Public Comment No. 1646-NFPA 70-2024 [Global Input]

This Global Public Comment is for CMP-6 to review the use of the terms "overcurrent", "overcurrent protective devices" and "overcurrent protection".

Additional Proposed Changes

File Name	Description	Approved
CMP-6_OCPD_TG-4_CMP-10.pdf	CMP-6_OCPD_TG-4 CMP-10	
All_CMP_Comments_Files_from_CMP-10_TG-4.pdf	All CMP Comments Files from CMP-10 TG-4	

Statement of Problem and Substantiation for Public Comment

This Public Comment is submitted on behalf of a Task Group formed under the purview of Code Making Panel 10 consisting of Randy Dollar, Thomas Domitrovich, Jason Doty, Diane Lynch, Alan Manche, Nathan Philips, David Williams, and Danish Zia. This Public Comment, along with other Public Comments, was developed with the goal of improving usability and accuracy on requirements associated with overcurrent protective devices.

The Task Group reviewed all instances of the term "overcurrent", "overcurrent protective devices" and "overcurrent protection" and provided recommended changes to align proposed and current defined terms.

For consistency, the task group chose to use the full defined term "overcurrent protective device" in the title of all sections or subdivisions and the acronym "OCPD" or "OCPDs" when used in the body of each code section.

The term overcurrent protection applies to the application of an overcurrent protective device OCPD, to protect conductors and equipment.

Two documents are attached: One for your specific code panel and the other is a comprehensive document illustrating all of the code-wide comments made by this task group.

The current term "Overcurrent Protective Device, Branch-Circuit" is being deleted and the new defined term "Overcurrent Protective Device (OCPD)" will be used instead.

The following are the proposed terms being submitted to CMP-10.

PC 1639 Overcurrent Protection.
Automatic interruption of an overcurrent

PC 1636 Overcurrent Protective Device (OCPD).
A device capable of providing protection over the full range of overcurrent between its rated current and its interrupting rating. (CMP-10)

Informational Note 1: Prior editions of NFPA 70 included the defined term "branch circuit overcurrent protective device" for overcurrent protective devices suitable for providing protection for service, feeder and branch circuits. This term has been revised to a generalized term of "overcurrent protective device" (OCPD). The specific requirements using this term may include modifiers (such as branch OCPD, feeder OCPD, service OCPD) to specify location or application of the OCPD, or to specify variations (such as supplementary OCPD).

Informational Note 2: See 240.7 for a list of overcurrent protective devices suitable for providing protection for service, feeder, branch circuits and equipment.

Related Item

• Global PI 4050 • PC 1636 • PC 1639

Submitter Information Verification

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Submittal Date: Sun Aug 25 21:43:13 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-8574-NFPA 70-2024
Statement: Editorial revision per CC request.

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-6			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
6	**Article 310**		
	310.10(G).	Overcurrent Protection	Fine as is
	310.15(A)	Overcurrent Protection	Fine as is
	310.16-T	Overcurrent Protection	Fine as is
	310.17-T	Overcurrent Protection	Fine as is
6	**Article 335**		
	335.90.	Overcurrent Protection	Fine as is
6	**Article 382**		
	382.4	Supplementary Overcurrent Protection	Supplementary Overcurrent Protective Device
6	**Article 400**		
	400.16	Overcurrent Protection	Fine as is
	400.16	protected against Overcurrent	shall be provided with overcurrent protection
6	**Article 402**		
	402.14 (X2)	Overcurrent Protection	Fine as is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-1			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
1	**Article 110**		
	110.10.	overcurrent protective devices	OCPDs
	110.10.	circuit protective devices	Fine as is
	110.26(C)(2)	overcurrent devices	OCPD
	110.26(C)(3)	overcurrent devices	OCPD
	110.52	Overcurrent protection	Fine as is
	110.52	Overcurrent	Motor-operated Equipment shall be provided with overcurrent protection
	110.52	Overcurrent	Transformers shall be provided with overcurrent protection

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-2			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
2	**Article 100**		
	Branch Circuit (Branch-Circuit)	overcurrent device	overcurrent protective device (OCPD)
2	**Article 120**		
	120.5(E)	overcurrent device	OCPD
	120.7(B)	overcurrent protective device	OCPD
	120.87(3)	Overcurrent protection	Fine as is
2	**Article 210**		
	210.4(A)	branch-circuit overcurrent protective device, OCPD	Fine as is
	210.4(C)	branch-circuit OCPD	Fine as is
	210.11(B)	branch-circuit OCPD	Fine as is
	210.12(A)	branch-circuit OCPD (X-8)	Fine as is
	210.18	~~overcurrent device~~ OCPD (X-2)	Fine as is
	210.19(A)(1)EX	branch-circuit OCPD	Fine as is
	210.20.	Overcurrent protection	Fine as is
	210.20.	branch-circuit OCPD	Fine as is
	210.20(A)	branch-circuit OCPD	Fine as is
	210.20(C)	branch-circuit OCPD	Fine as is
	T-210.24	Overcurrent protection	Fine as is
2	**Annex D**		
	D3. (X2)	Overcurrent Protection	CMP-2 To review references to OCPD and the revised terms.
	D3a. (X8)	Branch-Circuit OCPD	CMP-2 to Review
	D3a.	Overcurrent Protection	CMP-2 to Review
	D3a. (X2)	Branch-Circuit OCPD	CMP-2 to Review

