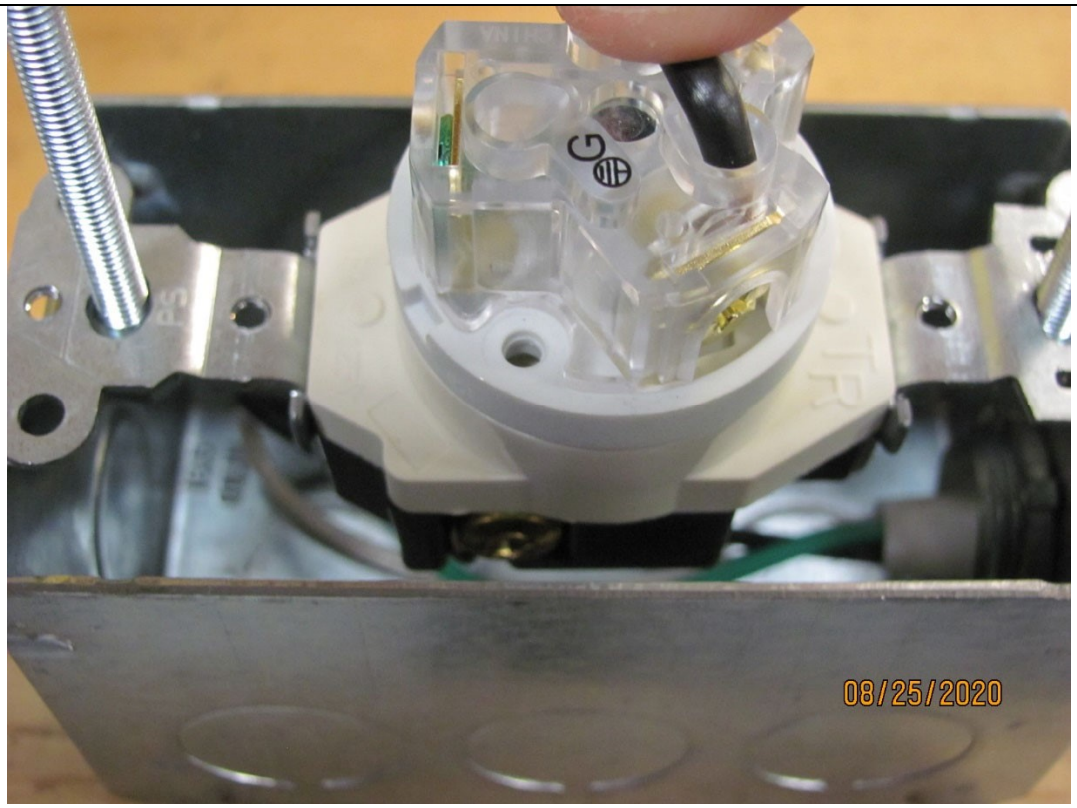


Photo 19 – Flexing Test Fully Inserted

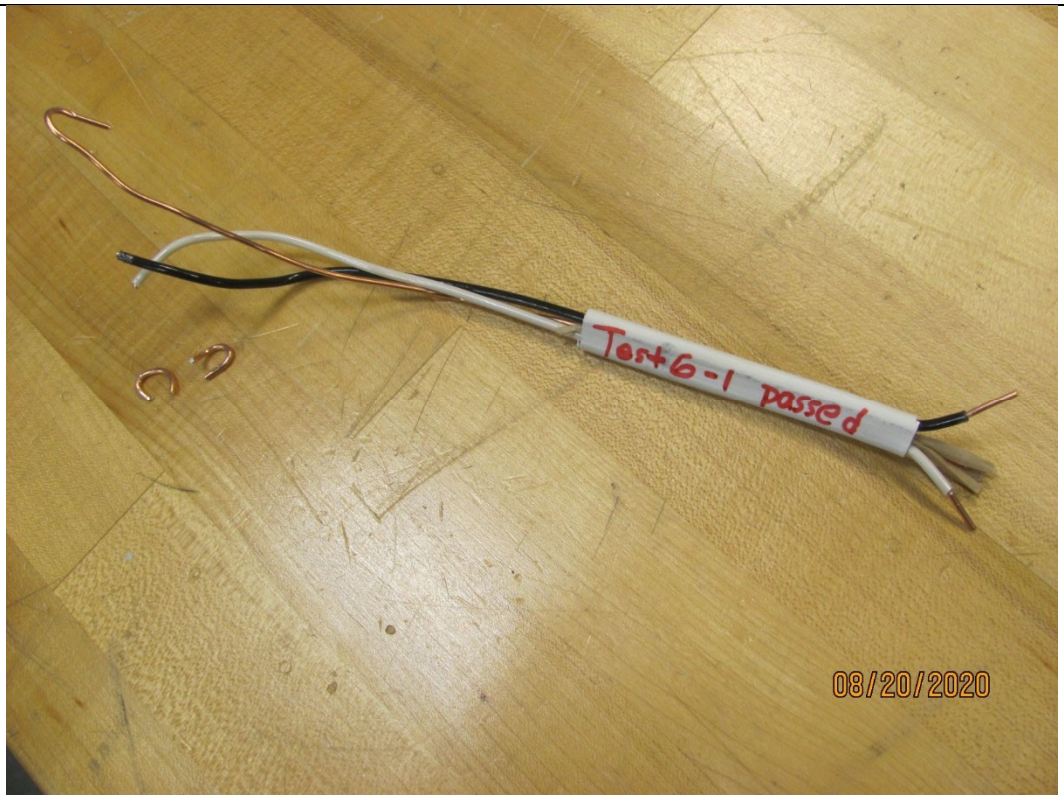


Photo 20 – Flexing Test Broken Conductors When Removing

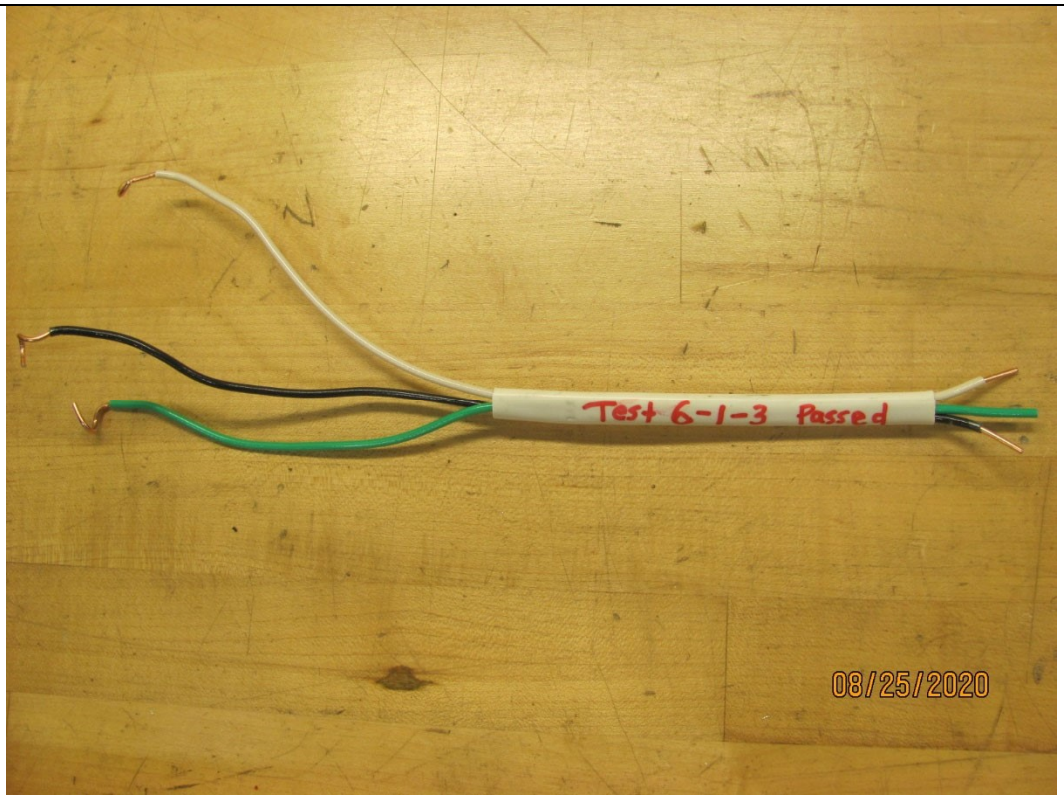


Photo 21 – Flexing Test Repeat No Conductor Breakage

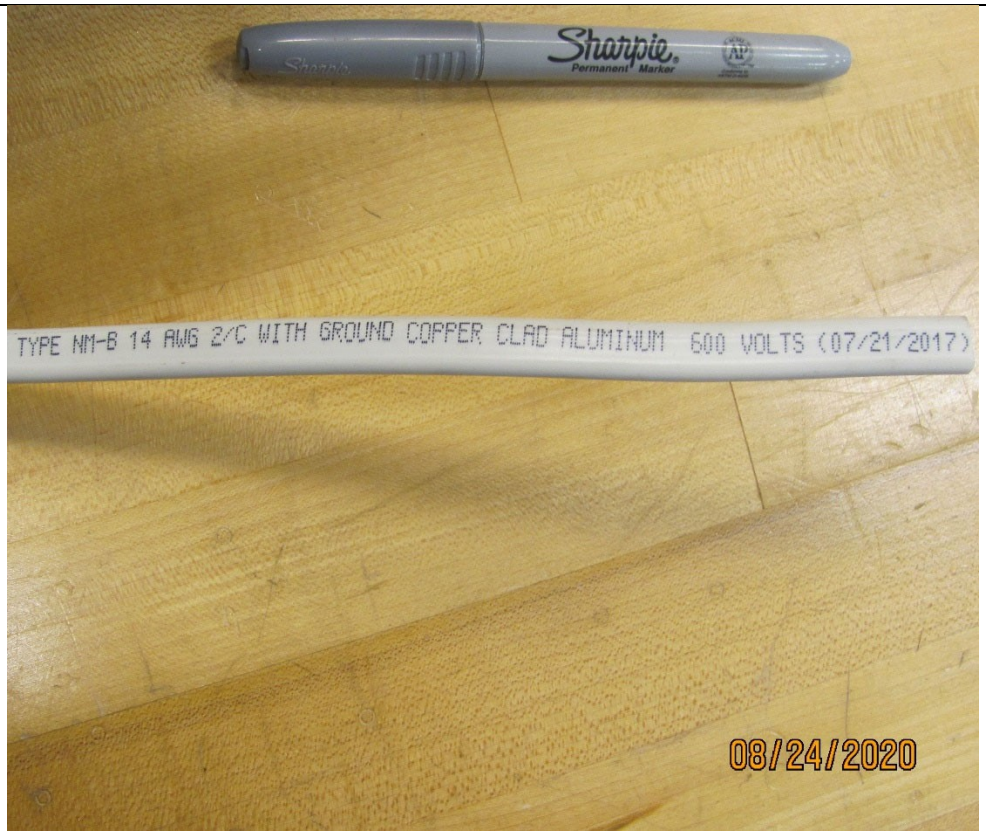


Photo 22 – Copper-Clad Aluminum NM-B Sample Packaging at Eaton

Photo 23 – Copper-Clad Aluminum THHN Sample Packaging at Eaton

Photo 24 – Copper-Clad Aluminum Sample Packaging at Eaton

COPPERWELD | Wired to Protect

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**

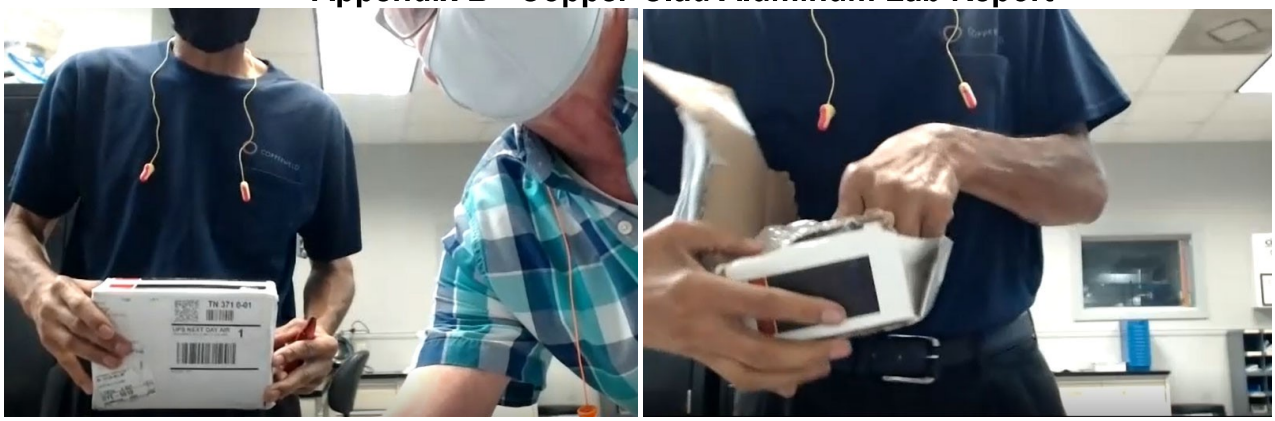
Analysis By:	**Sammy Hampton --Metallographer**
Authored By:	**Sammy Hampton –Metallographer**
Approved By:	**Bill Lewey– QA Manager**

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

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.



Opening the Package

Package Contents

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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**

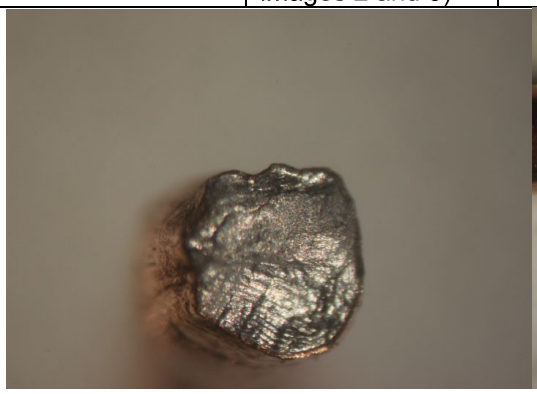


Image 1: adhesion test

Image 2: cohesion test (torsion)

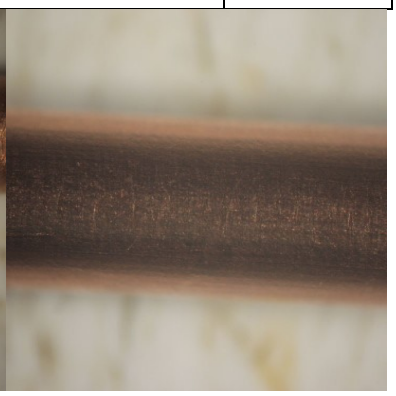


image 3: cohesion test (reverse torsion)

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			

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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	Fnd As	Lft 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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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

Revision Date:05/08/2020
Rev: 04
Page 1 of 2
QF0016

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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04
Page 2 of 2
QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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 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	Last Cal Date (As Of Cal Entry Date)	Next Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

Follow-up Service Inspection Report
E49118512008271652 02

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: Factory Rep Email:	931-433-0495 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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

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 #	→	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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C4 Static Heating Tests at 200% Rated Current

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			

Appendix C5 Static Heating Testing Schneider Circuit Breaker

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

Report No: JK202006300-003
Page 1 of 2

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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	

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

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						

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

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

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

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

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

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

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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

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	299.9	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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

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

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
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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.3	500.3	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.1	500.1	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.0	500.0	0.07
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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-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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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
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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 (1⁄4 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

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

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

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

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

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

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

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

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

Table of Contents

1.0 Introduction and Purpose 1
2.0 Testing Arrangement and Setup 2
3.0 Materials for Testing 6
4.0 Test Procedures 7
5.0 Test Results 11
6.0 Conclusions 16
7.0 Test Equipment and Calibration 17

Appendices

A – Photos ..... A1 – A12
B – Copper-Clad Aluminum Material Verification ..... B1 – B7
C – Static Heating Test Data
C1 – Static Heating Test at 100% Rated Current ..... C1-1 – C1-6
C2 – Static Heating Test at 135% Rated Current ..... C2-1 – C2-6
C3 – Static Heating Test at 150% Rated Current ..... C3-1 – C3-6
C4 – Static Heating Test at 200% Rated Current ..... C4-1 – C4-6
C5 – Static Heating Original 100% and 135% Trip Failure C5-1
D – Flexing Tests Data D1
E – Certificates of Calibration ..... E1 – E26

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.