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-3			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
3	**Article 100**		
	Fault Managed Power.	Overcurrent protection	Fine as is
	Fire Alarm Circuit	Overcurrent device	overcurrent protective device (OCPD)
3	**Article 300**		
	300.5-T	Overcurrent Protection	Fine as is
	300.17(I)	Overcurrent Device	OCPD
	300.28(C)(3). (X5)	Overcurrent Protection	Fine as is
3	**Article 590**		
	590.6(A)	Overcurrent Protection	Fine as is
	590.6(B)	be protected from Overcurrent	shall be provided with overcurrent protection
	590.9. Title	Overcurrent protective device	Fine as is
	590.9(A)	Overcurrent protective devices	OCPDs
	590.9(B) Title	Service Overcurrent protective devices	Fine as is
	590.9(B)	Overcurrent protective devices	OCPDs
3	**Article 721**		
	721.50(A)	Overcurrent	Fine as is
3	**Article 722**		
	722.1	Overcurrent Protection	Fine as is
3	**Article 724**	Class 1	
	724.40(B). (X3)	Overcurrent Devices	OCPDs
	724.40(B). (X2)	Overcurrent Device	OCPD
	724.40(B). (X2)	Overcurrent Protection	Fine as is
	724.43. (X4)	Overcurrent Protection	Fine as is
	724.45	Overcurrent Device	OCPD
	724.45. (X3)	Overcurrent Devices	OCPDs
	724.45(A)	Overcurrent Devices	OCPDs
	724.45(B)	Overcurrent Protection	Fine as is
	724.45(B)	Overcurrent Device	OCPD
	724.45(C). (X2)	Overcurrent protective devices	OCPDs
	724.45(D)	Overcurrent Protection	Fine as is
	724.45(E)	Overcurrent Protection	Fine as is
3	**Article 725**		
	725.1 In	Overcurrent Protection	Fine as is

	725.127	Overcurrent Device	OCPD
3	**Article 760**		
	760.41(B)	Overcurrent protective device	OCPD
	760.41(B)	Overcurrent protection devices	OCPDs
	760.43. (X3)	Overcurrent Protection	Fine as is
	760.45. Title	Overcurrent device	Overcurrent protective device
	760.45	Overcurrent protection devices	OCPDs
	760.45 Ex 1 & 2	Overcurrent Protection	Fine as is
	760.121(B)	Branch-Circuit Overcurrent protective device	OCPD
	760.121(B)	Overcurrent protection devices	OCPDs
	760.127	Overcurrent Protection	Fine as is
	760.127	Overcurrent Device	OCPD
3	**Article 794**		
	794.1	Overcurrent Protection	Fine as is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-4			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
4	**Article 690**		
	690.2	PV dc Overcurrent protective devices	PV dc OCPDs
	690.8	Overcurrent Device	OCPD and OCPDs
	690.9. Title	Overcurrent Protection	Fine as is
	690.9(A). (X2)	be protected from Overcurrent	shall be provided with overcurrent protection
	690.9(A)(1). Title	Overcurrent Protection	Fine as is
	690.9(A)(1).	Overcurrent protective devices	OCPDs
	690.9(A)(2). Title	Overcurrent Protection	Fine as is
	690.9(A) (2)	be protected from Overcurrent	shall be provided with overcurrent protection
	690.9(A) (2) In	Overcurrent protection	Fine as is
	690.9(A) (2) In	Overcurrent device	OCPD
	690.9(A)(3)	Overcurrent	Fine as is
	690.9(B)	shall be permitted to prevent overcurrent of conductors	Fine as is
	690.9(B)	Overcurrent device	OCPD and OCPDs
	690.9(C)	Overcurrent protective device and Devices	OCPD and OCPDs
	690.31(E)	Overcurrent protective devices	OCPDs
	690.45	Overcurrent protective device	OCPD
	690.45	Overcurrent Device	OCPD
4	**Article 692**		
	692.8. Title	Overcurrent Device	Overcurrent Protective Devices
	692.8	Overcurrent protective device	OCPDs
	692.9	Overcurrent Protection	Fine as is
	692.9	Overcurrent Devices	OCPDs
4	**Article 694**		
	694.7(D)	Overcurrent Device	OCPD
	694.12(B). Title	Overcurrent Device	Overcurrent Protective Device
	694.12(B)(2). Title	Overcurrent Devices	Overcurrent Protective Devices
	694.12(B)(2)	Overcurrent Devices	OCPDs
	694.15	Overcurrent Protection	Fine as is
	694.15	Overcurrent Devices	OCPDs
	694.15 In	Overcurrent Protection	Fine as is
	694.15(B)(1)	Overcurrent Protection	Fine as is
	694.15(C)	Overcurrent Devices	OCPDs

4	**Article 705**		
	705.11(C). Title	Overcurrent Protection	Fine as is
	705.11(C)	be protected from overcurrent	have overcurrent protection
	705.11(C)(1). (1) (2) (3)	Overcurrent protective device	OCPD
	705.11(C)(2)	Overcurrent protection devices	OCPDs
	705.12(A)(2). (X4)	Overcurrent Device	OCPD
	705.12(A)(3)	Overcurrent Devices	OCPDs
	705.12(B)	(Multiple) Overcurrent Device and (s)	OCPD. And OCPDs
	705.12(B)	(Warning labels) Overcurrent Device and (s)	Overcurrent Protective Device and Devices
	705.28(B)Ex.1	Overcurrent Devices	OCPDs
	705.28(B)Ex.3	Overcurrent Device	OCPD
	705.30. Title	Overcurrent Protection	Fine as is
	705.30(A). (X2)	Overcurrent Protection	Fine as is
	705.30(A)	Overcurrent Devices	OCPDs
	705.30.(C)	Overcurrent Devices	OCPDs
	705.30.(F)	Overcurrent Protection	Fine as is
	705.70.	Overcurrent Devices	OCPDs
	705.70.	Overcurrent Protection	Fine as is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-5			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
5	**Article 100**		
	Ground-Fault Current Path, Effective	overcurrent protective device	overcurrent protective device (OCPD)
	Ground-Fault Protection of Equipment	overcurrent device	overcurrent protective device (OCPD)
5	**Article 200**		
	200.10(E)	overcurrent device	OCPD
5	**Article 250**		
	250.4(A)(5). Title	Overcurrent protective Device	Fine as is
	250.4(A)(5)	Overcurrent Device	OCPD
	250.4(B)(4)	Overcurrent Devices	OCPDs
	250.30(A)(1)	Overcurrent Device	OCPD
	250.30(A)(1)	Overcurrent Devices	OCPDs
	250.32(B)(2). (X4)	Overcurrent Protection	Fine as is
	250.32(C)(2). (X4)	Overcurrent Protection	Fine as is
	250.35(B)	Overcurrent Protection	Fine as is
	250.36(D)	Overcurrent Device	Fine as is
	250.36(E)(1)	Overcurrent Device	OCPD
	250.102(B)(2)	Overcurrent Protection	Fine as is
	250.102(D). (X3)	Overcurrent Devices	OCPDs
	250.118(A)(5)	Overcurrent Devices	OCPDs
	250.118(A)(6)	Overcurrent Devices	OCPDs
	250.118(A)(7)	Overcurrent Devices	OCPDs
	250.122(C)	Overcurrent Device	OCPD
	250.122(F)(1). (X3)	Overcurrent protective device	OCPD
	250.122(G)	Overcurrent Device	OCPD
	250.142. (X2)	Overcurrent Device	OCPD
	250.148	Overcurrent Device	OCPD
	250.164	Overcurrent Device	OCPD
	250.166	Overcurrent Protection	Fine as is
	250.169	Overcurrent Devices	OCPD
5	**Article 270**		
	270.4(A)(5)	Overcurrent Device	OCPD
	270.4(B)(4)	Overcurrent Devices	OCPDs
	270.30(A)(1)	Overcurrent Devices	OCPDs

	270.32(B)(2). (X4)	Overcurrent Protection	Fine as is
	270.32(C)(2). (X4)	Overcurrent Protection	Fine as is
	270.35(B)	Overcurrent Protection	Fine as is
	270.35(B)	Overcurrent protective device	OCPD
	270.36(D)	Overcurrent Device	OCPD
	270.36(E)	Overcurrent Devices	OCPDs
	270.102(C)(2)	Overcurrent Protection	Fine as is
	270.102(D)	Overcurrent Device	OCPDs
	270.114(C)(3)	Overcurrent setting	CMP to review Language based on new terms
	270.118	Overcurrent Devices	OCPDs
	270.142	Overcurrent Devices	OCPDs
	270.148(B)	Overcurrent Device	OCPD
	270.164(B)	Overcurrent Device	OCPD
	270.166(A)	Overcurrent Protection	Fine as is
	270.169	Overcurrent Devices	OCPDs

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-6			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
6	**Article 310**		
	310.10(G).	Overcurrent Protection	Fine as is
	310.15(A)	Overcurrent Protection	Fine as is
	310.16-T	Overcurrent Protection	Fine as is
	310.17-T	Overcurrent Protection	Fine as is
6	**Article 335**		
	335.90.	Overcurrent Protection	Fine as is
6	**Article 382**		
	382.4	Supplementary Overcurrent Protection	Supplementary Overcurrent Protective Device
6	**Article 400**		
	400.16	Overcurrent Protection	Fine as is
	400.16	protected against Overcurrent	shall be provided with overcurrent protection
6	**Article 402**		
	402.14 (X2)	Overcurrent Protection	Fine as is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-7			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
7	**Article 100**		
	Service Equipment, Mobile Home	overcurrent protective devices	overcurrent protective devices (OCPDs)
7	**Article 545**		
	545.24	Branch-circuit overcurrent protective device	Branch-circuit OCPD
	545.24(B) Title	Branch Circuit Overcurrent Protection Device	Overcurrent protective devices
	545.24(B)	a Branch Circuit Overcurrent Protective Device	an OCPD
7	**Article 547**		
	547.41(A)(6). (X2)	Overcurrent Protection	Fine as is
	547.41(B)	Overcurrent Protection	Fine as is
	547.42	Overcurrent Protection	Fine as is
7	**Article 550**		
	550.11(B). Title	Branch-Circuit protective equipment	Branch-Circuit Overcurrent Protection
	550.11(B)	Overcurrent Protection	Fine as is
	550.11(B)	Branch-Circuit Overcurrent Devices	OCPDs
	550.11(B)	Overcurrent protection size	OCPD rating
	550.15(E)	Branch-circuit overcurrent protective device	OCPD
	550.32	Overcurrent Protection	Fine as is
7	**Article 551**		
	551.31(A)	Overcurrent protective device	OCPD
	551.31(C)	Overcurrent protective device	OCPD
	551.31(D)	Overcurrent Protection	Fine as is
	551.42	Overcurrent Protection	Fine as is
	551.43. Title	Branch-Circuit protection	Branch-Circuit Overcurrent Protection
	551.43(A)	Branch Circuit Overcurrent Devices	Branch-Circuit OCPDs
	551.43(A)(3)	Overcurrent Protection	Fine as is
	551.45(C)	Overcurrent protective device	OCPD
	551.47(Q)	Overcurrent protective device	OCPD
	551.47(R)	Overcurrent Protection	Fine as is
	551.47(S)	Overcurrent Protection	Fine as is
	551.74	Overcurrent Protection	Fine as is
7	**Article 552**		
	552.10.(E) Title	Overcurrent Protection	Fine as is
	552.10(E)(1)	Overcurrent protective devices	OCPDs