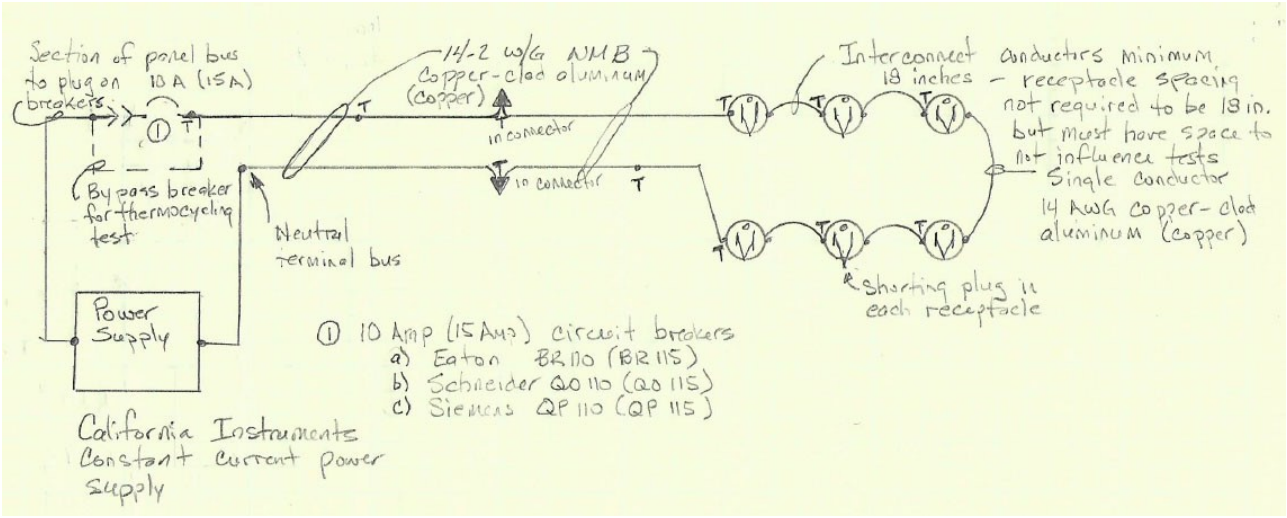


Figure 1 – Typical Test Circuit Diagram

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

Appendix A - Photos

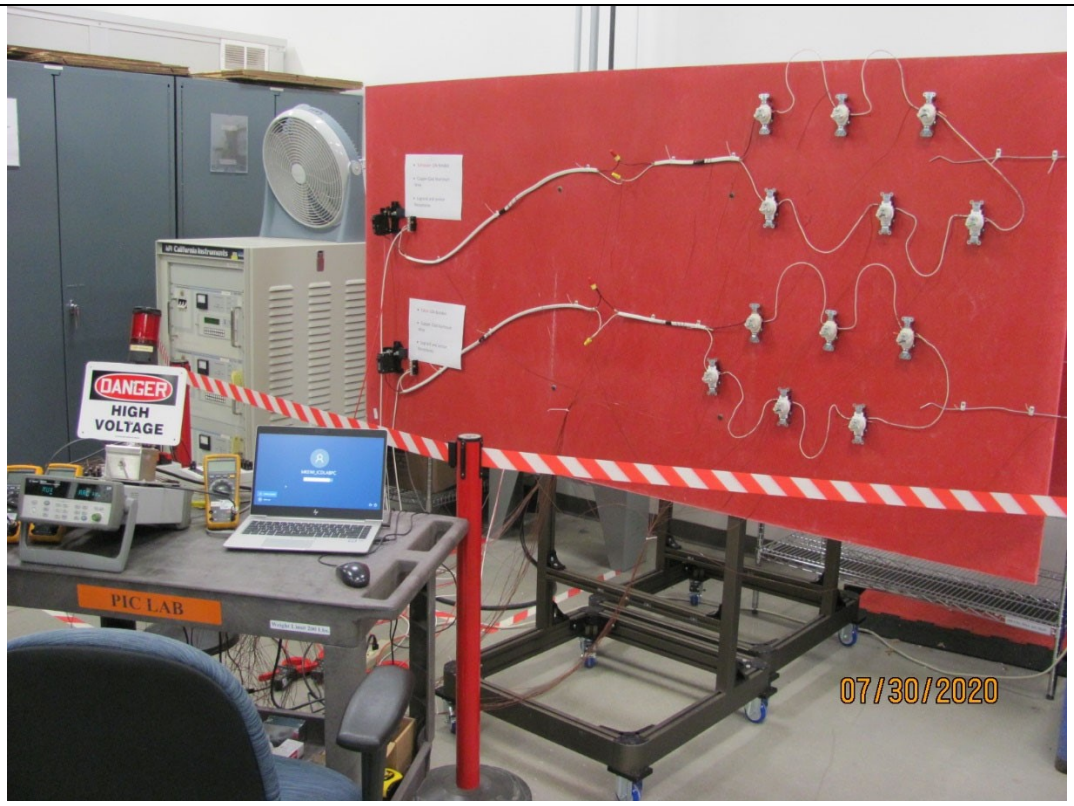


Photo 3 – Test Board and Test Equipment Arrangement

Photo 4 – Copper-Clad Aluminum with Eaton and Hubbell Receptacles

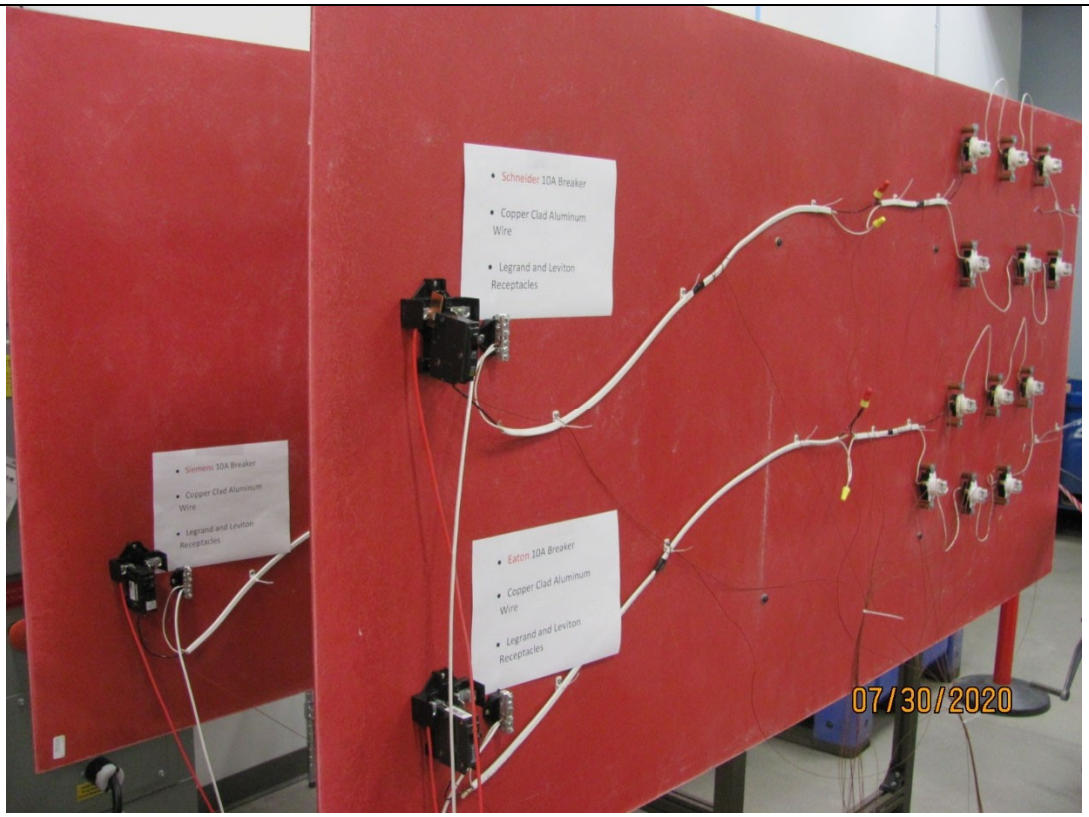


Photo 5 – Copper-Clad Aluminum with Legrand and Leviton Receptacles

Photo 6 – Copper with Eaton and Hubbell Receptacles

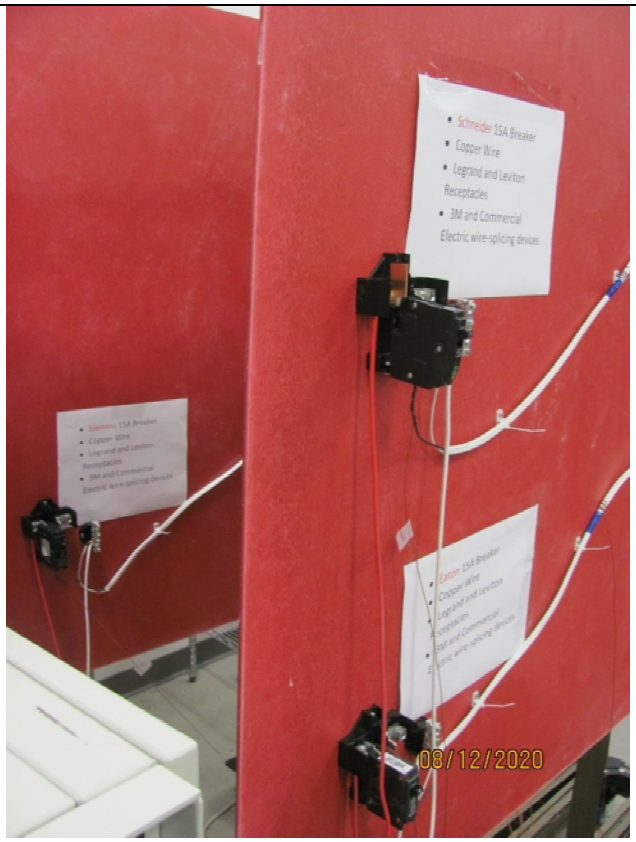


Photo 7 – Copper with Legrand and Leviton Receptacles

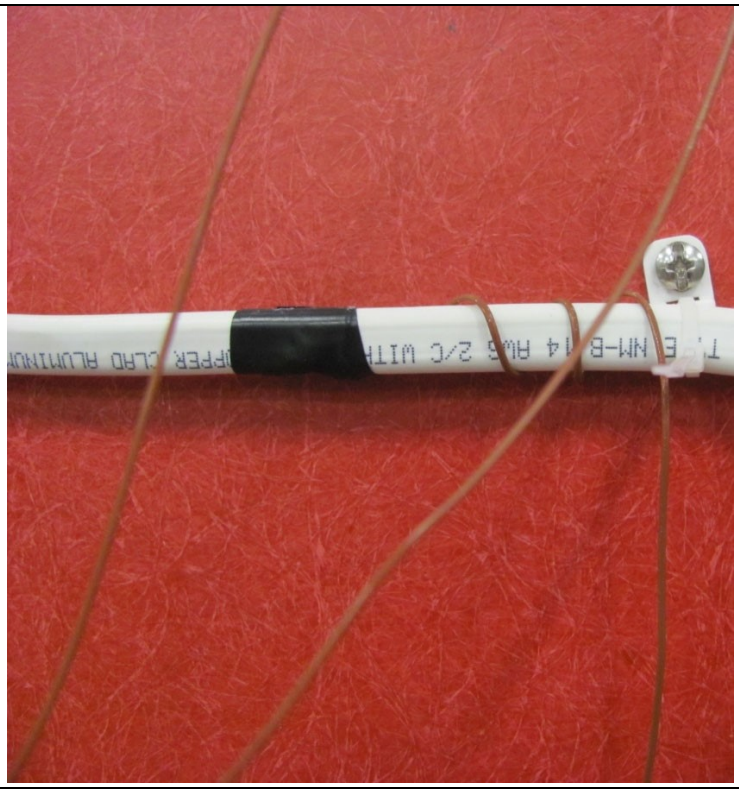


Photo 8 – Copper-Clad Aluminum NM-B Cable

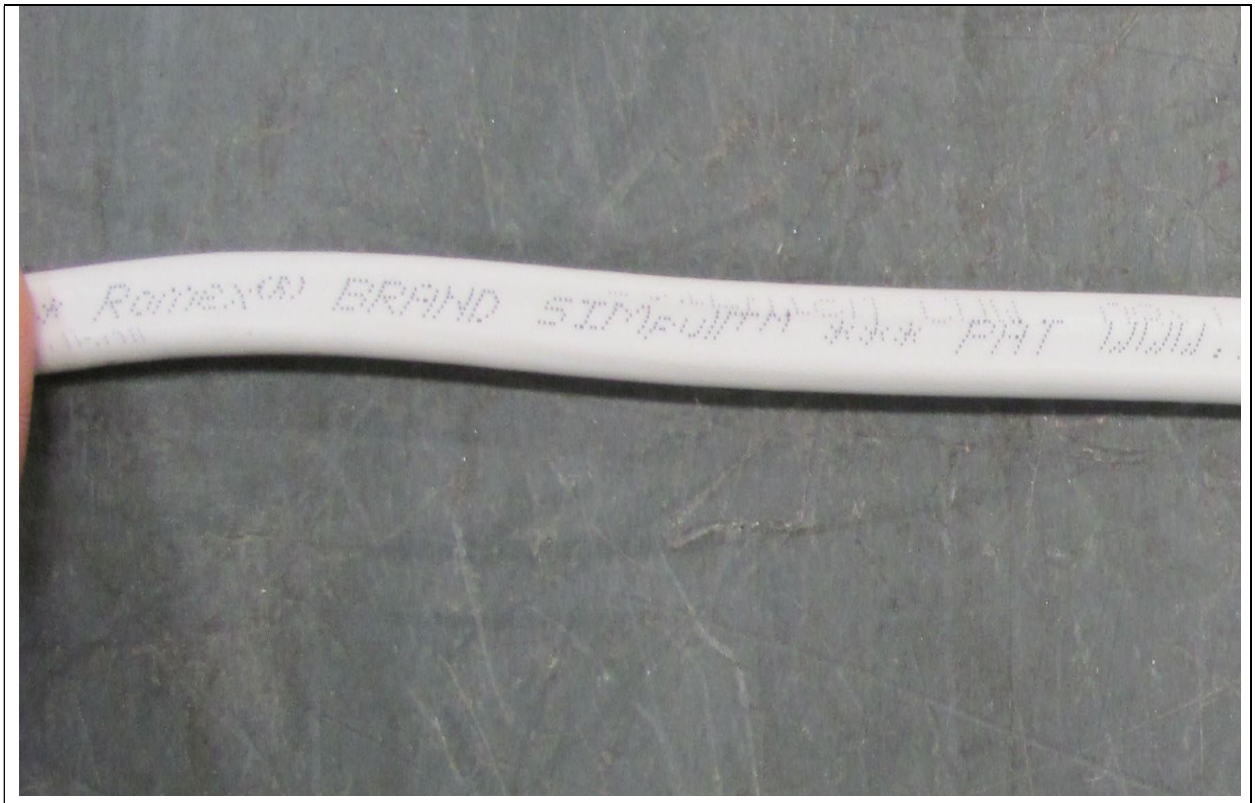


Photo 9 – Copper NM-B Cable

Photo 10 – Copper NM-B Cable Packaging

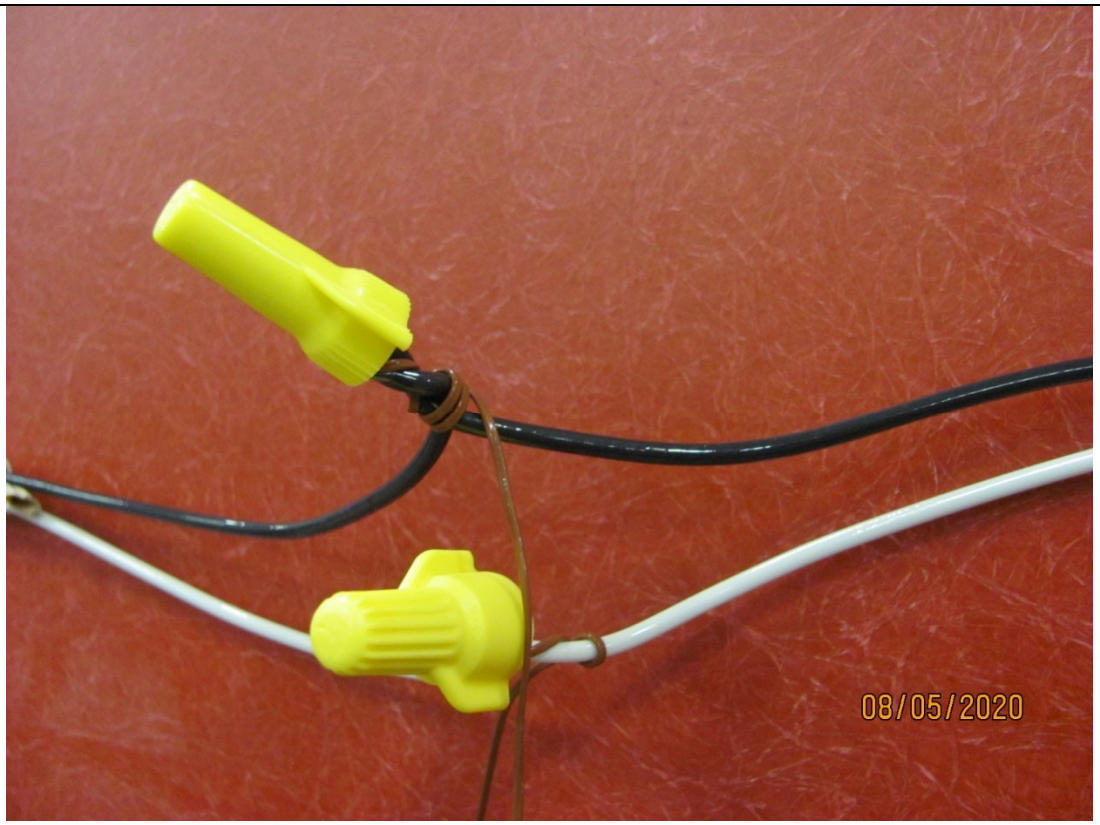


Photo 11 – Typical Installation of Wire Splicing Devices with Thermocouple

Photo 12 – Typical Installation of Receptacle using Wire Binding Screw

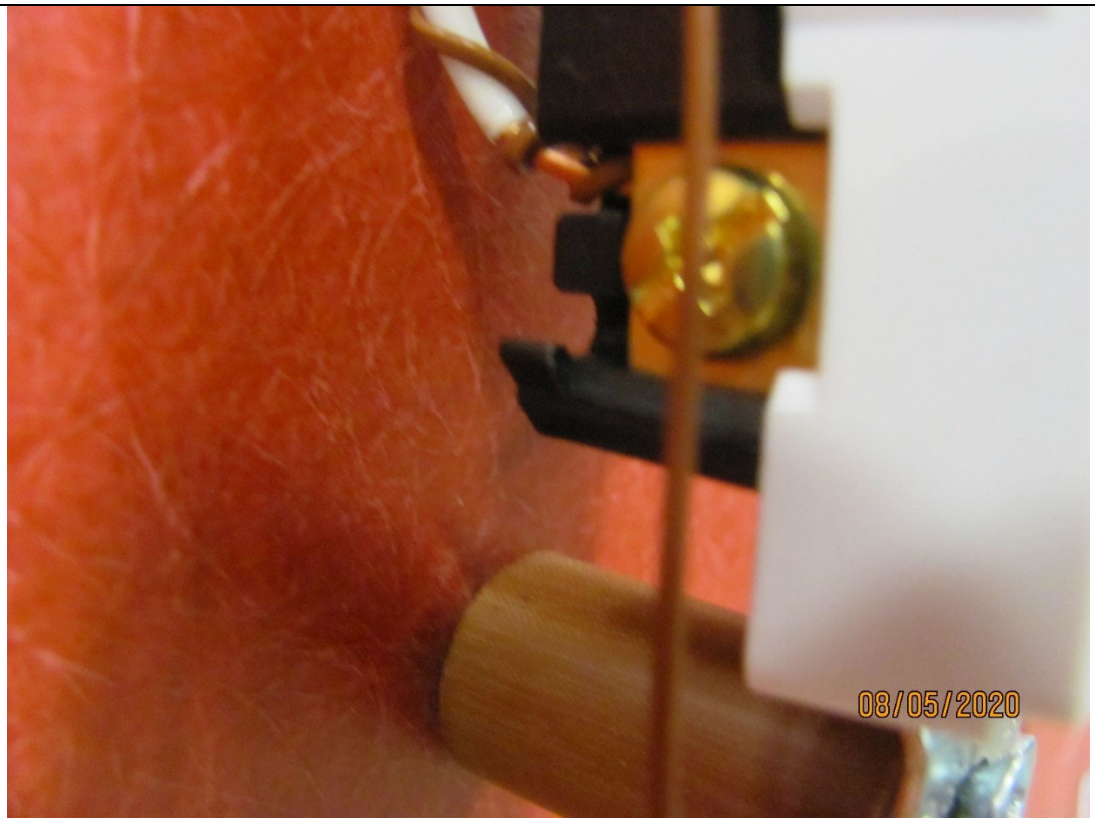


Photo 13 – Typical Installation of Receptacle Since Conductor Back Wired

Photo 14 – Typical Installation of Receptacle Two Conductors Back Wired

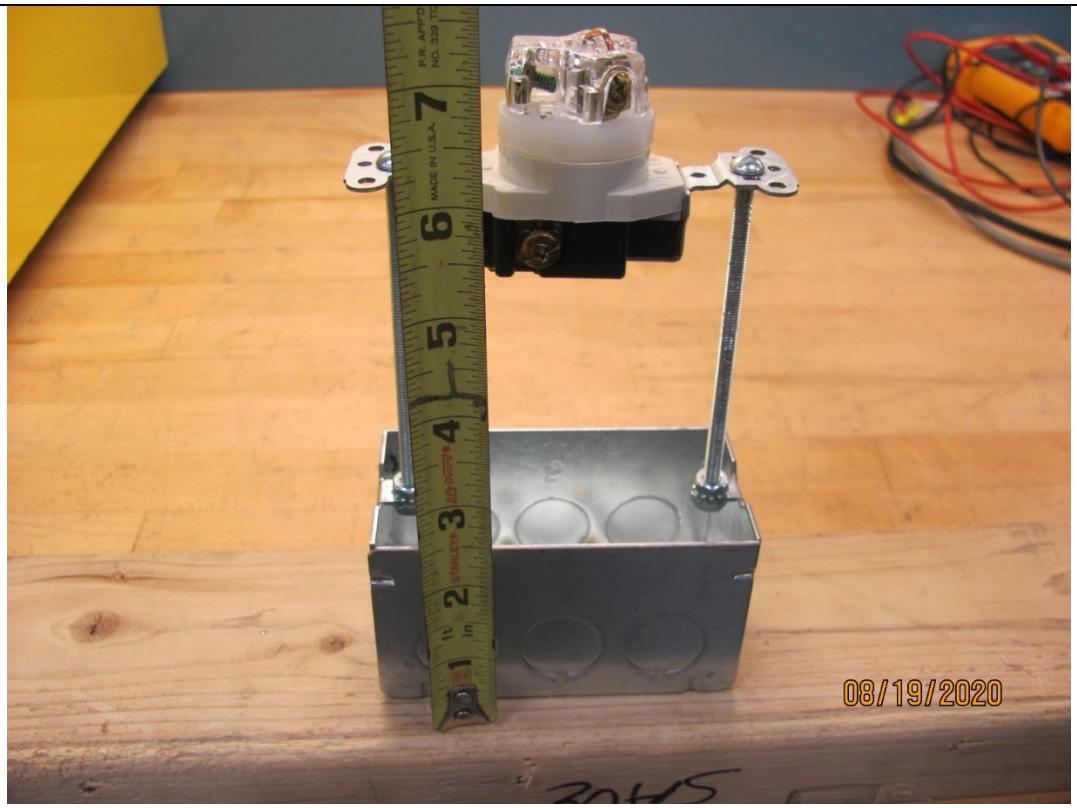


Photo 15 – Flexing Test Setup

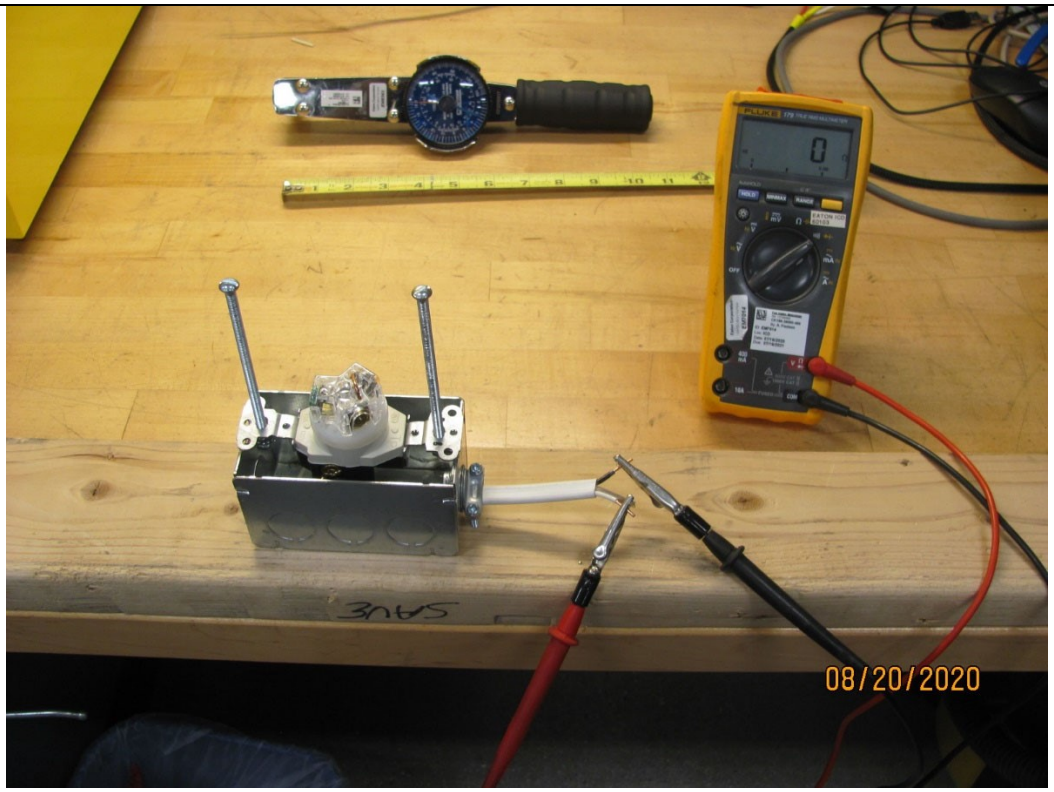


Photo 16 – Flexing Test Setup

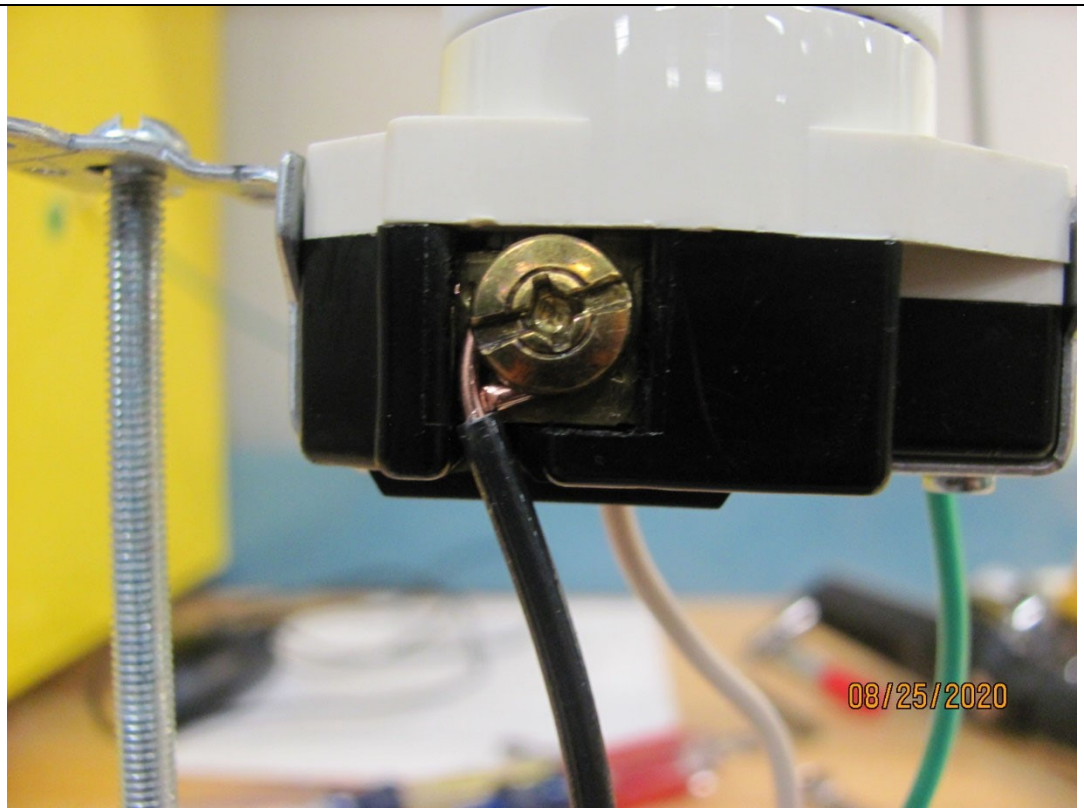


Photo 17 – Flexing Test Fully Extended

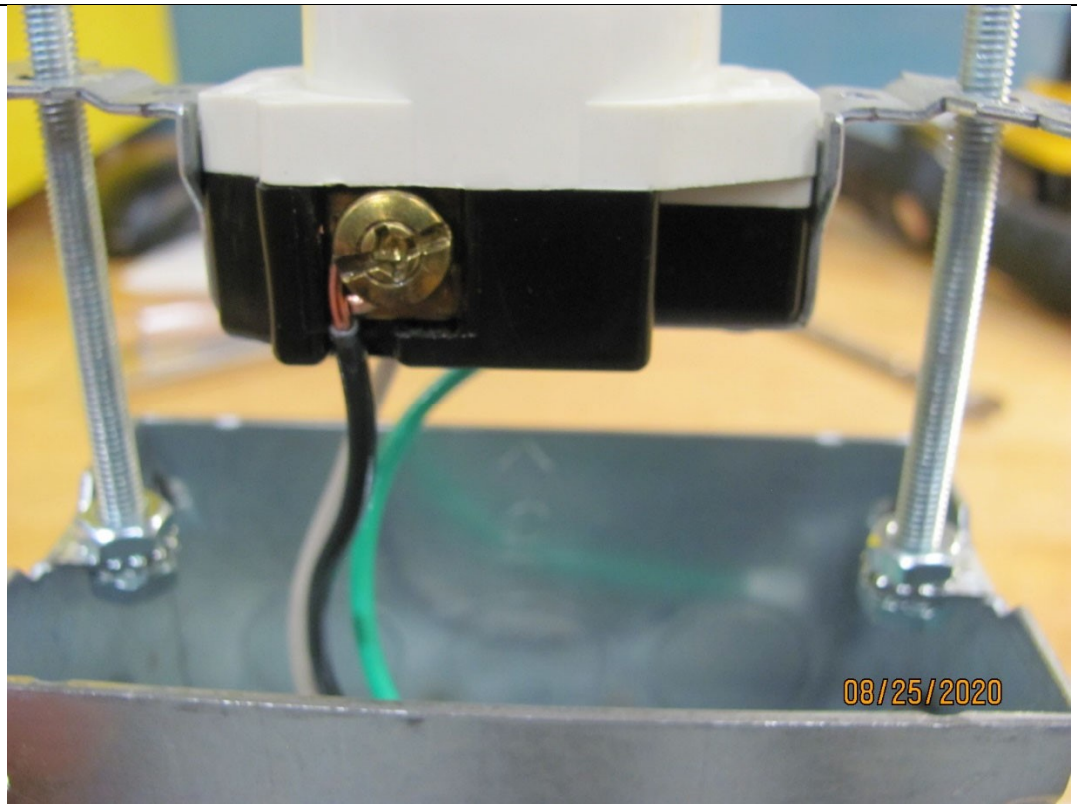


Photo 18 – Flexing Test Partial Insertion

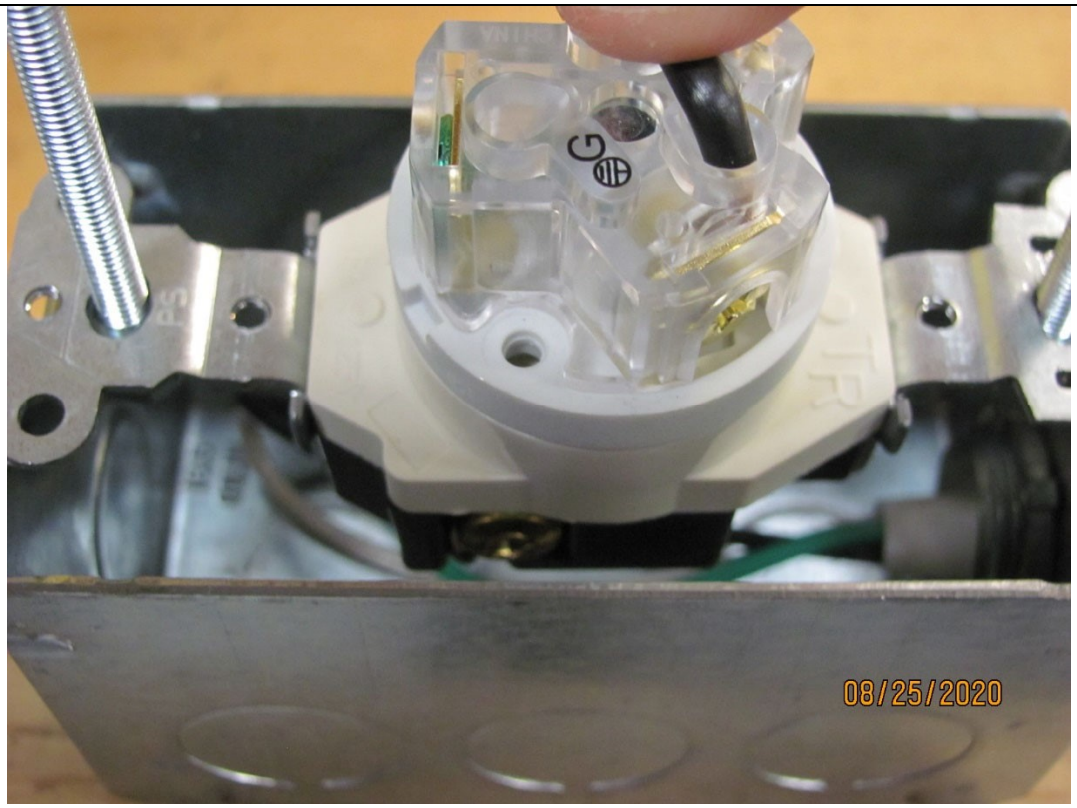


Photo 19 – Flexing Test Fully Inserted

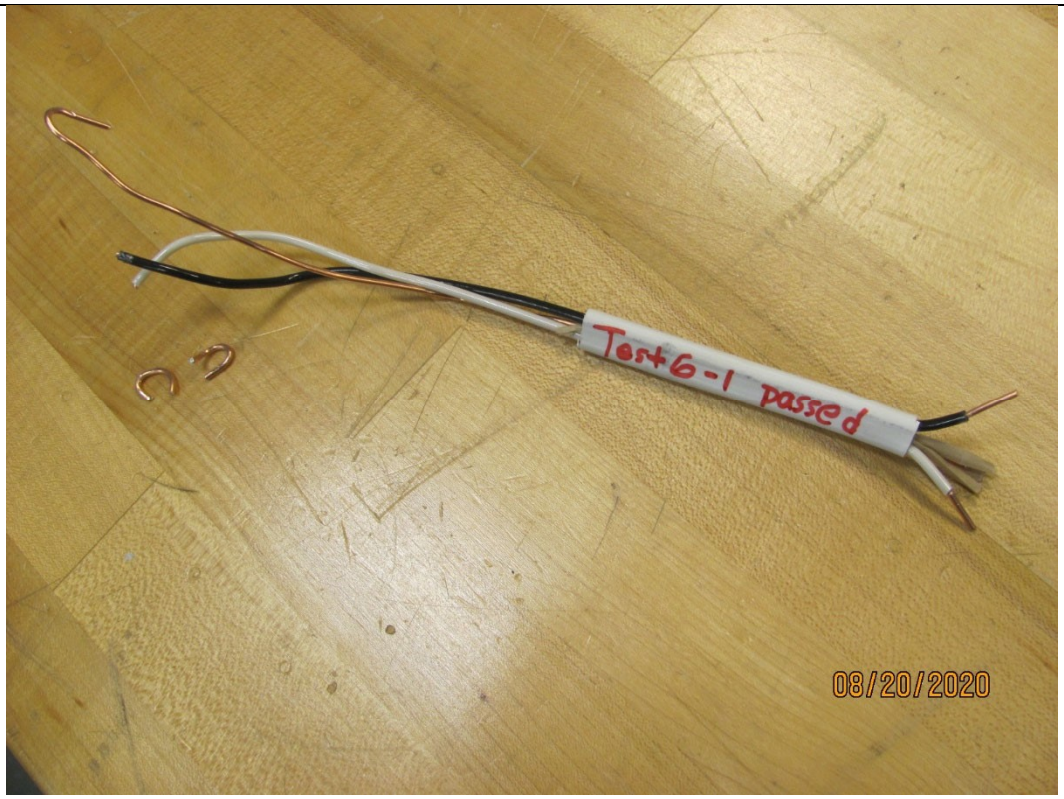


Photo 20 – Flexing Test Broken Conductors When Removing

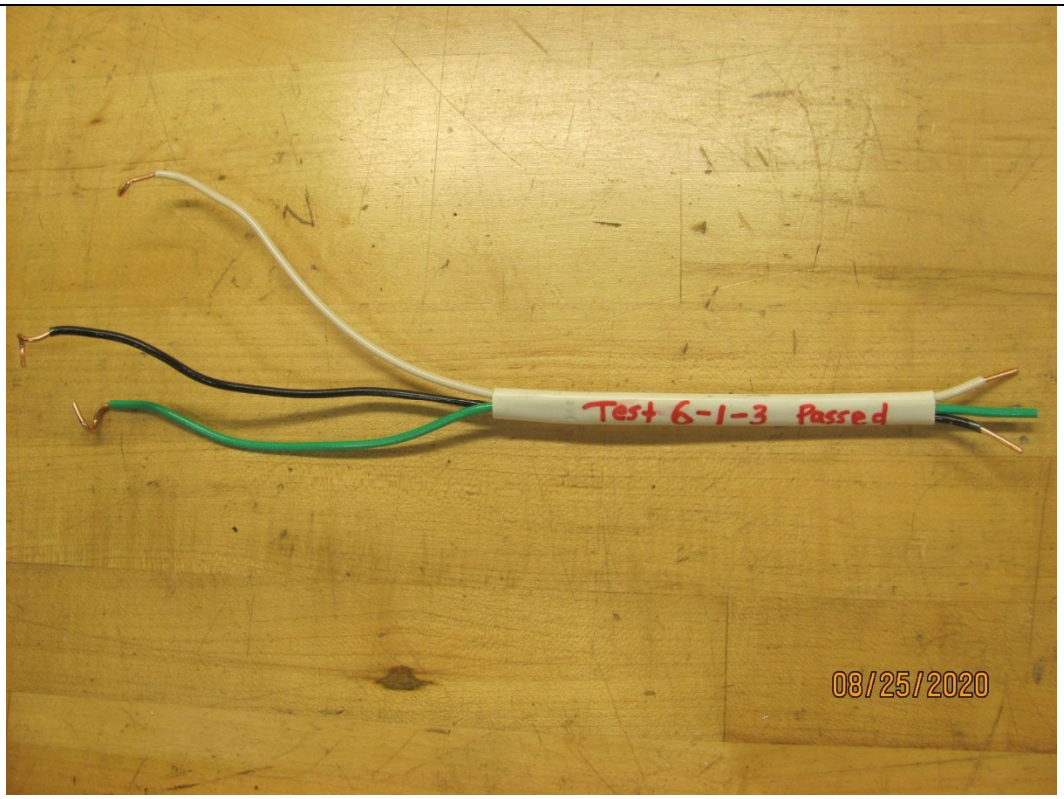


Photo 21 – Flexing Test Repeat No Conductor Breakage

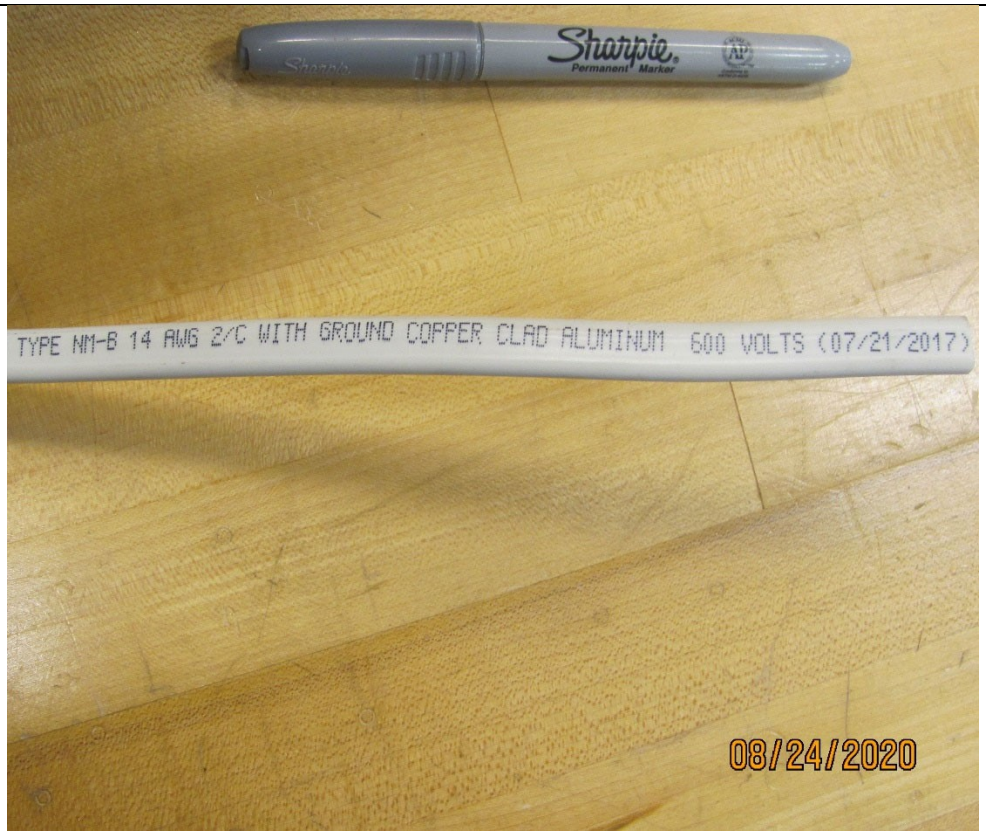


Photo 22 – Copper-Clad Aluminum NM-B Sample Packaging at Eaton

Photo 23 – Copper-Clad Aluminum THHN Sample Packaging at Eaton

Photo 24 – Copper-Clad Aluminum Sample Packaging at Eaton

COPPERWELD | Wired to Protect

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**

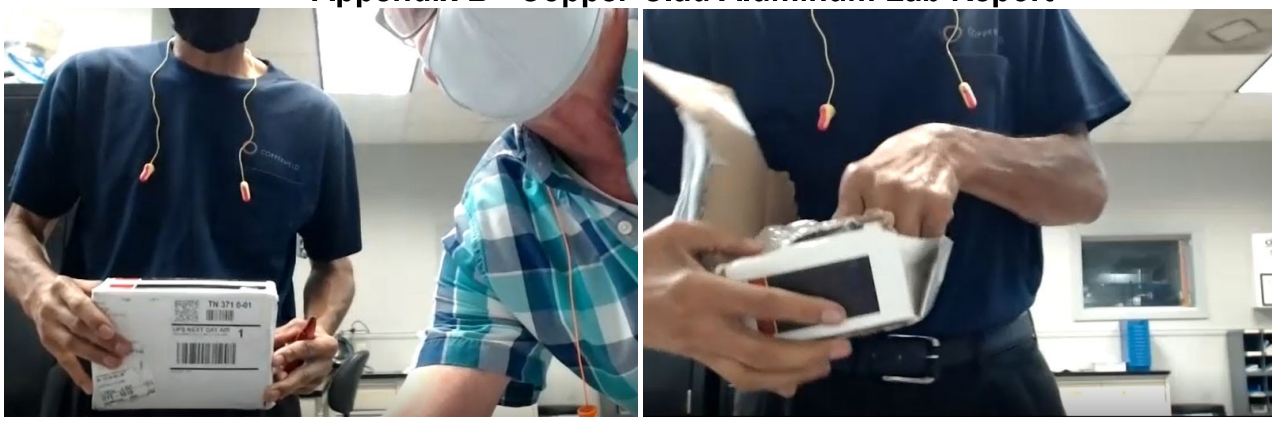
Analysis By:	**Sammy Hampton --Metallographer**
Authored By:	**Sammy Hampton –Metallographer**
Approved By:	**Bill Lewey– QA Manager**

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

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.



Opening the Package

Package Contents

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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**

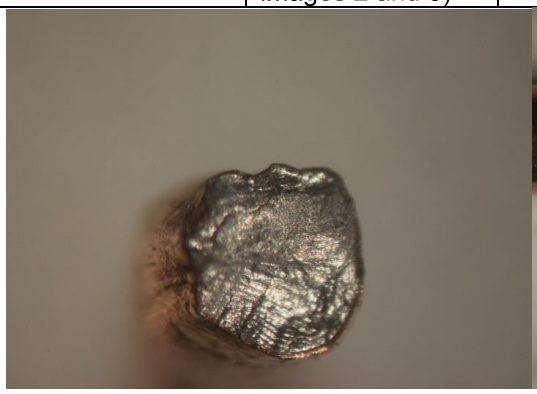


Image 1: adhesion test

Image 2: cohesion test (torsion)

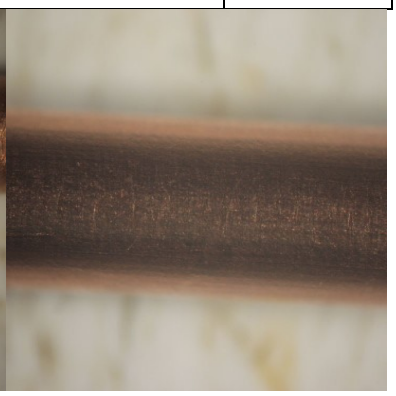


image 3: cohesion test (reverse torsion)

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			

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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	Fnd As	Lft 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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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

Revision Date:05/08/2020
Rev: 04
Page 1 of 2
QF0016

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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04
Page 2 of 2
QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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 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	Last Cal Date (As Of Cal Entry Date)	Next Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

Follow-up Service Inspection Report
E49118512008271652 02

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: Factory Rep Email:	931-433-0495 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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

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 #	→	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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C4 Static Heating Tests at 200% Rated Current

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			

Appendix C5 Static Heating Testing Schneider Circuit Breaker

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

Report No: JK202006300-003
Page 1 of 2

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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	

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

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						

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

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

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

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

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

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

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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

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	299.9	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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

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

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
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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.3	500.3	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.1	500.1	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.0	500.0	0.07
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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-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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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
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

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

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

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

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

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

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

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

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

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

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

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

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:
State:
Zip:
Submittal Date: Wed Sep 09 17:20:16 EDT 2020
Committee: NEC-P06

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
Organization: County of Henrico, Virginia
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 17:32:37 EDT 2020
Committee: NEC-P06

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.