	T-552.10(E)(1)	Overcurrent Protection	Fine as is
	552.10(E)(4). (X2)	Overcurrent protective device	OCPD
	552.42(A)	Branch Circuit Overcurrent Devices	OCPDs
	552.42(A)	Overcurrent Protection	Fine as is
	552.45(C)	Overcurrent protective device	OCPD
	552.46(A) IN	Overcurrent Protection	Fine as is
	552.47(P)	Overcurrent protective device	OCPD
	552.47(Q)	Overcurrent Protection	Fine as is
7	**Article 555**		
	555.53	Overcurrent protective device	OCPD
7	**Article 675**		
	675.6	Branch Circuit Overcurrent Protective Device	OCPD
	675.7	Branch Circuit Overcurrent Protective Devices	OCPDs
	675.8	Overcurrent Protection	Fine as is
7	**Article 682**		
	682.15(B)	Feeder Overcurrent protective device	Feeder OCPD

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-8			
CMP	NEC Section (using First Draft of 2026 NEC)	Current Language	"New" Language
8	Article 312		
	312.11. Title	Overcurrent Devices	Overcurrent Protective Device
	312.11	Overcurrent Devices	OCPDs
	312.11(A). (X3)	Overcurrent Device	OCPDs
	312.11(B)	Overcurrent Devices	OCPDs
	312.11(B)(1)	Overcurrent Device	OCPD
8	Article 366		
	366.12	Overcurrent Devices	OCPDs
	366.56(D)	Overcurrent Protection	Fine as is
8	Article 368		
	368.17(A). Title	Overcurrent Protection	Fine as is
	368.17	Overcurrent Protection	Fine as is
	368.17(A)	Protected against Overcurrent	shall be provided with overcurrent protection
	368.17(B). (X2)	Overcurrent Protection	Fine as is
	368.17(B)	Overcurrent Device	OCPD
	368.17(C)	Overcurrent Devices	OCPDs
	368.17(C)Ex.2	Branch-Circuit Overcurrent Device	Branch-Circuit OCPD
	368.17(C)Ex.3	Overcurrent Device	OCPD
	368.17(C)Ex.4	Branch-Circuit overcurrent plug-in device	CMP to review Language based on new terms
	368.17(D). Title	Overcurrent Protection	Fine as is
	368.17(D)	Protected against Overcurrent	shall be provided with overcurrent protection
8	Article 370		
	370.23. Title	Overcurrent Protection	Fine as is
	370.23	Protected against Overcurrent	shall be provided with overcurrent protection
8	Article 371		
	371.17. Title	Overcurrent Protection	Fine as is
	371.17	Overcurrent Protection	Fine as is
	371.17 (A)-(C). Titles	Overcurrent Protection	Fine as is
	371.17(A)-(C)	Protected against Overcurrent	shall be provided with overcurrent protection
	371.17(D)	Protected against Overcurrent	shall be provided with overcurrent protection
	371.17(F)	Overcurrent	shall be provided with overcurrent protection
	371.17(G)	Overcurrent Protection	
	371.17(G)Ex	Overcurrent Protection	Fine as is
	371.17(G)Ex	Overcurrent Device	OCPD

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-9			
CMP	NEC Section (using First Draft of 2026 NEC)	Current Language	"New" Language
9	**Article 265**		
	265.18	Overcurrent Device	OCPD
	265.20.	Overcurrent Protection	Fine as is
	265.20.	Overcurrent protective devices	OCPDs
	265.20.	Overcurrent Devices	OCPDs
9	**Article 266**		
	266.1	Overcurrent Protection	Fine as is
	266.5	Overcurrent Protection	Fine as is
	266.5	Protected against overcurrent	shall be provided with overcurrent protection
	266.5	Overcurrent Device	OCPD
9	**Article 268**		
	268.2. (X2)	Overcurrent Protection	Fine as is
	268.70(F)	Overcurrent Devices	OCPDs
	268.82. (X4)	Overcurrent Protection	Fine as is
	Art. 268 Part VII	Overcurrent Protection	Fine as is
	268.90.	Overcurrent Device	OCPD
	268.90.	Overcurrent Devices	OCPDs
	268.91	Overcurrent Device	OCPD
	268.92	Overcurrent Devices	OCPDs
	268.93	Overcurrent Device	OCPD
9	**Article 450**		
	450.5 (previously 450.3). (X3)	overcurrent protection	Fine As Is
	450.5(A) and Table. (X3)	overcurrent protection	Fine As Is
	Table 450.5(A) Footnote 2. (X4)	overcurrent device	OCPD
	450.5(B)	overcurrent protection	Fine As Is
	Table 450.5(B) and Table (X2)	overcurrent protection	OCPD
	Table 450.5(B) Footnote 2. (X3)	overcurrent device	OCPD
	Table 450.5(B) Footnote 3	overcurrent protection	OCPD
	450.6(A) Title	overcurrent protection	Fine As Is
	450.6(A) (X3)	overcurrent device	OCPD
	450.6(A) Exception	overcurrent device	OCPD
	450.7(A)(1). (X2)	overcurrent protection	OCPD
	450.7(A)(2). Title	overcurrent protection	Fine As Is

	450.7(A)(2)	overcurrent sensing device	Fine As Is
		overcurrent protection	OCPD
		overcurrent device	OCPD
		branch or feeder protective devices	branch or feeder OCPDs
	450.7(A)(3)	overcurrent device	OCPD
	450.7(B)(2)	overcurrent protection	Fine As Is
	450.7(B)(2)(a)	overcurrent protective device	OCPD
	450.7(B)(2)(b)	overcurrent protection	OCPD
	450.7(B)(2)(b)	overcurrents	Fine As Is
	450.7(B)(2)(b) Exception	overcurrent device	OCPD
	450.8(A). (X2)	overcurrent protection	Fine As Is
	450.8(A)(1)	overcurrent protection	Fine As Is
	450.8(A)(2)	overcurrent protection	Fine As Is
	450.8(A)(3)	protective device	OCPD
	450.8(A)(4)(a)	protective device	OCPD
	450.8(B). Title	Overcurrent Protection	Fine As Is
	450.8(B)	overcurrent device	OCPD
	450.9	overcurrent protection	Fine As Is
	450.9	protective devices (2x)	OCPDs
	450.23(A)(1)(d) Informational Note	overcurrent protection	OCPD
	450.23(B)(1) Informational Note 2	overcurrent protection	OCPD
9	**Article 495**		
	495.62. Title	Overcurrent Protection	Fine As Is
	495.72	Overcurrent Relay	Fine As Is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-10			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
10	**Article 100**		
	Circuit Breaker	Overcurrent	Fine as is
	Coordination, Selective. (Selective Coordination)	Overcurrent condition	Fine as is
	Coordination, Selective. (Selective Coordination)	overcurrent protective devices	overcurrent protective devices (OCPDs)
	Coordination, Selective. (Selective Coordination)	overcurrents	Fine as is
	Coordination, Selective. (Selective Coordination)	overcurrent protective device	overcurrent protective device (OCPD)
	Current Limiting (as applied to overcurrent protection devices)	overcurrent protection devices	overcurrent protective devices (OCPDs)
	Feeder	final branch-circuit overcurrent protective device	overcurrent protective device (OCPD)
	Fuse	overcurrent protective device	overcurrent protective device (OCPD)
	Fuse	overcurrent	Fine as is
	Fuse, Electronically Actuated	overcurrent protective device	overcurrent protective device (OCPD)
	Fuse, Electronically Actuated	overcurrent	Fine as is
	Overcurrent	Overcurrent protection	Fine as is
	Overcurrent Protective Device, Branch-Circuit	Revise with the term Overcurrent Protective Device. (OCPD)	
	Overcurrent **Protective** Device, Supplementary (need to Revise term with acronym)	overcurrent protective device	overcurrent protective device (OCPD)
	Panelboard	overcurrent devices	overcurrent protective devices (OCPDs)
	Surge-Protective Device (SPD). (X2)	overcurrent device. (X2)	overcurrent protective device (OCPD)
	Switchboard	overcurrent	overcurrent protective devices (OCPDs)
	Tap Conductor	Overcurrent protection	Fine as is
10	**Article 215**		
	215.1	Overcurrent protection	Fine as is
	215.4(A)(1)Ex.1	overcurrent devices protecting the feeders	feeder OCPD
	215.4(A)(1)Ex.3	overcurrent device	OCPD
	215.5 Title	Overcurrent protection	Fine as is
	215.5	Feeders shall be protected against overcurrent	Feeders shall be provided with overcurrent protection in accordance with Article 240, Parts I
	215.5	overcurrent device	OCPD
	215.5Ex	overcurrent device protecting the feeders	feeder OCPDs
	215.5Ex	overcurrent device	OCPD

	215.18(B)	branch circuit overcurrent devices	OCPDs
10	**Article 225**		
	225.40. Title	Overcurrent protective devices	Fine as is
	225.40.	feeder overcurrent device (x2)	feeder OCPD
	225.40.	branch circuit overcurrent devices	Branch circuit OCPDs
	225.42(B)	branch circuit overcurrent devices	OCPDs
10	**Article 230**		
	230.7 Ex.2	Overcurrent protection	Fine as is
	230.42(A)(1)	overcurrent device (X3)	OCPD
	230.82(6)	Overcurrent protection	Fine as is
	230.82(7)	Overcurrent protection	Fine as is
	230.82(8)	Overcurrent protection	Fine as is
	230.82(9)	Overcurrent protection	Fine as is
	230.82(10)	Overcurrent protection	Fine as is
	230 Part VII	Overcurrent protection	Fine as is
	230.90(A)	overcurrent device	OCPD
	230.90(A)Ex.3	overcurrent device	OCPD
	230.90(B)	overcurrent device	OCPD
	230.91	overcurrent device (X2)	OCPD
	230.92	overcurrent device (X4)	OCPDs and OCPD
	230.93	overcurrent device	OCPD
	230.94	overcurrent device (X3)	OCPD
	230.94	Overcurrent protection (X2)	Fine as is
	230.95(A)	overcurrent device	OCPD
	230.95(B)	overcurrent device	OCPD
10	**Article 240**		
	240	Overcurrent Protection	Fine as is
	240.1 (X3)	Overcurrent protection	Fine as is
	240.2	branch-circuit Overcurrent protective devices	~~branch-circuit~~ Overcurrent protective devices
	240.4. Title	Protection of Conductors	Overcurrent Protection of Conductors
	240.4	Protected against overcurrent	shall be provided with overcurrent protection in accordance with
	240.4(B). Title	Overcurrent devices	Overcurrent protective Devices
	240.4(B)	Overcurrent device	OCPD
	240.4(B)	Overcurrent protective device	OCPD