Submitter Information Verification

Submitter Full Name: David Humphrey
Organization: County of Henrico, Virginia
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 17:04:32 EDT 2020
Committee: NEC-P06

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

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

Submitter Full Name: Megan Hayes
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 28 10:13:59 EDT 2020
Committee: NEC-P06

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
Organization: IEC
Affiliation: NEC Correlating Committee Task Group
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 07 10:49:03 EDT 2020
Committee: NEC-P06

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

Table of Contents

1.0 Introduction and Purpose 1
2.0 Testing Arrangement and Setup 2
3.0 Materials for Testing 6
4.0 Test Procedures 7
5.0 Test Results 11
6.0 Conclusions 16
7.0 Test Equipment and Calibration 17

Appendices

A – Photos ..... A1 – A12
B – Copper-Clad Aluminum Material Verification ..... B1 – B7
C – Static Heating Test Data
C1 – Static Heating Test at 100% Rated Current ..... C1-1 – C1-6
C2 – Static Heating Test at 135% Rated Current ..... C2-1 – C2-6
C3 – Static Heating Test at 150% Rated Current ..... C3-1 – C3-6
C4 – Static Heating Test at 200% Rated Current ..... C4-1 – C4-6
C5 – Static Heating Original 100% and 135% Trip Failure C5-1
D – Flexing Tests Data D1
E – Certificates of Calibration ..... E1 – E26

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.

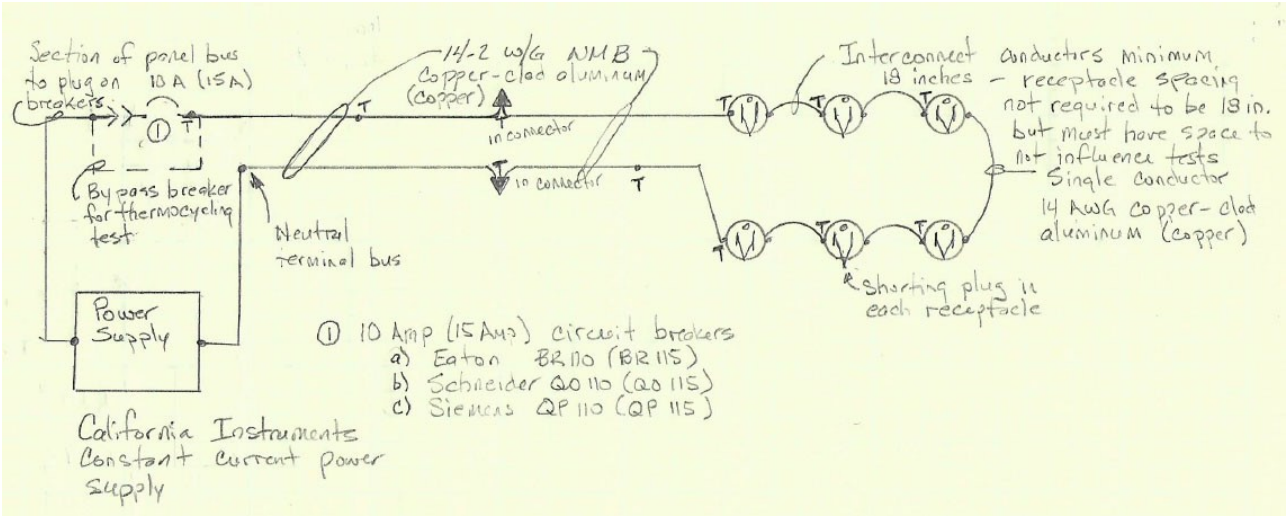


Figure 1 – Typical Test Circuit Diagram

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

Appendix A - Photos

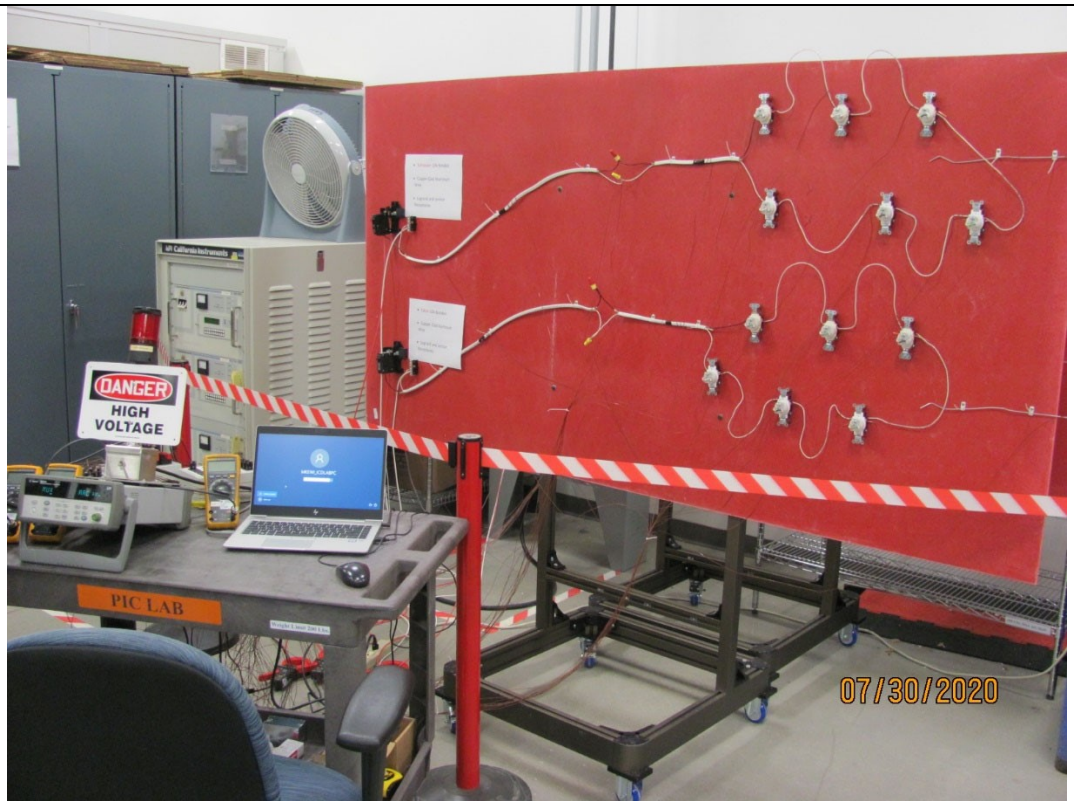


Photo 3 – Test Board and Test Equipment Arrangement

Photo 4 – Copper-Clad Aluminum with Eaton and Hubbell Receptacles

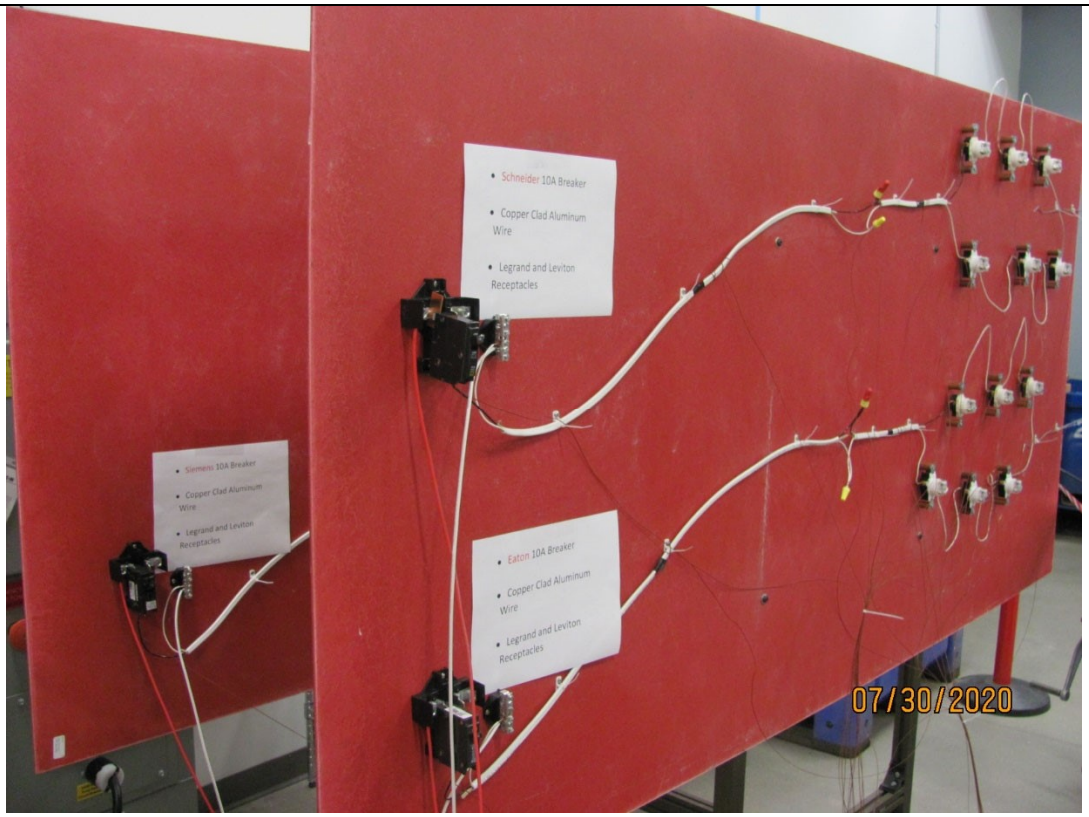


Photo 5 – Copper-Clad Aluminum with Legrand and Leviton Receptacles

Photo 6 – Copper with Eaton and Hubbell Receptacles

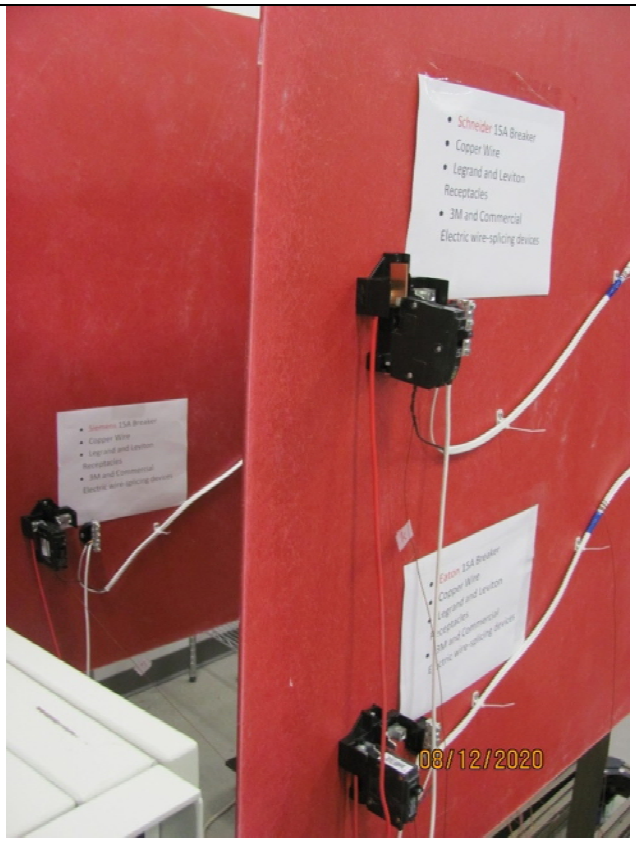


Photo 7 – Copper with Legrand and Leviton Receptacles

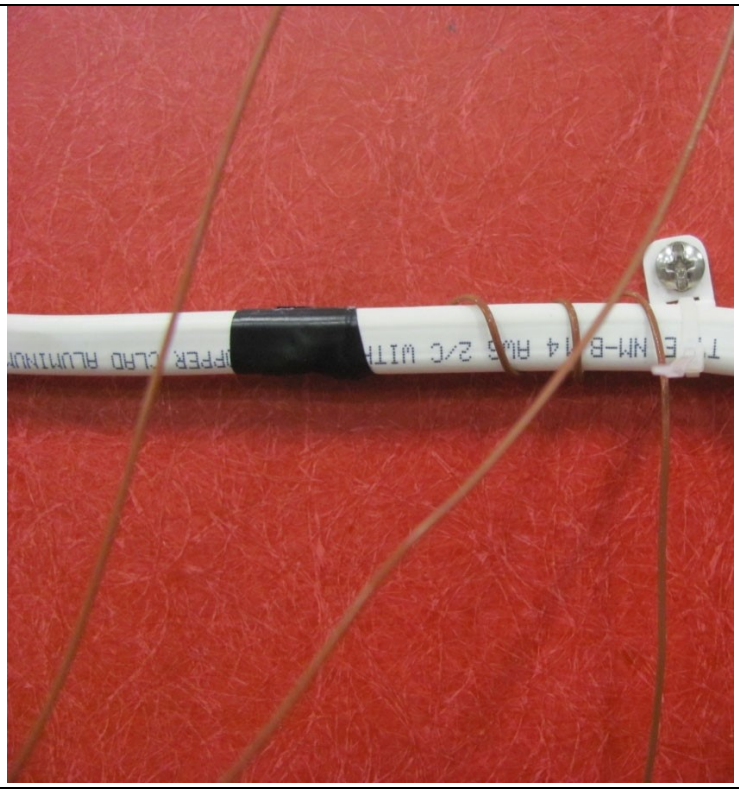


Photo 8 – Copper-Clad Aluminum NM-B Cable

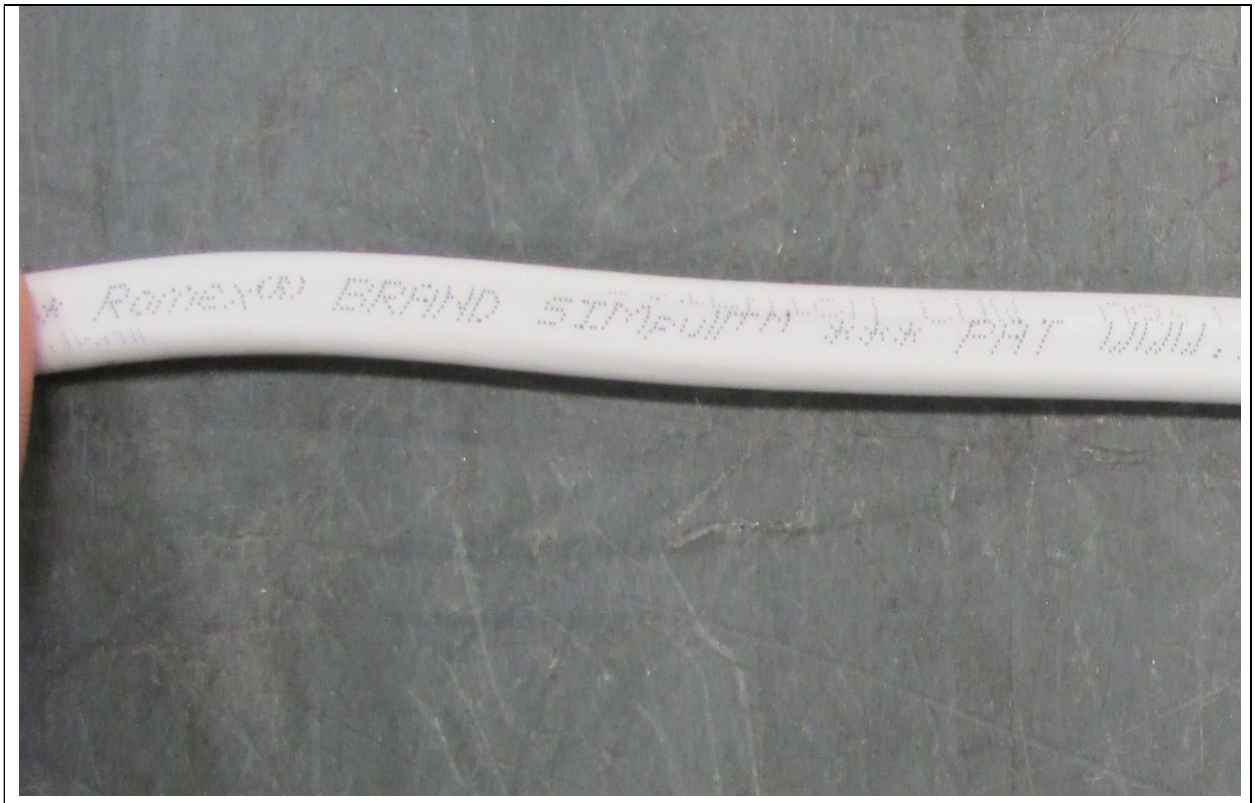


Photo 9 – Copper NM-B Cable

Photo 10 – Copper NM-B Cable Packaging

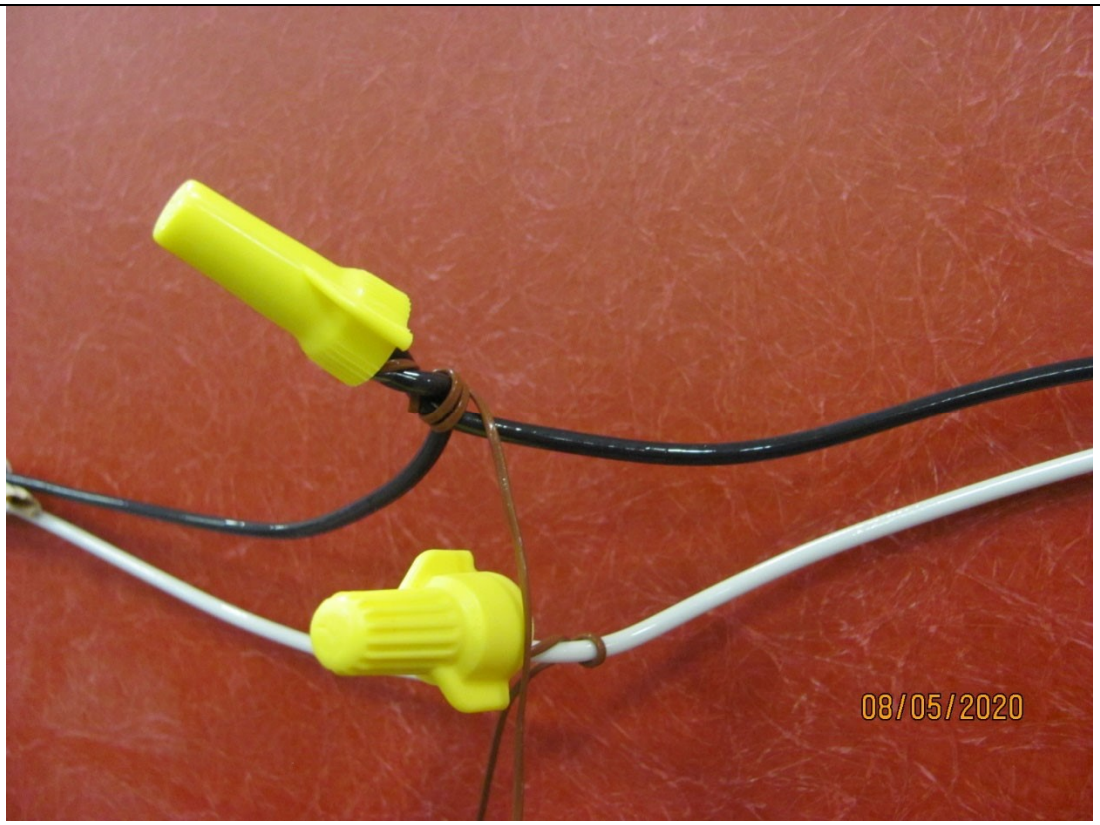


Photo 11 – Typical Installation of Wire Splicing Devices with Thermocouple

Photo 12 – Typical Installation of Receptacle using Wire Binding Screw

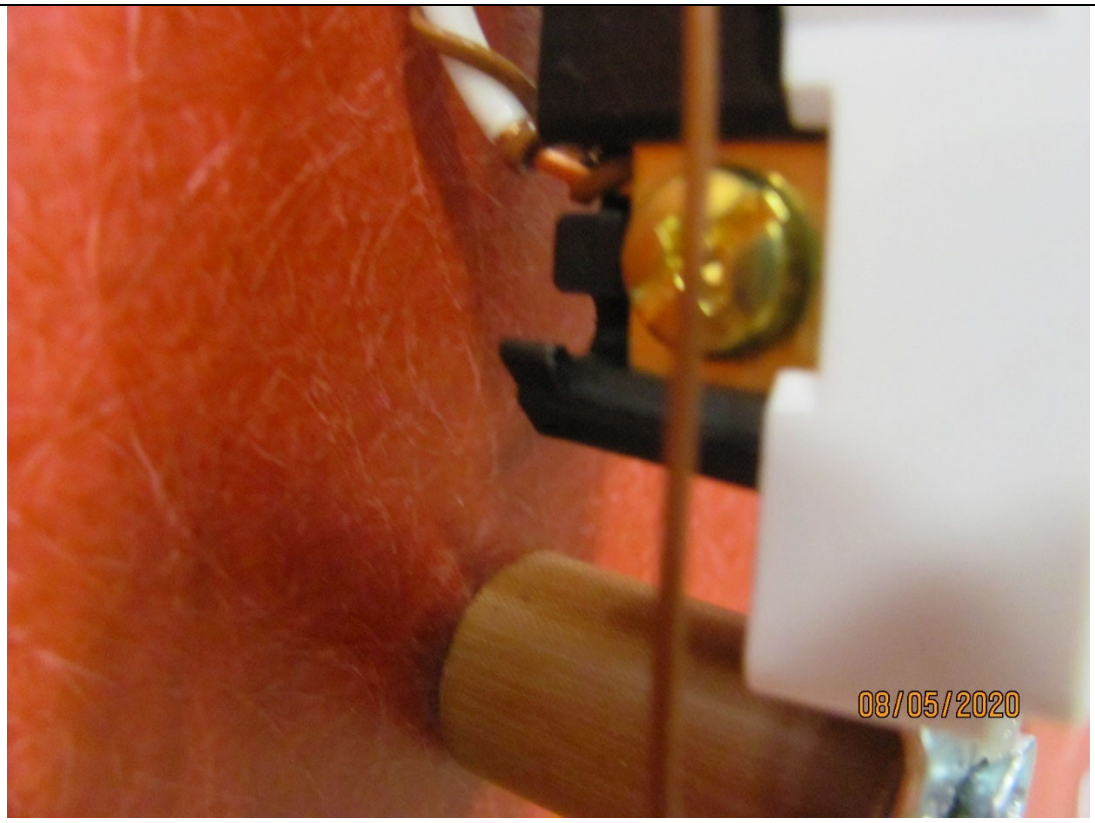


Photo 13 – Typical Installation of Receptacle Since Conductor Back Wired

Photo 14 – Typical Installation of Receptacle Two Conductors Back Wired

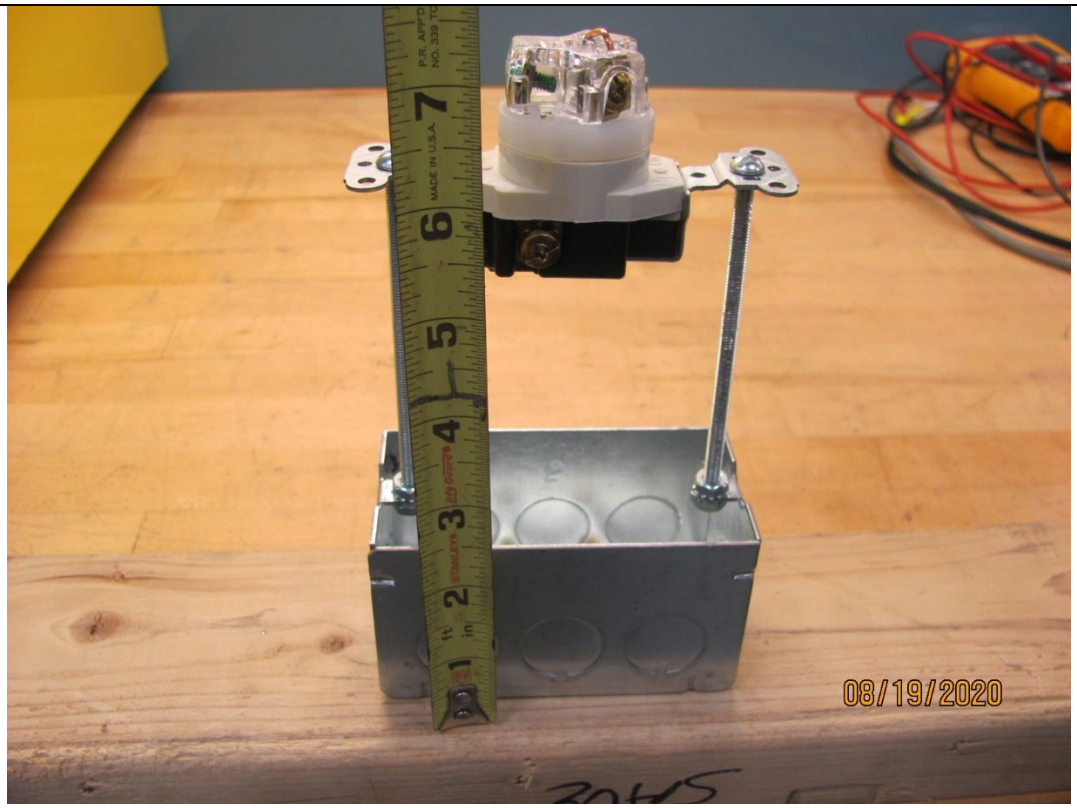


Photo 15 – Flexing Test Setup

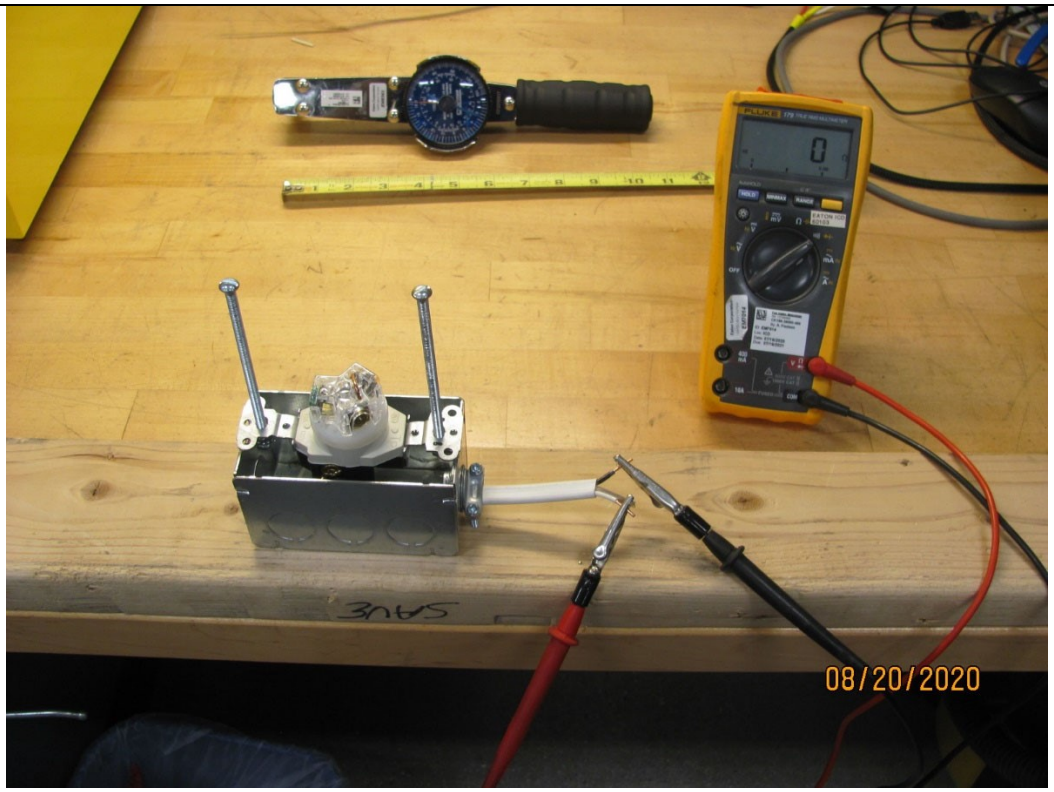


Photo 16 – Flexing Test Setup

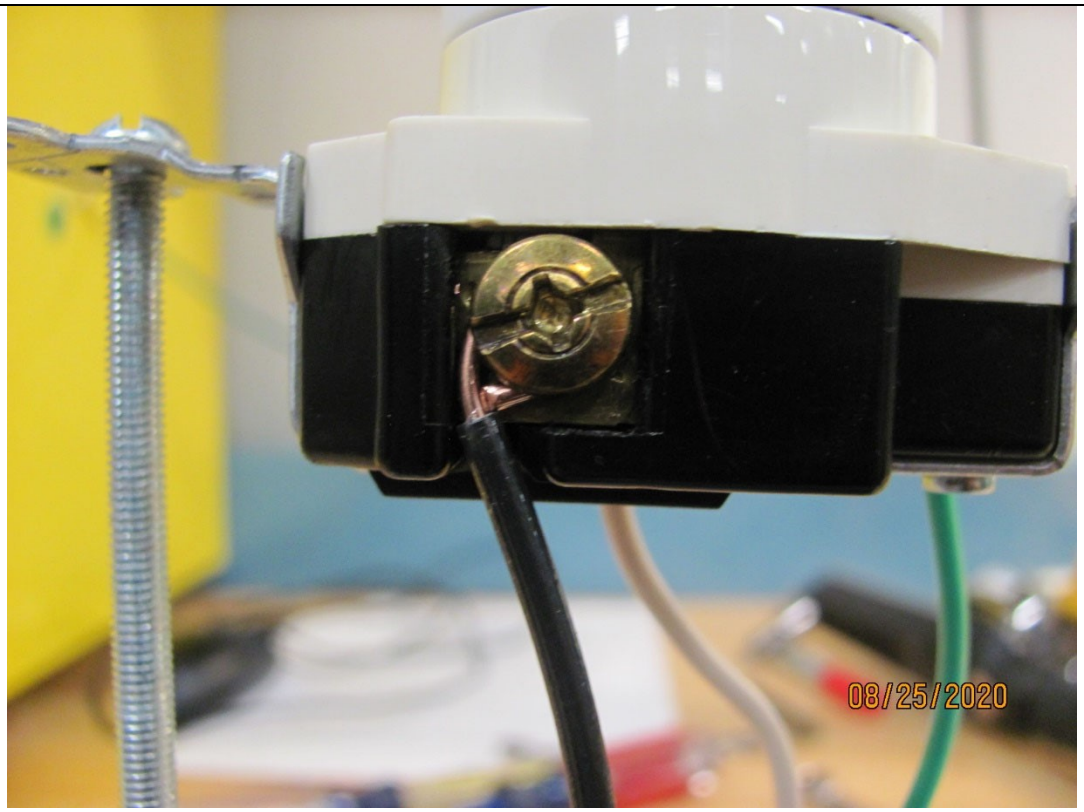


Photo 17 – Flexing Test Fully Extended

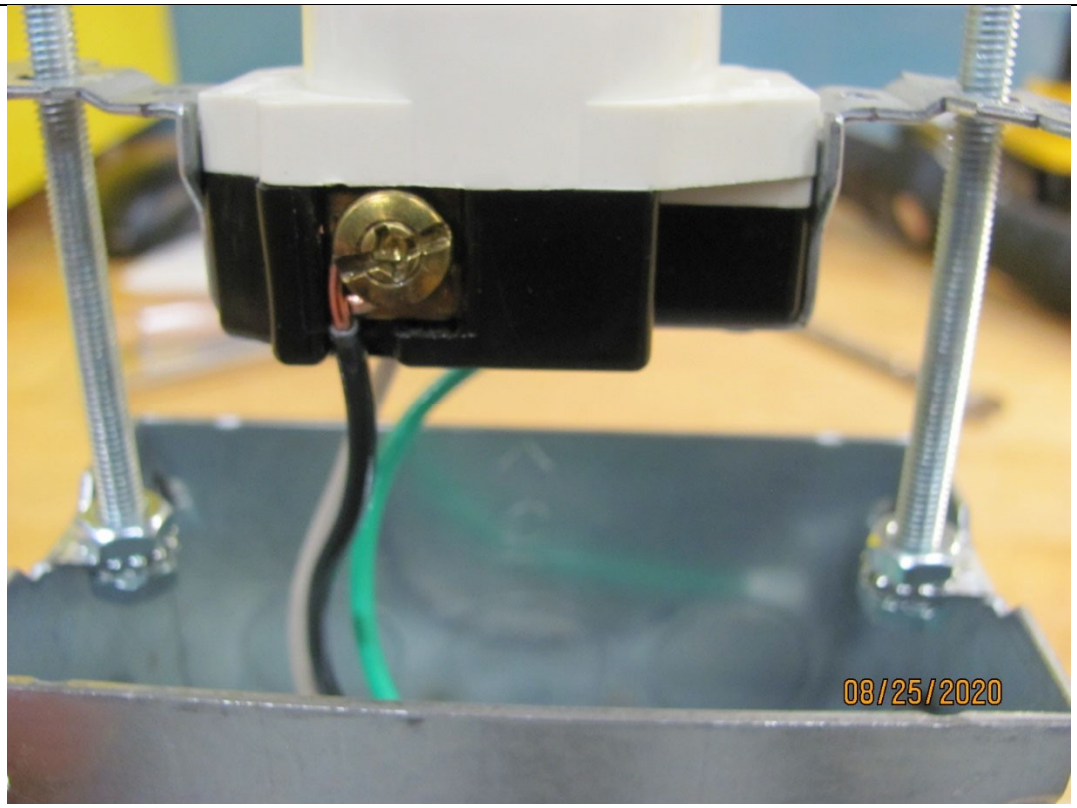


Photo 18 – Flexing Test Partial Insertion

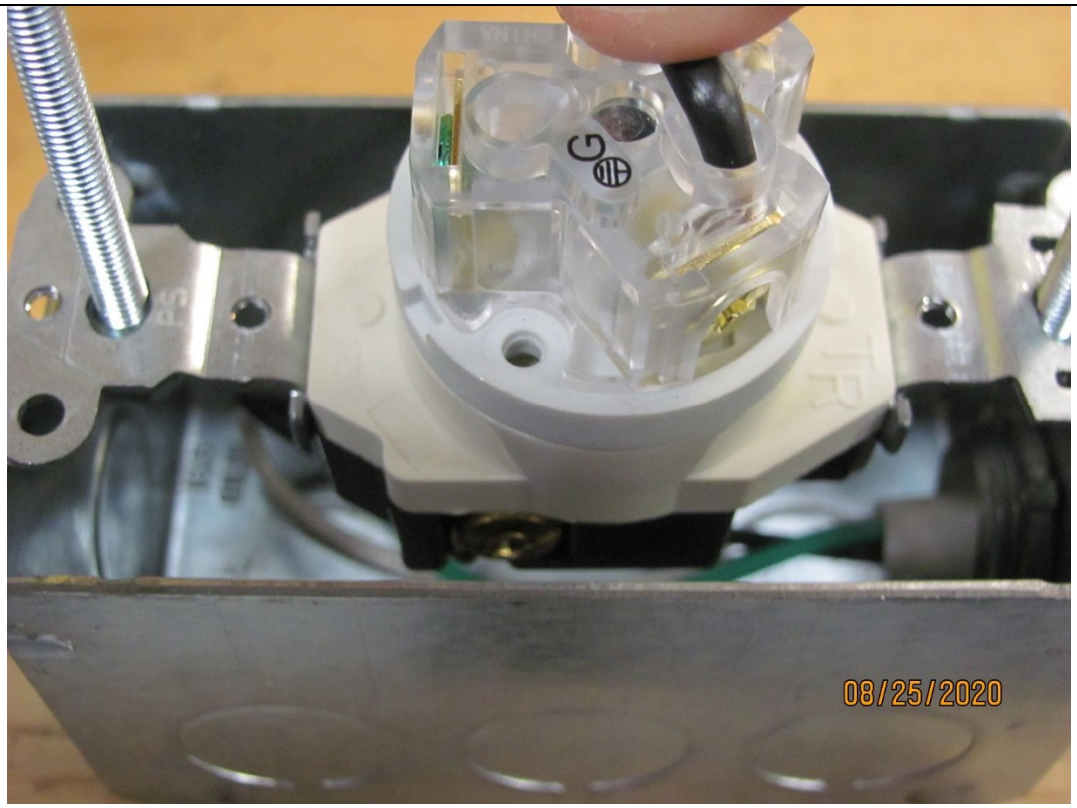


Photo 19 – Flexing Test Fully Inserted

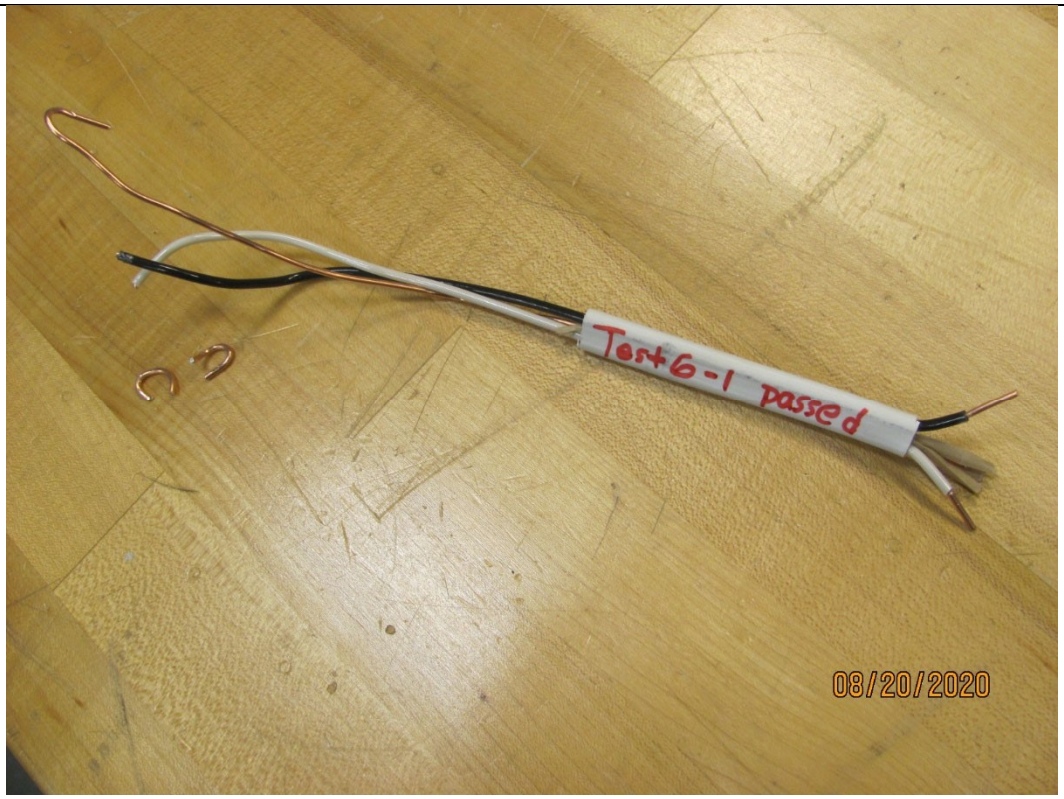


Photo 20 – Flexing Test Broken Conductors When Removing

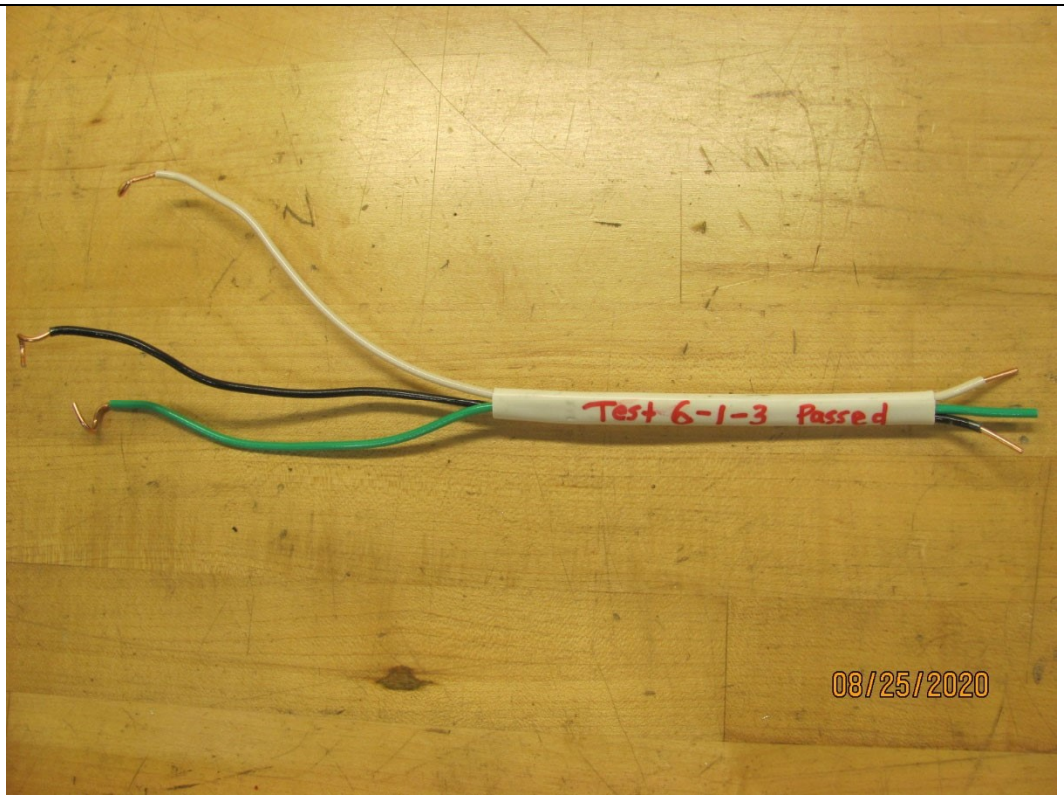


Photo 21 – Flexing Test Repeat No Conductor Breakage

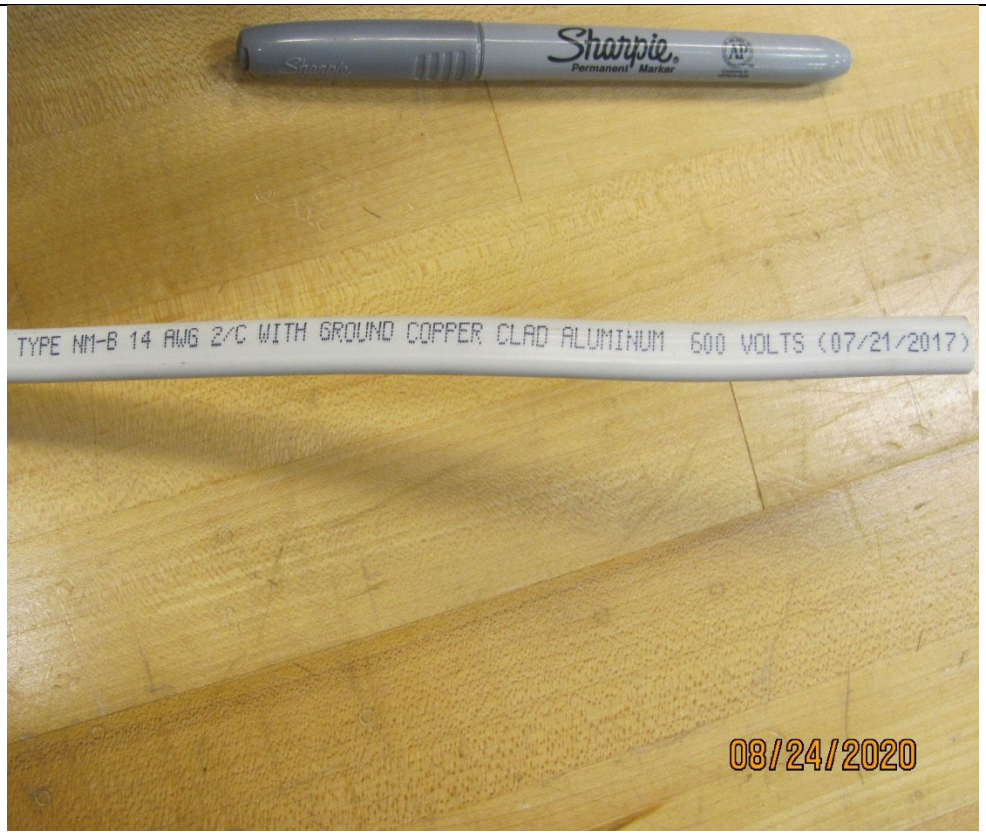


Photo 22 – Copper-Clad Aluminum NM-B Sample Packaging at Eaton

Photo 23 – Copper-Clad Aluminum THHN Sample Packaging at Eaton

Photo 24 – Copper-Clad Aluminum Sample Packaging at Eaton

COPPERWELD | Wired to Protect

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**

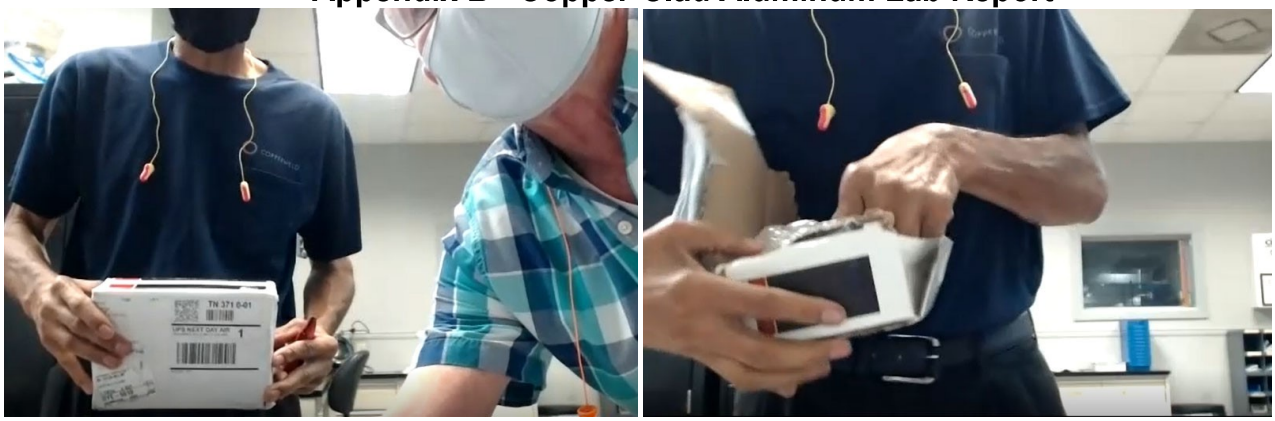
Analysis By:	**Sammy Hampton --Metallographer**
Authored By:	**Sammy Hampton –Metallographer**
Approved By:	**Bill Lewey– QA Manager**

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

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.



Opening the Package

Package Contents

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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**

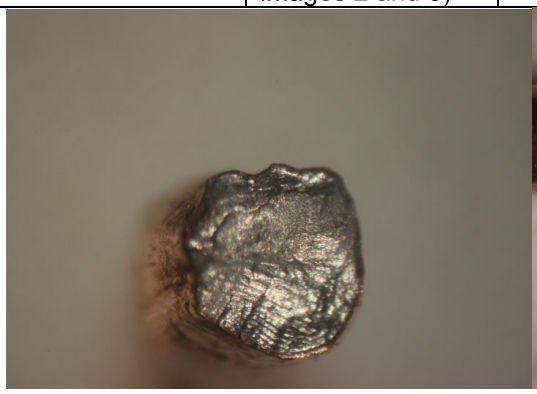


Image 1: adhesion test

Image 2: cohesion test (torsion)

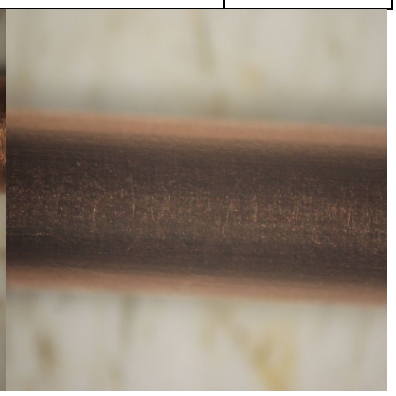


image 3: cohesion test (reverse torsion)

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			

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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	Fnd As	Lft 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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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

Revision Date:05/08/2020
Rev: 04
Page 1 of 2
QF0016

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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04
Page 2 of 2
QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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 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	Last Cal Date (As Of Cal Entry Date)	Next Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

Follow-up Service Inspection Report