	240.4(C). Title	Overcurrent devices	Overcurrent protective Devices
	240.4(C). (X2)	Overcurrent device.	OCPD
	240.4(D)	Overcurrent Protection	Fine as is
	240.4(D)(1)	Overcurrent protection	Fine as is
	240.4(D)(1)(2)		(a) OCPDs in accordance with 240.7 shall be marked for use with 18 AWG copper conductor (b) Delete (c) change to (b)
	240.4(D)(2)	Overcurrent protection	Fine as is
	240.4(D)(2)(2)		(a) OCPDs in accordance with 240.7 shall be marked for use with 16 AWG copper conductor (b) Delete (c) change to (b)
	240.4(D)(3)	Overcurrent protection	Fine as is
	240.4(D)(3)(2)		~~(a) Fuses and circuit breakers in accordance with 240.7 marked for use with 14 AWG copper-clad aluminum conductor~~ ~~(b) Delete~~
	240.4(D)(3)(2)		OCPDs in accordance with 240.7 shall be marked for use with 14 AWG copper-clad aluminum conductor
	240.4(E)	Protected against overcurrent	shall be permitted to have overcurrent protection in accordance with the following
	240.4(F)	Overcurrent protection	Fine as is
	240.4(F)	Overcurrent protective device	OCPD
	240.4(G). (X2)	Overcurrent protection	Fine as is
	240.4(H)	Protected against overcurrent	shall be provided with overcurrent protection in accordance with
	240.5	Protected against overcurrent	shall be provided with overcurrent protection in accordance with
	240.5(A)	Overcurrent device	OCPD
	240.5(A)	Protected against overcurrent	Fixture wires shall be provided with overcurrent protection in accordance with
	240.5(A)	Supplementary overcurrent protection	Fine as is
	240.5(B) Title	Branch-circuit overcurrent device.	Branch-Circuit Overcurrent protective Devices

	240.9	Protection of conductors against overcurrent	Fine as is
	240.10. Title	Supplementary Overcurrent protection	Fine as is
	240.10.	Supplementary overcurrent protection	Fine as is
	240.10.	Branch-Circuit overcurrent devices	OCPDs
	240.10.	Supplementary overcurrent devices	Supplementary OCPDs
	240.11. (X2)	Feeder overcurrent protective devices.	Feeder OCPDs
	240.11. (X2)	Service overcurrent protective device.	Service OCPD
	240.15(A). Title	Overcurrent device	Overcurrent protective device required
	240.15(A)	Overcurrent device	OCPD
	240.15(A)	Overcurrent trip. Overcurrent relay	Fine as is
	240.15(B) Title	Overcurrent device	Circuit breaker as Overcurrent protective device
	240.16	Branch circuit overcurrent protective devices	OCPDs
	240.21	Overcurrent Protection	Fine as is
	240.21	overcurrent protective device	OCPD
	240.21 (A)	Overcurrent Protection	Fine as is
	240.21 (B)	Overcurrent Protection	Fine as is
	240.21 (B) (1) (1) (b)	Overcurrent device(s)	OCPDs
	240.21 (B) (1) (1) (b)	overcurrent protective device	OCPD
	240.21 (B)(1) (1) (4)	Overcurrent device	OCPD
	240.21 (B) (1)(1) (4) In	Overcurrent Protection	Fine as is
	240.21 (B) (2) (1)	Overcurrent device	OCPD
	240.21 (B) (2) (2)	Overcurrent devices	OCPDs
	240.21 (B) (3) (1)	Overcurrent device	OCPD
	240.21 (B) (3) (2)	Overcurrent device	OCPD
	240.21 (B) (4) (3)	Overcurrent device	OCPD
	240.21 (B) (4) (4)	Overcurrent device	OCPD
	240.21 (B) (4) (4)	Overcurrent devices	OCPDs
	240.21 (B) (5) (2)	Overcurrent device	OCPD
	240.21 (B) (5) (2)	Overcurrent devices	OCPDs
	240.21 (B) (5) (3)	Overcurrent device	OCPD
	240.21 (C). (X2)	Overcurrent Protection	Fine As Is
	240.21 (C) (1). Title	Title change	Overcurrent Protective Device
	240.21 (C) (1)	"...protected by overcurrent protection..."	Fine As Is
	240.21 (C) (1)	Overcurrent protective device	OCPD
	240.21 (C) (2) (1) (b)	Overcurrent device(s)	OCPDs