E49118512008271652 02

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: Factory Rep Email:	931-433-0495 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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

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 #	→	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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C4 Static Heating Tests at 200% Rated Current

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			

Appendix C5 Static Heating Testing Schneider Circuit Breaker

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

Report No: JK202006300-003
Page 1 of 2

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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	

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

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						

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

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

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

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

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

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

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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

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	299.9	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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

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

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
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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.3	500.3	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.1	500.1	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.0	500.0	0.07
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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-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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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
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

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

Copyright Assignment

I, Tj Woods, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and

authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Tj Woods, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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]

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]

Applications and limitations for receptacles

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 10:54:21 EDT 2020
Committee: NEC-P06

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

Table of Contents

1.0 Introduction and Purpose 1
2.0 Testing Arrangement and Setup 2
3.0 Materials for Testing 6
4.0 Test Procedures 7
5.0 Test Results 11
6.0 Conclusions 16
7.0 Test Equipment and Calibration 17

Appendices

A – Photos ..... A1 – A12
B – Copper-Clad Aluminum Material Verification ..... B1 – B7
C – Static Heating Test Data
C1 – Static Heating Test at 100% Rated Current ..... C1-1 – C1-6
C2 – Static Heating Test at 135% Rated Current ..... C2-1 – C2-6
C3 – Static Heating Test at 150% Rated Current ..... C3-1 – C3-6
C4 – Static Heating Test at 200% Rated Current ..... C4-1 – C4-6
C5 – Static Heating Original 100% and 135% Trip Failure C5-1
D – Flexing Tests Data D1
E – Certificates of Calibration ..... E1 – E26

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.