	240.21 (C) (2) (1) (b)	Overcurrent device	OCPD
	240.21 (C) (2) (4)	Overcurrent device	OCPD
	240.21 (C) (2) (4)	Overcurrent device	OCPD
	240.21 (C) (2) (4)	Overcurrent protection	Fine as is
	240.21 (C) (3) (2)	Overcurrent devices	OCPDs
	240.21 (C) (3) (3)	Overcurrent devices	OCPDs
	240.21 (C) (4) (2)	Overcurrent device	OCPD
	240.21 (C) (4) (2)	Overcurrent devices	OCPDs
	240.21 (C) (4) (3)	Overcurrent device	OCPD
	240.21 (C) (5)	Overcurrent Protection	Fine As Is
	240.21 (C) (6) (1)	Overcurrent device	OCPD
	240.21 (D)	Overcurrent devices	OCPDs
	240.21 (E)	.shall be permitted to be protected against overcurrent.	"..shall be permitted to have overcurrent protection.."
	240.21 (F)	.shall be permitted to be protected against overcurrent.	"..shall be permitted to have overcurrent protection.."
	240.21 (H). (X2)	Overcurrent Protection	Fine As Is
	240.22. (X2)	Overcurrent device	OCPD
	240.24(A)	Supplementary overcurrent protection	Fine as is
	240.24(A). (X4)	Overcurrent protective devices	OCPDs
	240.24(B)	Overcurrent devices	OCPDs
	240.24(B)(1). Title	Feeder overcurrent protective devices	Feeder OCPDs
	240.24(B)(1)	Service overcurrent protective devices	Service OCPDs
	240.24(B)(2). TITLE	Branch-circuit overcurrent protective device	Fine as is
	240.24(B)(2).	Branch-circuit overcurrent protective device	Branch-Circuit OCPD
	240.24(C)	Overcurrent protective devices	OCPDs
	240.24(D)	Overcurrent protective devices	OCPDs
	240.24(E)	Overcurrent protective devices	OCPDs
	240.24(E)	Supplementary overcurrent protection	Fine as is
	240.24(E) (X2)	Overcurrent protective devices	OCPDs
	240.24(F)	Overcurrent protective devices	OCPDs
	240.30(A)	Overcurrent devices	OCPDs
	240.32	Overcurrent devices	OCPDs
	240.33	Overcurrent devices	OCPDs
	240.86	Overcurrent device	OCPD
	240.86(B)	Overcurrent device	OCPD
	240.86(C)	Overcurrent device	OCPD

	240.87	Overcurrent device	OCPD
	240.90.	Overcurrent protection	Fine as is
	240.91(B). (X2)	Overcurrent device	OCPD
	240.92	Overcurrent device	OCPD
	240.92(A)	~~be protected~~	shall be provided with overcurrent protection
	240.92(C)	Overcurrent protection	Fine as is
	240.92(C)(1)(1)	Overcurrent device	OCPD
	240.92(C)(1)(2)	protective devices	Fine as is
	240.92(C)(1)(3)	Overcurrent devices	OCPDs
	240.92(C)(2)(1)	Overcurrent device	OCPD
	240.92(C)(2)(2) (X3)	Overcurrent devices	OCPDs
	240.92(C)(2)(3)	Overcurrent relaying	Fine as is
	240.92(C)(2)(4)	Overcurrent device	OCPD
	240.92(D)	Overcurrent protection	Fine as is
	240.92(D)(2). (X3)	Overcurrent devices	OCPDs
	240.92(D)(4)	Overcurrent device	OCPD
	240.92(E)	Overcurrent device	OCPD
	240.92(E)	Overcurrent protection	Fine as is
10	**Article 242**		
	242.14(ABC)	Overcurrent device	OCPD
	242.16	Overcurrent protection	Branch-circuit OCPD
10	**Article 404**		
	404.5	Overcurrent Devices	OCPDs
10	**Article 408**		
	408.4(A)	Overcurrent device	OCPD
	408.6 (X2)	Overcurrent protection devices	OCPDs
	408.36. Title	Overcurrent protection	Fine as is
	408.36. (X2)	Overcurrent protective device	OCPD
	408.36. (X3)	Overcurrent devices	OCPDs
	408.36(A)	Overcurrent protection	Fine as is
	408.36(B)	Overcurrent protection	Fine as is
	408.36(C)	Overcurrent device	OCPD
	408.36(D)	Overcurrent protection devices	OCPDs
	408.52	Overcurrent devices	OCPDs
	408.54	Overcurrent devices	OCPDs

	408.55	Overcurrent devices	OCPDs

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-11			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
11	**Article 409**		
	409.21. TITLE	Overcurrent Protection	Fine as is
	409.21(A)	Overcurrent Protection	Fine as is
	409.21(B)	Protection	Overcurrent protection
	409.21(B)	overcurrent protective device	OCPD
	409.21(B)	Overcurrent Protection	Fine as is
	409.21(C). (X2)	overcurrent protective device	OCPD
	409.104	Overcurrent Devices	OCPDs
11	**Article 430**		
	430.10(A) In.	Overcurrent Device	OCPD
	430.22(G)(1)(1)	Overcurrent Protection	Fine as is
	430.22(G)(1)(2)	Overcurrent Protection	Fine as is
	430.22(G)(2)(1)	Overcurrent Protection	Fine as is
	430.22(G)(2)(2)	Overcurrent Protection	Fine as is
	430.28	Branc-Circuit protective device	OCPD
	430.28	Overcurrent Device	OCPD
	430.51	Overcurrent	Fine as is
	430.53(C)(5)	Overcurrent Protection	Fine as is
	430.55	Overcurrent Protection	Fine as is
	430.61	Overcurrents	Fine as is
	430.62(A)Ex.2	Feeder Overcurrent protective device	Feeder OCDP
	430.62(A)Ex.2	Overcurrent Protection	Fine as is
	430.62(B)	Feeder Overcurrent protective device	Feeder OCDP
	430.63Ex.	Feeder Overcurrent device	Feeder OCDP
	430.63Ex.	Overcurrent Protection	Fine as is
	430.72. Title	Overcurrent Protection	Fine as is
	430.72(A)	protected against overcurrent	shall be provided with overcurrent protection in accordance with
	430.72(A)	Branch-circuit overcurrent protective devices	OCPDs
	430.72(A)	protected against overcurrent	shall be provided with overcurrent protection in accordance with
	430.72(B). (X2)	Overcurrent Protection	Fine as is
	430.72(B)	Overcurrent Device	OCPD