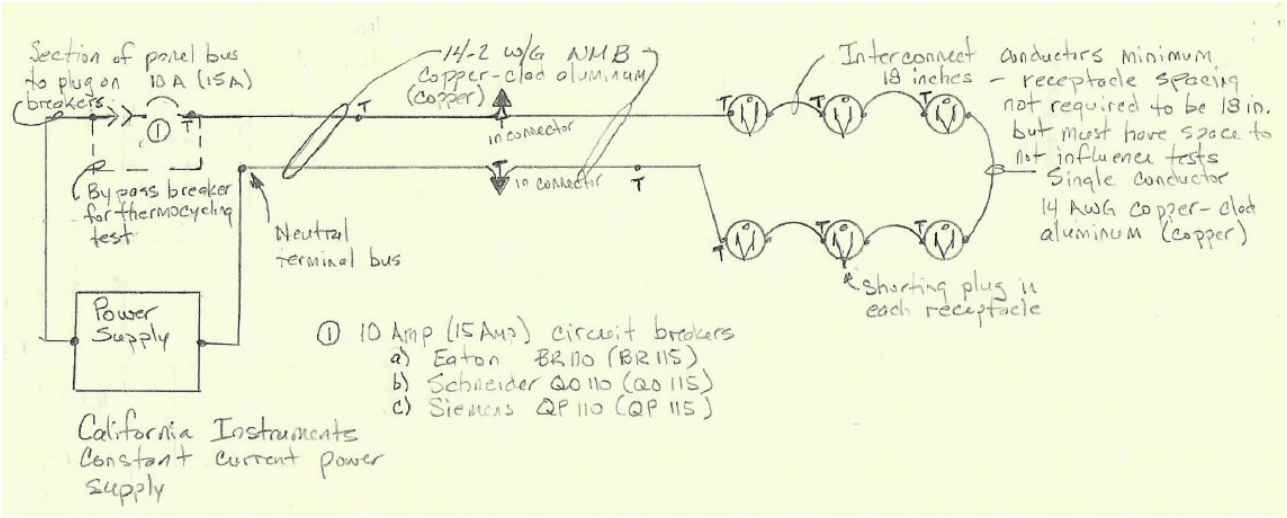


Figure 1 – Typical Test Circuit Diagram

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

Appendix A - Photos

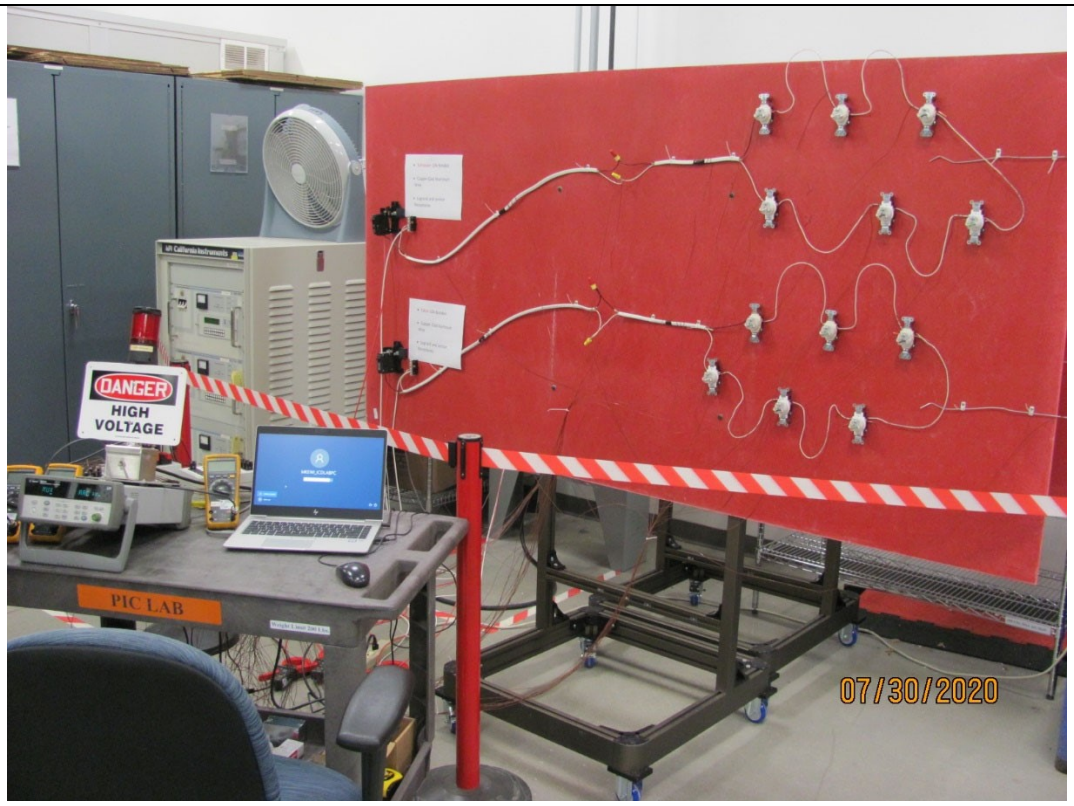


Photo 3 – Test Board and Test Equipment Arrangement

Photo 4 – Copper-Clad Aluminum with Eaton and Hubbell Receptacles

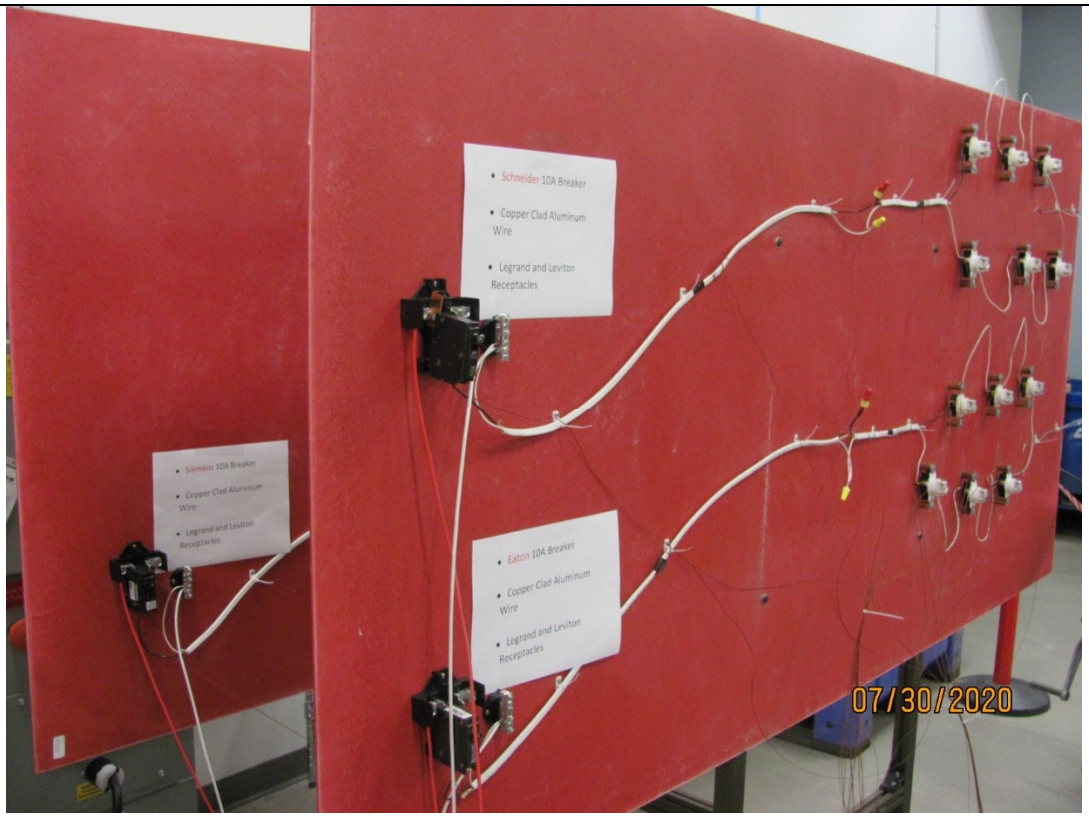


Photo 5 – Copper-Clad Aluminum with Legrand and Leviton Receptacles

Photo 6 – Copper with Eaton and Hubbell Receptacles

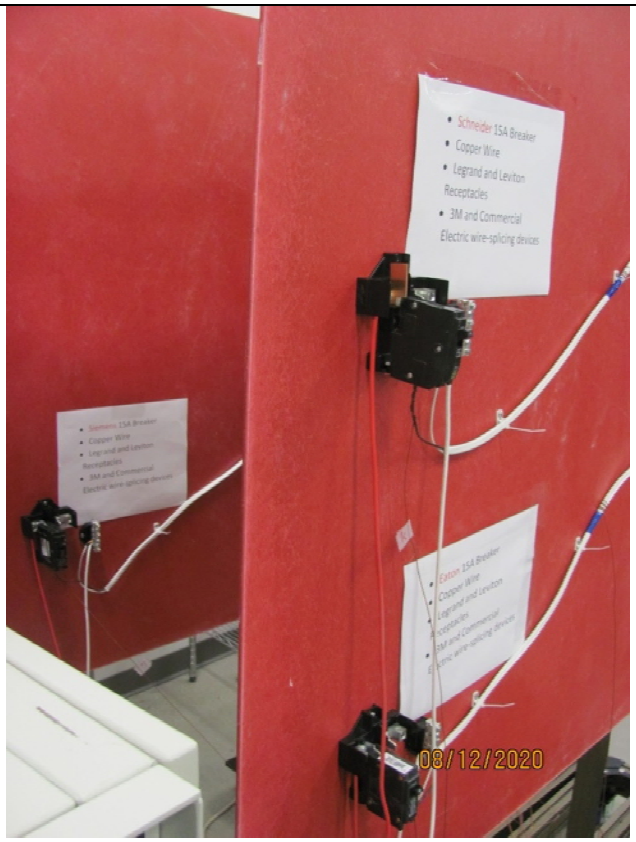


Photo 7 – Copper with Legrand and Leviton Receptacles

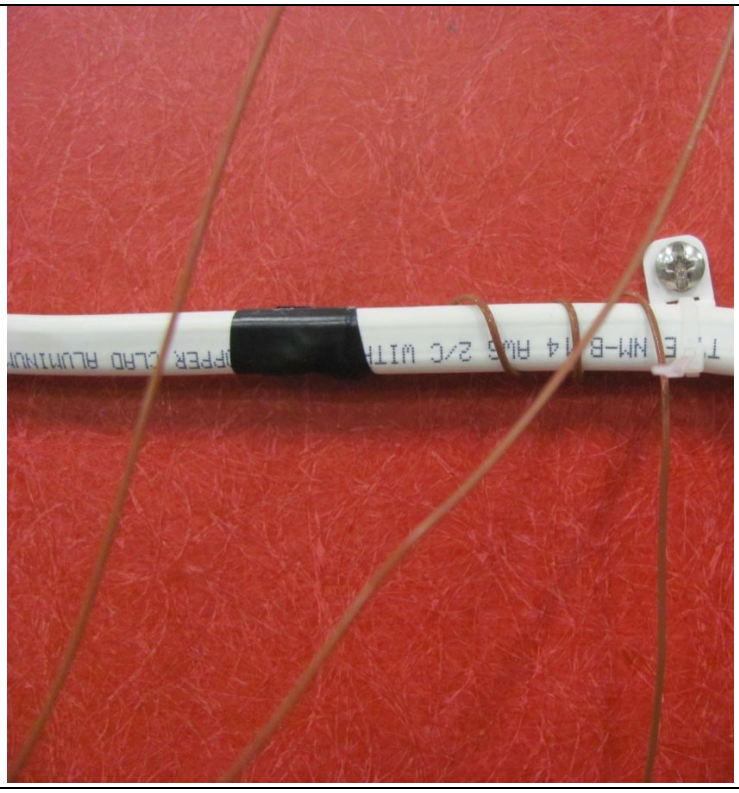


Photo 8 – Copper-Clad Aluminum NM-B Cable

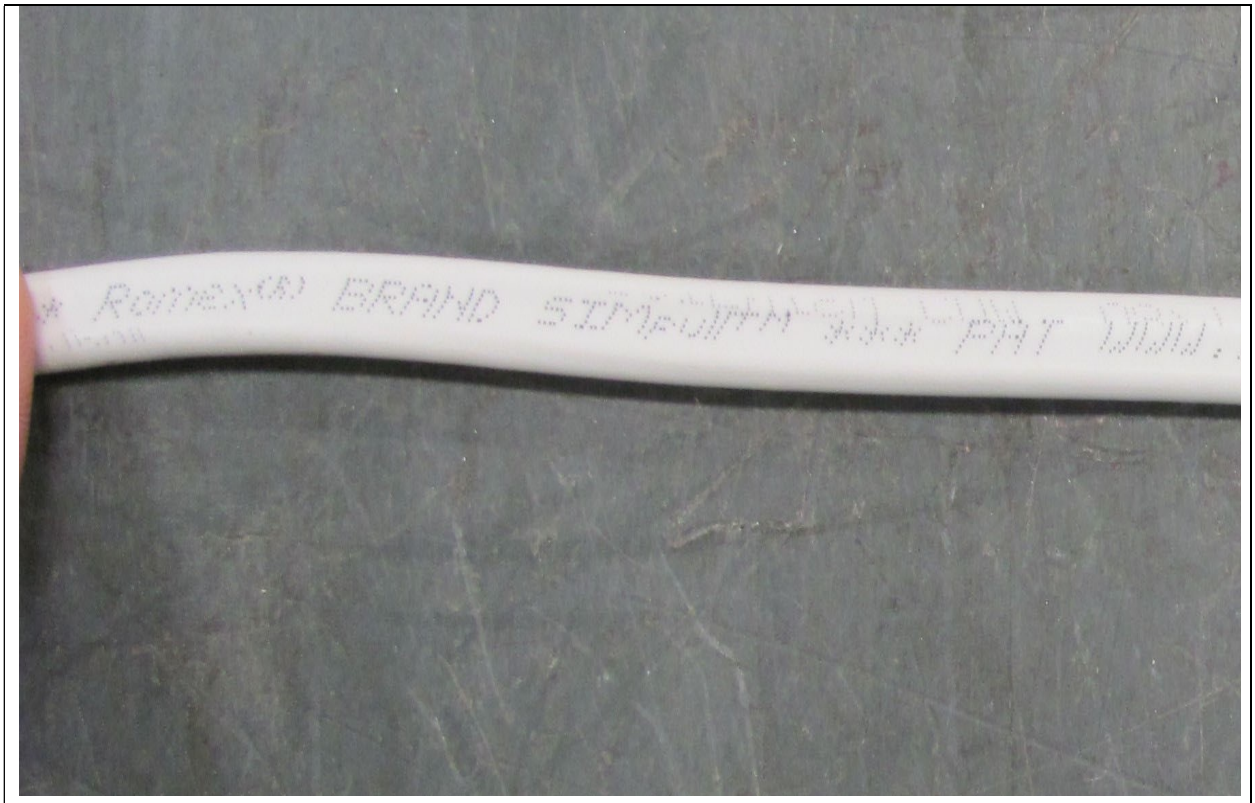


Photo 9 – Copper NM-B Cable

Photo 10 – Copper NM-B Cable Packaging

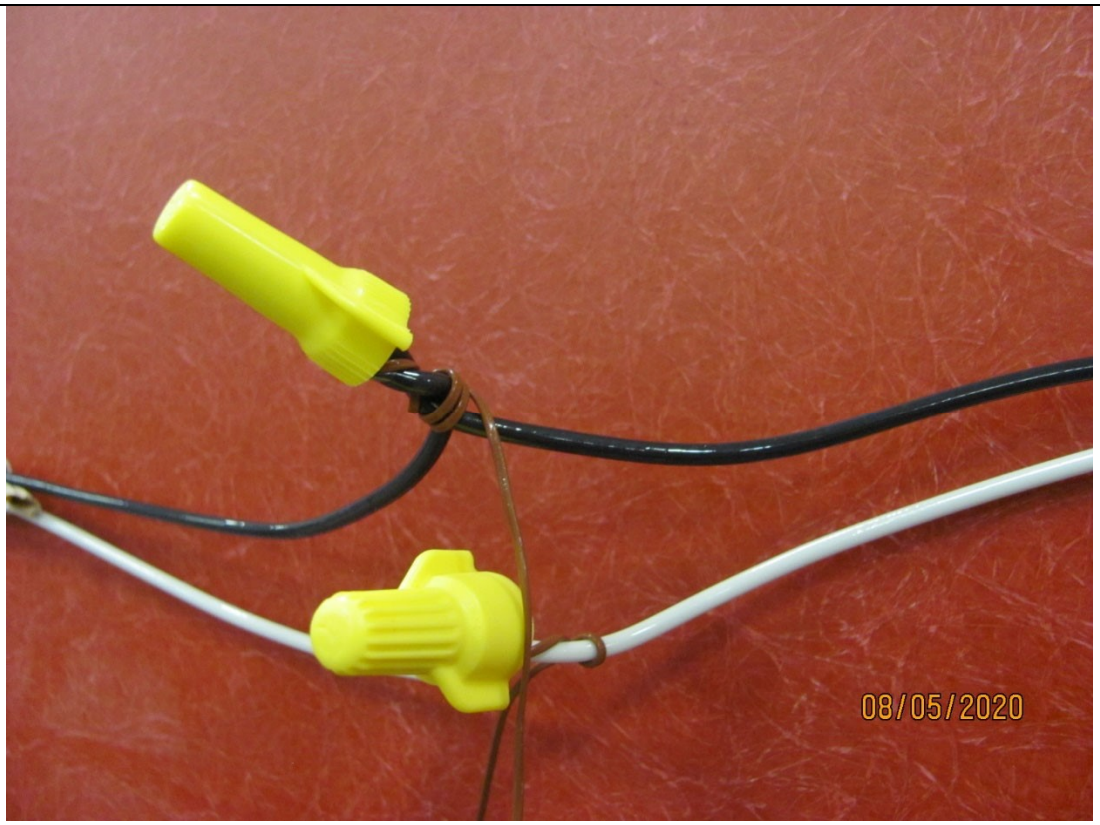


Photo 11 – Typical Installation of Wire Splicing Devices with Thermocouple

Photo 12 – Typical Installation of Receptacle using Wire Binding Screw

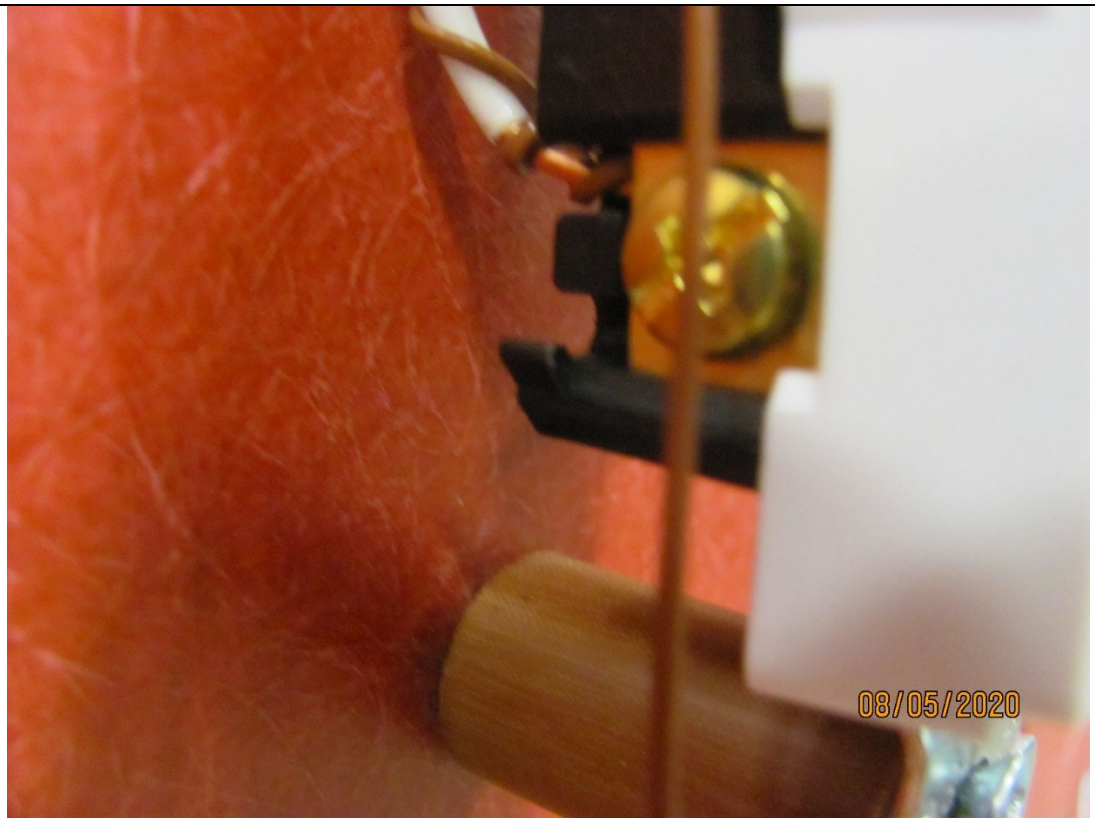


Photo 13 – Typical Installation of Receptacle Since Conductor Back Wired

Photo 14 – Typical Installation of Receptacle Two Conductors Back Wired

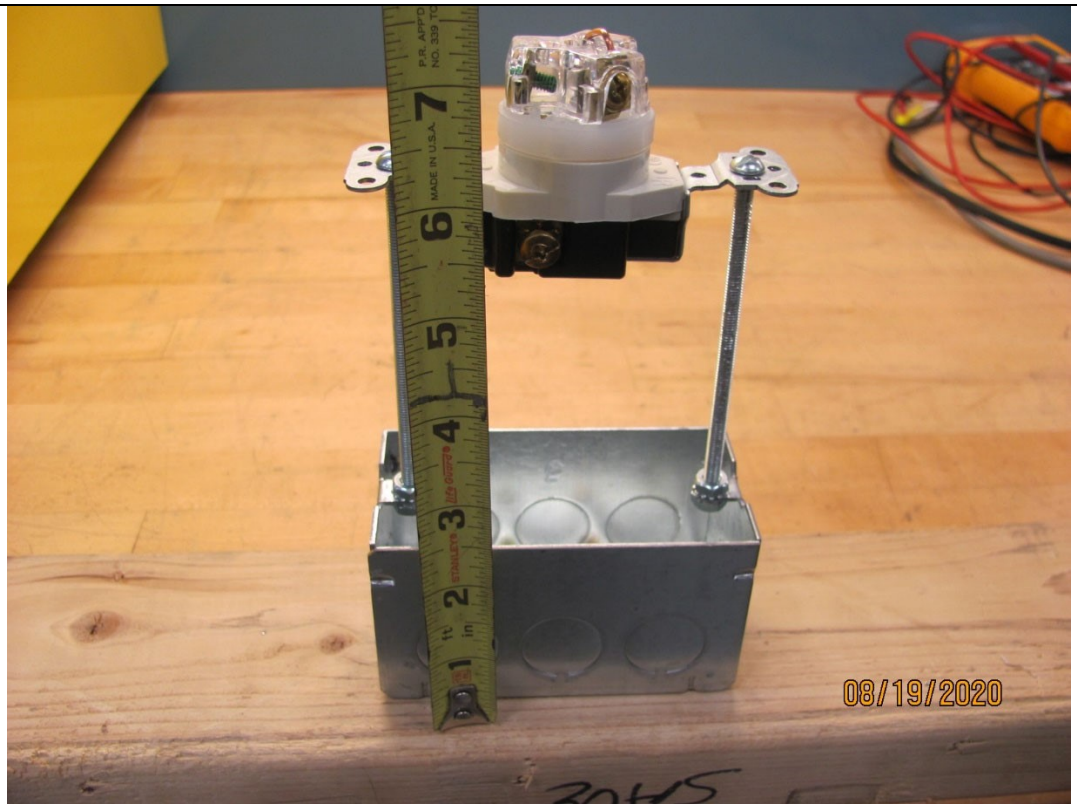


Photo 15 – Flexing Test Setup

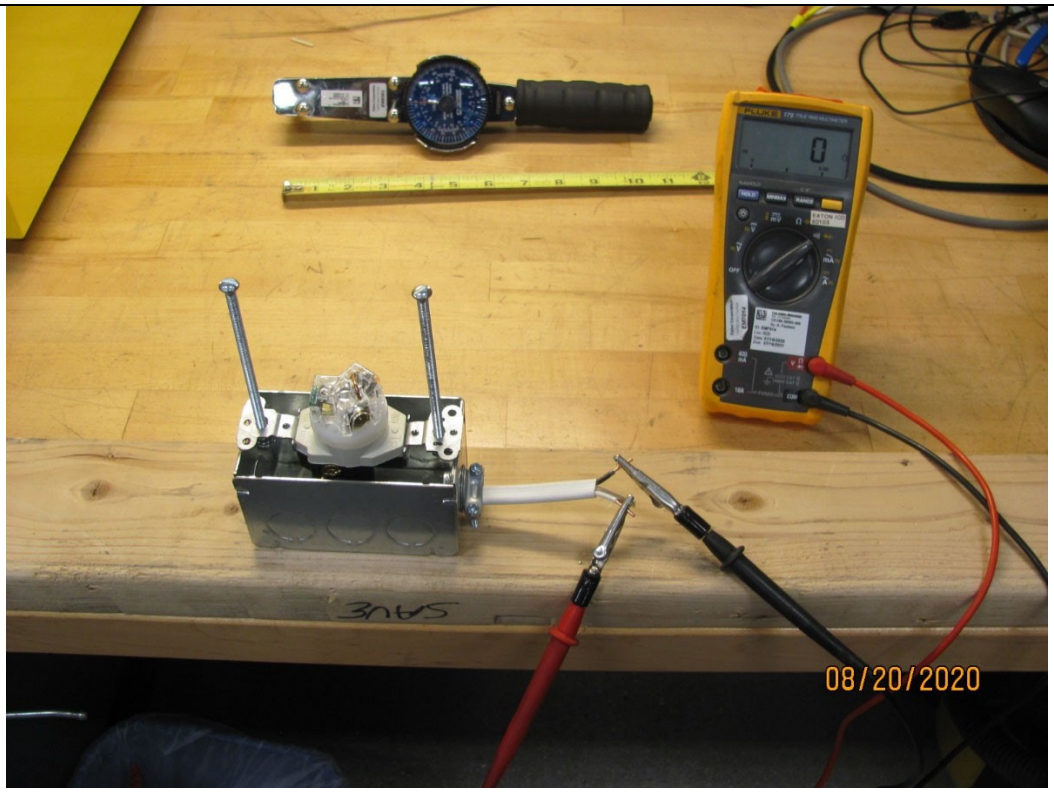


Photo 16 – Flexing Test Setup

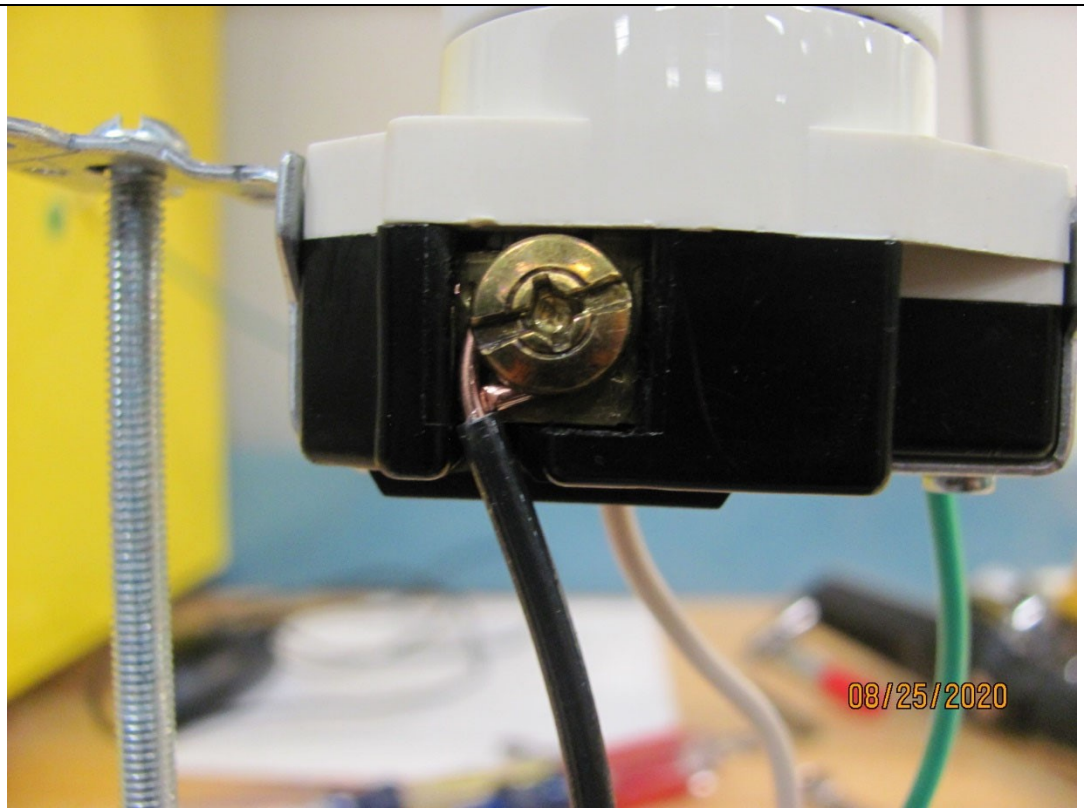


Photo 17 – Flexing Test Fully Extended

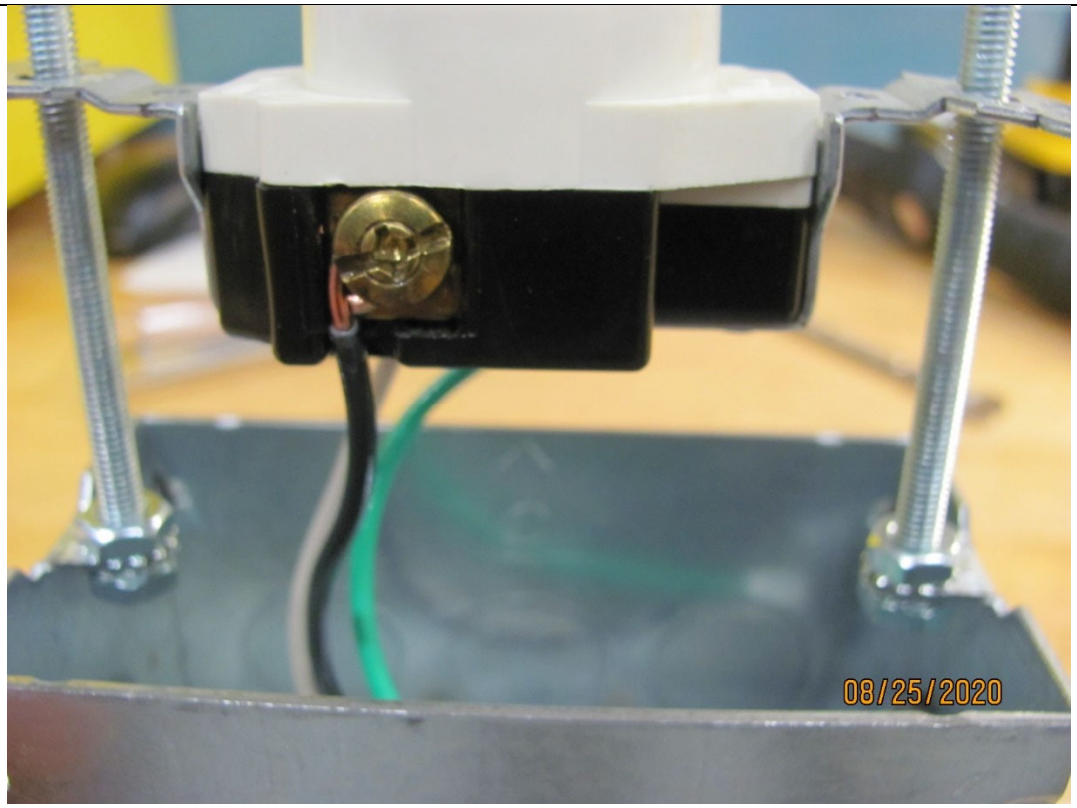


Photo 18 – Flexing Test Partial Insertion

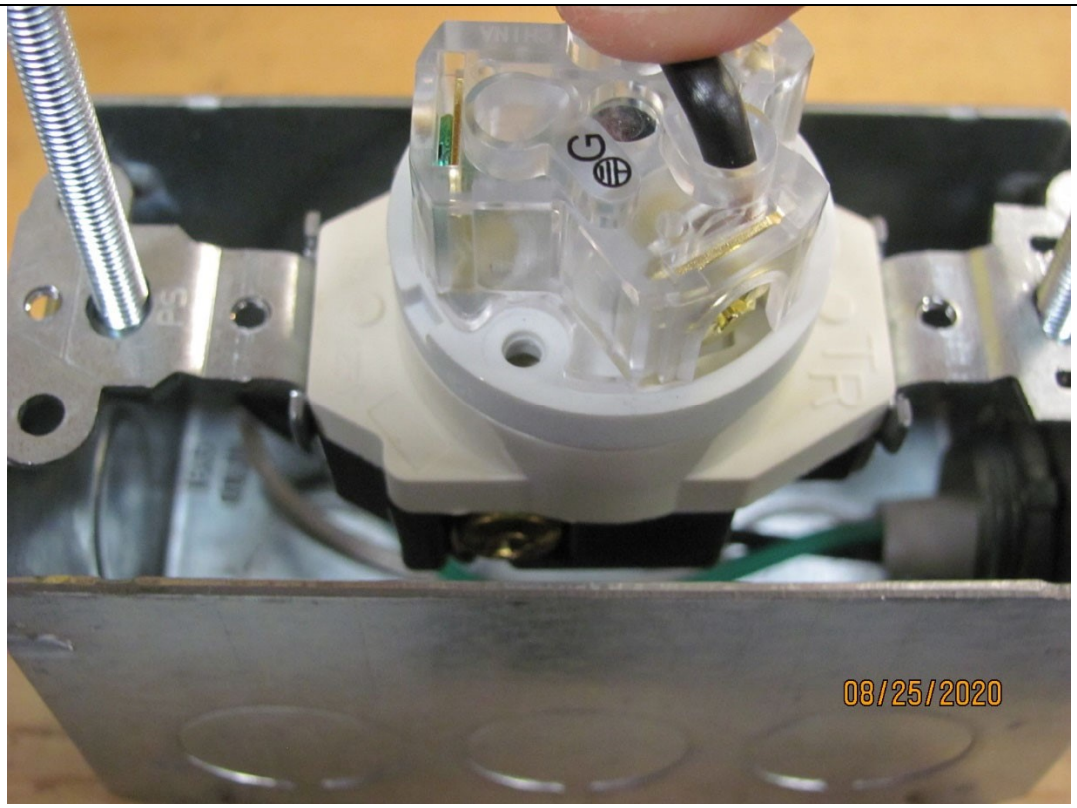


Photo 19 – Flexing Test Fully Inserted

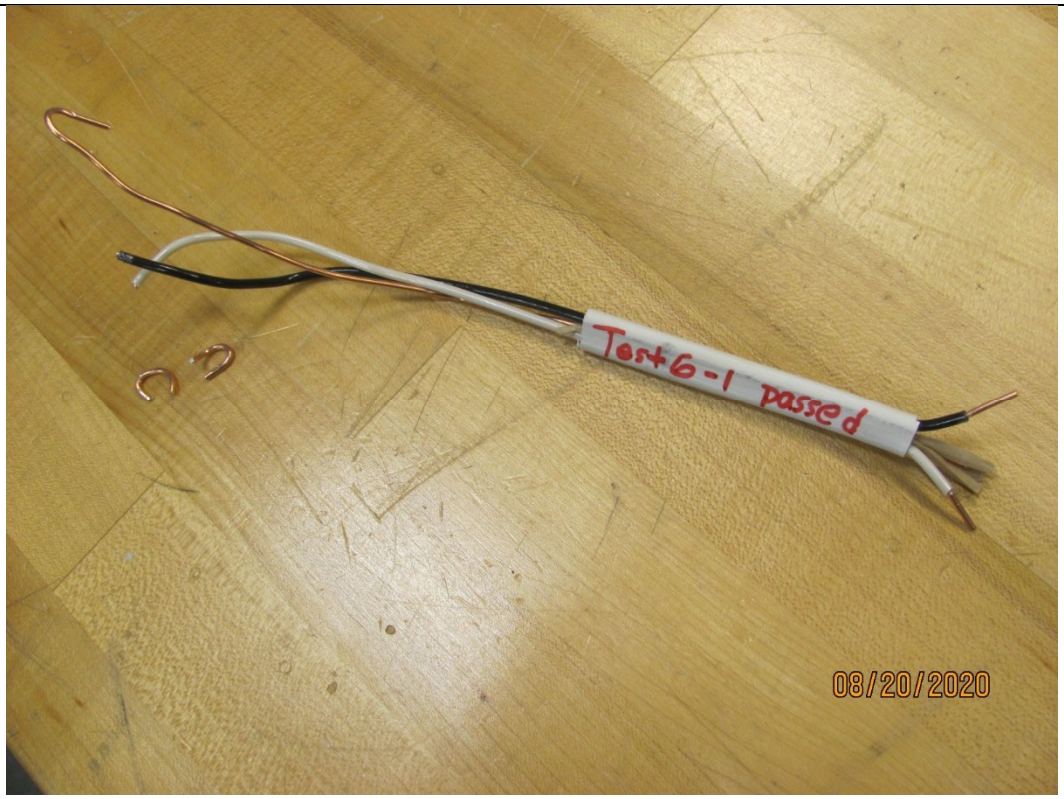


Photo 20 – Flexing Test Broken Conductors When Removing

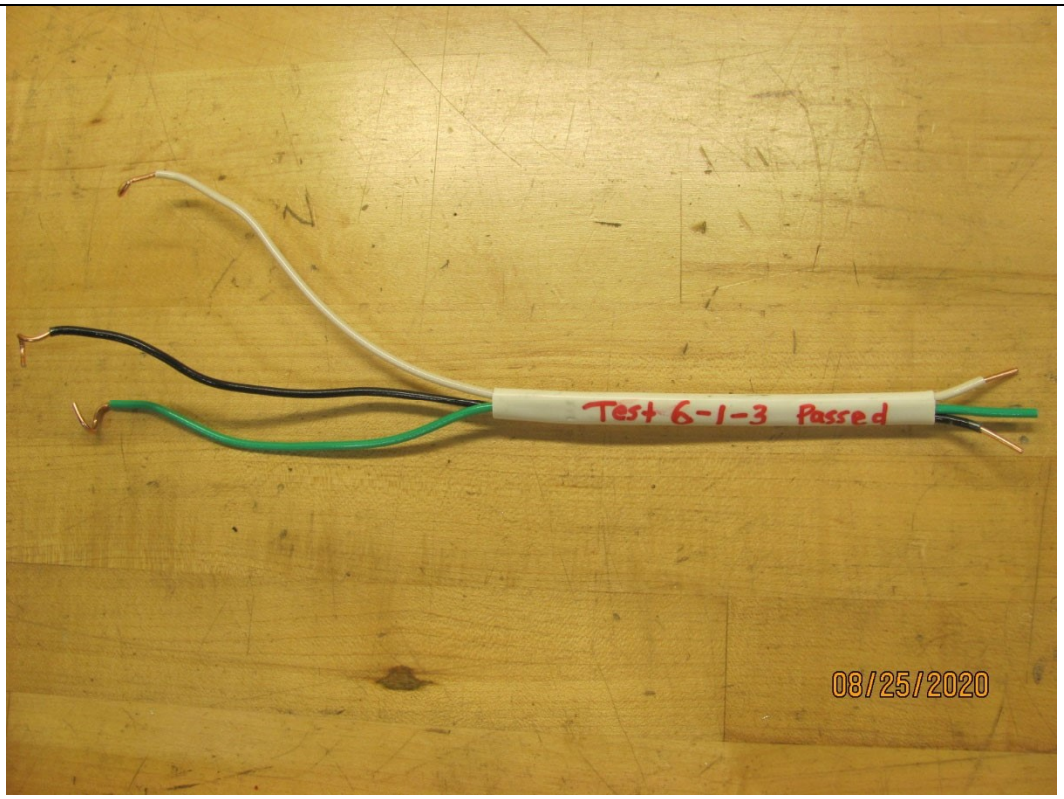


Photo 21 – Flexing Test Repeat No Conductor Breakage

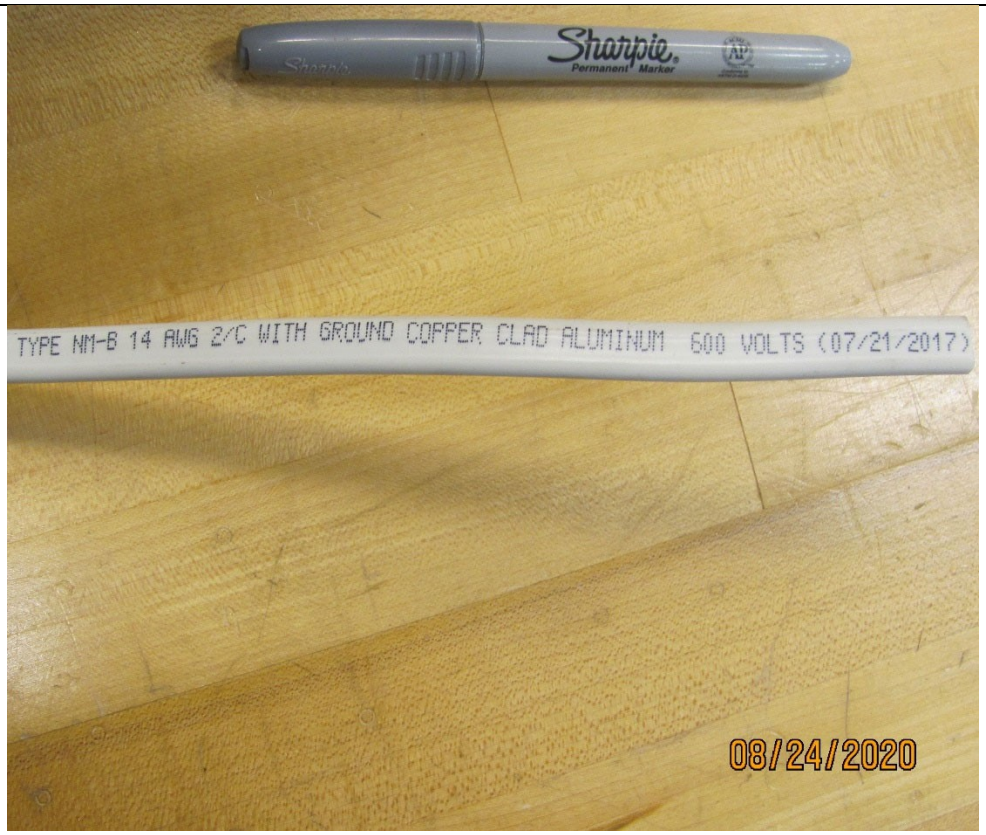


Photo 22 – Copper-Clad Aluminum NM-B Sample Packaging at Eaton

Photo 23 – Copper-Clad Aluminum THHN Sample Packaging at Eaton

Photo 24 – Copper-Clad Aluminum Sample Packaging at Eaton

COPPERWELD | Wired to Protect

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**

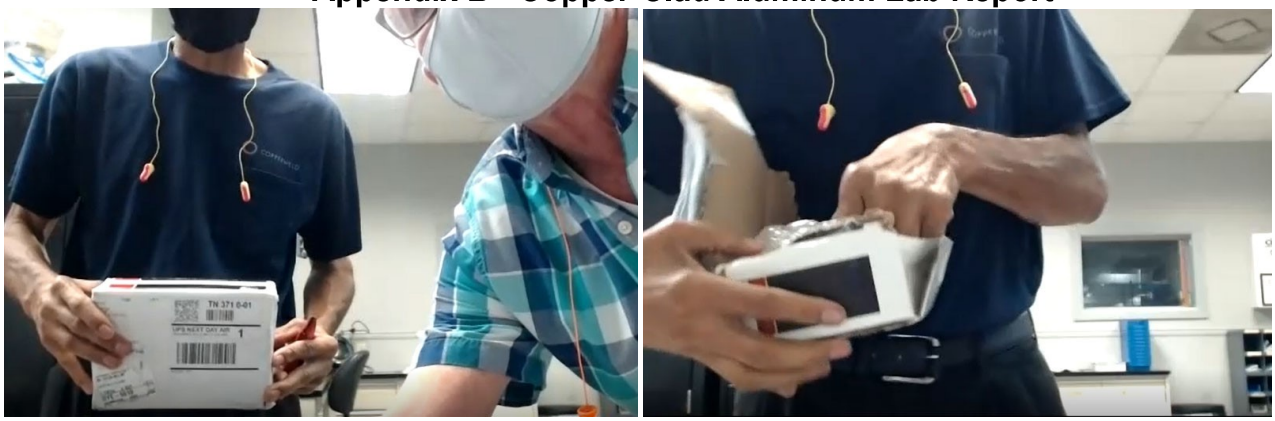
Analysis By:	**Sammy Hampton --Metallographer**
Authored By:	**Sammy Hampton –Metallographer**
Approved By:	**Bill Lewey– QA Manager**

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

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.



Opening the Package

Package Contents

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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**

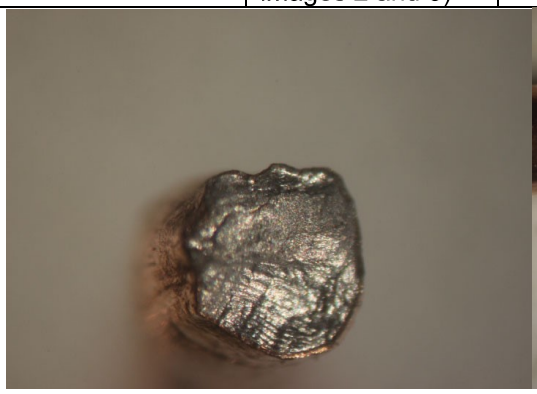


Image 1: adhesion test

Image 2: cohesion test (torsion)

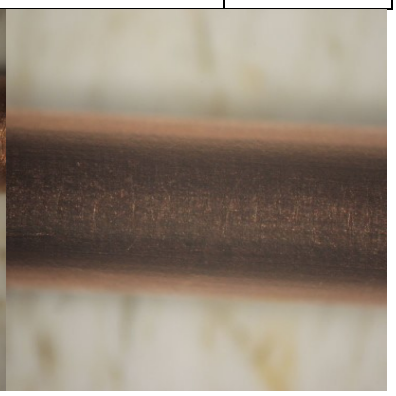


image 3: cohesion test (reverse torsion)

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			

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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	Fnd As	Lft 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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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

Revision Date:05/08/2020
Rev: 04
Page 1 of 2
QF0016

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	Last Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04
Page 2 of 2
QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

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 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	Last Cal Date (As Of Cal Entry Date)	Next Cal Date (As Of Cal Entry 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.

This document may not be reproduced except in full.

Laboratory Authorized Signature

Revision Date:05/08/2020
Rev: 04

Page 1 of 1

QF0016

This document may contain confidential and proprietary information which is the exclusive property of Copperweld. It is delivered on the express condition that it is not to be disclosed, reproduced or used, in whole or part, for the manufacture, sales or use by anyone other than Copperweld without its express written consent.

Follow-up Service Inspection Report
E49118512008271652 02

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: Factory Rep Email:	931-433-0495 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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

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 #	→	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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C1 Static Heating Testing at 100% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C2 Static Heating Tests at 135% Rated Current

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			

Appendix C4 Static Heating Tests at 200% Rated Current

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			

Appendix C5 Static Heating Testing Schneider Circuit Breaker

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

Report No: JK202006300-003
Page 1 of 2

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

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

This report shall not be reproduced except in full without written approval of Eustis Co.,Inc./Pyrocom Calibration lab.

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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	

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

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						

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

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

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

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

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

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

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB ACCREDITED ISO IEC 17025 CALIBRATION AND TESTING LABORATORY

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

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	299.9	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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

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

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
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

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

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						

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

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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.3	500.3	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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	10.1	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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.1	500.1	0.06
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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

Feature	Nominal	Lower Limit	Upper Limit	As Found	As Left	Uncertainty
50 A	500.0	498.5	501.5	500.0	500.0	0.07
	(V AC)	(V AC)	(V AC)	(V AC)	(V AC)	(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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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-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

Fox Valley Metrology
3114 Medalist Drive
Oshkosh, WI 54902
(920) 426-5894 • Fax (920) 426-8120
http://www.FoxValleyMetrology.com

CERTIFICATE OF CALIBRATION

ilac-MRA ANAB 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

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
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 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

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 08:16:33 EDT 2020
Committee: NEC-P06

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
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 28 10:04:17 EDT 2020
Committee: NEC-P06

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
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 08:31:19 EDT 2020
Committee: NEC-P06

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:
State:
Zip:
Submittal Date: Wed Sep 09 14:29:13 EDT 2020
Committee: NEC-P06

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
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 08:32:31 EDT 2020
Committee: NEC-P06

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

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

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

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

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:
Zip:
Submittal Date: Wed Sep 09 08:34:29 EDT 2020
Committee: NEC-P06

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 8–2	1.14 1.52	45 60				
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	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

	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	Refrigerators, room air conditioners, and as permitted in 422.16(B)	Damp locations	Not hard usage			
Range, dryer cable	SRD	300	10–4	3 or 4	Thermoset	10–4	1.14	45	None	Thermoset	Portable	Damp locations	
SRDE	300	10–4	3 or 4	Thermoplastic elastomer	None	Thermoplastic elastomer							
SRDT	300	10–4	3 or 4	Thermoplastic	None	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	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 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		—	—
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.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:

Zip:

Submittal Date: Sun Feb 02 08:52:31 EST 2020

Committee: NEC-P06

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 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 or rayon Pendant or portable Dry loca-~~

~~tions 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 thermo-~~

~~plastic~~

~~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 loca-~~

~~tions 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 - - 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~~
~~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
Organization: Master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Sun Apr 26 10:51:39 EDT 2020
Committee: NEC-P06

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
Organization: Submission is independent of employer.
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 23 11:37:43 EDT 2020
Committee: NEC-P06

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 elastome
	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	mm
	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

Submitter Full Name: Jeffrey Blain
Organization: Edgett Williams Consulting Group

Affiliation:	National Elevator Industry
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Fri Sep 04 10:16:23 EDT 2020
Committee:	NEC-P06

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 cotto outer one flame retard and moist resist	
						20–16 15–12	0.51 0.76	20 30	Flexible nylon jacket		

						12–10 8–2	1.14 1.52	45 60				
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	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

	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 1.52 60 Refrig-erators, room air condi-tioners, and as permitted in 422.16(B) Damp loca-tions Not hard usage

15–14 2.03 80

12 2.41 95

10 2.80 110

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

Submitter Full Name: David Hittinger
Organization: IEC
Street Address:
City:
State:
Zip:
Submittal Date: Sun Mar 15 17:31:27 EDT 2020
Committee: NEC-P06

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

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

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

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

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

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

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

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

Portable Power Feeder Cables	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	
	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

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, <u>up to 2000 Volts</u>, 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
Organization: Master Electrican
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jan 13 15:12:59 EST 2020
Committee: NEC-P06

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	mm	mils	Outer Covering	Thickness of Ins	
							Maximum Operating Temperature	App Pro
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 (167°F)	Fixtu wirin
	FFHH-2			-				(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	mm	mils	Outer Covering	Thickness of Ins	
							Maximum Operating Temperature	App Pro
nickel-coated copper)		roethylene					(302°F)	nick 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*	Cross-linked synthetic polymer	18–16	0.76	30	None or non-metallic covering	90°C (194°F)	Fixtu wirin
	RFHH-3*		18–16	1.14	45			
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	0.76	30	Nonmetallic covering	200°C (392°F)	Fixtu wirin
			10	1.14	45			
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	0.76	30	Nonmetallic covering	150°C (302°F)	Fixtu wirin
			10	1.14	45			

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-jacketed or equivalent	90°C (194°F)	Fixtu wirin
Heat-resistant thermoplastic covered fixture wire — flexible stranded	TFFN*	Thermoplastic	18–16	0.38	15	Nylon-jacketed 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 — lin 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 — lin 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	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

Submitter Full Name: Andrew Smith
Organization: E Light Electric Services, Inc
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 07 18:02:36 EDT 2020
Committee: NEC-P06

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

Submitter Full Name: Richard Holub
Organization: The DuPont Company, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 14:37:24 EDT 2020
Committee: NEC-P06

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

Submitter Full Name:	Michael Anthony
Organization:	Standards Michigan + JRH Consulting
Affiliation:	IEEE Education & Healthcare Facilities Electrotechnology Committee
Street Address:	
City:	

State:
Zip:
Submittal Date: Tue Sep 08 08:21:53 EDT 2020
Committee: NEC-P06

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 (I00°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.

Submitter Information Verification

Submitter Full Name: Joseph Wages
Organization: Self
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 08:19:05 EDT 2020
Committee: NEC-P06

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

Submitter Full Name: Rick Trujillo
Organization: Nustar Energy
Street Address:
City:
State:
Zip:
Submittal Date: Tue Apr 14 10:09:35 EDT 2020
Committee: NEC-P06

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 80~~
~~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 80~~
~~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

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
Organization: Self Employed
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 07 10:56:52 EDT 2020
Committee: NEC-P06

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
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 27 14:27:55 EDT 2020
Committee: NEC-P06

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
Organization: JC Electric, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 31 14:53:55 EDT 2020
Committee: NEC-P06

Public Input No. 137-NFPA 70-2019 [Section No. Table]

Table 8

Table 8 Conductor Properties

Size (AWG or kcmil)	Area mm²	Area Circular mils	Conductors Quantity	Stranding Diameter mm	Stranding Diameter in.	Overall Diameter mm	Overall Diameter in.	Overall Area mm²	Overall Area 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 (AWG or kcmil)	Area mm²	Circular mils	Quantity	Conductors Stranding Diameter mm	Stranding Diameter in.	Overall Diameter mm	Overall Diameter in.	Overall Area mm²	Overall 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 $\alpha_{cu} = 0.00323$, $\alpha_{AL} = 0.00330$ 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
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Nov 21 13:59:55 EST 2019

Committee: NEC-P06

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.

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: Correlating Committee Task Group
Affiliation: NFPA Correlating Committee Task Group
Street Address:
City:
State:
Zip:
Submittal Date: Tue May 05 10:11:01 EDT 2020
Committee: NEC-P06

Copyright Assignment

I, David Hittinger, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am David Hittinger, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature

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. 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 mils
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
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
						20–16 15–12 12–10 8–2	0.51 0.76 1.14 1.52	20 30 45 60
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	20 30 45

						8–2	1.52	60
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)	30 (20)
						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	Thermoplastic elastomer with optional nylon	18–15	0.76 (0.51)	30 (20)

				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)
	EVJE 5,6	300	18–12			18–12	0.76 (0.51)	30 (20)
	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)
						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)
Portable power cable	G	2000	12–500	2–6 plus equipment grounding conductor(s)	Thermoset	12–2	1.52	60
						1–4/0	2.03	80
						250–500	2.41	95

	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
Heater cord	HPD	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.38 0.76	15 30
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
Thermoset jacketed heater cords	HSJ	300	18–12	2, 3, or 4	Thermoset	18–16 15–12	0.76 1.14	30 45
	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	15
	NISP-2	300	18–16			18–16	0.76	30
	NISPE-1 [8]	300	20–18		Thermoplastic elastomer	20–18	0.38	15
	NISPE-2 [8]	300	18–16			18–16	0.76	30
	NISPT-1 [8]	300	20–18		Thermoplastic	20–18	0.38	15
	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
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
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
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
	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	30 45 60
	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	30 45	
	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	30 45
	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	30
	SOW [7,9]	600						
	SOO [7]	600			Oil-resistant thermoset	14–9 8–2	1.14 1.52	45 60
	SOOW [7,9]	600						

All thermoset parallel cord	SP-1	300	20–18	2 or 3	Thermoset	20–18	0.76	30	
	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	
All elastomer (thermo-plastic) parallel cord	SPE-1 [8]	300	20-18	2 or 3	Thermoplastic elastomer	20–18	0.76	30	
	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	
All thermoplastic parallel cord	SPT-1	300	20–18	2 or 3	Thermoplastic	20–18	0.76	30	
	SPT-1W [9]	300		2					
	SPT-2	300	18–16	2 or 3		18–16	1.14	45	
	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	60 80 95 110
Range, dryer cable	SRD	300	10–4	3 or 4	Thermoset	10–4	1.14	45
	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	30 45 60
	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	15

	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	30	
Jacketed tinsel cord	TST [11]	300	27	2	Thermoplastic	27	0.38	15	
Portable power cable	W [7]	2000	12–500 501–1000	1–6 1	Thermoset	12–2 1–4/0	1.52 2.03	60 80	

						250–500	2.41	95
						501–1000	2.80	110

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		Types HPD, HPN, HSJ, HSJO, HSJOW, HSJOO, HSJOOW
		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		
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

Copyright Assignment

I, Alfio Torrisi, hereby irrevocably grant and assign to the National Fire Protection Association (NFPA) all and full rights in copyright in this Public Input (including both the Proposed Change and the Statement of Problem and Substantiation). I understand and intend that I acquire no rights, including rights as a joint author, in any publication of the NFPA in which this Public Input in this or another similar or derivative form is used. I hereby warrant that I am the author of this Public Input and that I have full power and authority to enter into this copyright assignment.

☑ By checking this box I affirm that I am Alfio Torrisi, and I agree to be legally bound by the above Copyright Assignment and the terms and conditions contained therein. I understand and intend that, by checking this box, I am creating an electronic signature that will, upon my submission of this form, have the same legal force and effect as a handwritten signature