	430.72(B)	Overcurrent Protection	Fine as is
	430.72(B)(1) (X3)	Overcurrent Protection	Fine as is
	430.72(B)(2) Title	Branch-circuit overcurrent protective device	Fine as is
	430.72(B)(2) (X2)	protective devices	OCPDs
	430.72(C)Ex.	Overcurrent Protection	Fine as is
	430.72(C)(3)	Overcurrent Devices	OCPDs
	430.72(C)(4)	Overcurrent Device	OCPD
	430.72(C)(5)	Protection	Overcurrent protection
	430.87	Overcurrent Device	OCPD
	430.94. (X2)	Overcurrent Protection	Fine as is
	430.94. (X3)	Overcurrent protective device	OCPD
	430.109(A)(7)	Overcurrent protection	Fine as is
	430.109(B)	Branch-circuit overcurrent device	branch-circuit OCPD
	430.111(A). (X2)	Overcurrent Device	Fine as is
	430.112 Ex.	Branch circuit protective device	Suggest CMP to Review
	430.206. Title	Overcurrent protection	Fine as is
	430.206(B)(2)	considered to have Overcurrent	Overload
	430.206(C)	Fault-Current protection	Suggest CMP to Review
	430.207	Overcurrent (overload)Relays	Fine as is
	430.207	Overcurrent Relays	Fine as is
11	**Article 440**		
	440.21	Overcurrent	Fine as is
	440.21	Overcurrent Protection	Fine as is
	440.22(B)(2)Ex.	Overcurrent device	OCPD
	440.52(B)	Overcurrent	shall be provided with overcurrent protection
11	**Article 460**		
	460.9. Title	Overcurrent Protection	Fine As Is
	460.9. (X3)	Overcurrent Device	OCPD
	460.25	Overcurrent Protection	Fine As Is
	460.28(B)	Overcurrent Device	OCPD

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-12			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
12	**Article 610**		
	610. Part V	Overcurrent Protection	Fine as is
	610.41(A)	Overcurrent Devices	OCPDs
	610.43(A)(1)	Branch Circuit Overcurrent Device	OCPD
	610.53 Title	Overcurrent Protection	Fine as is
	610.53	be protected from Overcurrent	shall be provided with overcurrent protection
	610.53	Overcurrent Devices	OCPDs
	610.53(B)	Branch Circuit Overcurrent Devices	OCPDs
12	**Article 620**		
	620.12(A)(4)	Overcurrent Protection	Fine as is
	620.22(A)(2) Title	Overcurrent protective device	Fine as is
	620.22(A)(2)	Overcurrent Device protecting	branch-circuit OCPD
	620.22(A)(2)	Overcurrent Device	OCPD
	620.22(B)	Overcurrent Device protecting	branch-circuit OCPD
	620.22(B)	Overcurrent Device	OCPD
	620.25 Title	Overcurrent Devices	Overcurrent Protective Devices
	620.25. (X2)	Overcurrent Devices	OCPDs
	620.53	Overcurrent protective device	OCPD
	620.54	Overcurrent protective device	OCPD
	620.55	Overcurrent protective device	OCPD
	Art 620 Part VII	Overcurrent Protection	Fine as is
	620.61	Overcurrent Protection	Fine as is
	620.61(A). (X2)	be protected against Overcurrent	shall be provided with overcurrent protection
	620.62(A)	Overcurrent protective devices, (OCPD)	OCPDs
	620.62(B)	OCPDs	Fine as is
	620.62(C)	OCPDs. And. Overcurrent Devices	Fine as is. And. OCPDs
	620.62	Overcurrent protective devices	OCPDs
	620.65. (X3)	Overcurrent Devices	OCPDs
12	**Article 625**		
	625.60(C). (X4)	Overcurrent Protection	Fine as is
12	**Article 627**		
	627.41	Overcurrent Protection	Fine as is
	627.41(A)	Overcurrent Protection	Fine as is

	627.41(B)	Overcurrent Devices	OCPDs
12	**Article 630**		
	630.12	Overcurrent Protection	Fine as is
	630.12	Overcurrent Device	OCPD
	630.12(A). (X2)	Overcurrent Protection	Fine as is
	630.12(A). (X5)	Overcurrent Device	OCPD
	630.13	Overcurrent Protection	Fine as is
	630.32	Overcurrent Protection	Fine as is
	630.32	Overcurrent Device	OCPD
12	**Article 640**		
	640.9(C)	Overcurrent Protection	Fine as is
	640.22	Overcurrent protection devices	OCPDs
	640.22	Overcurrent Devices	OCPDs
	640.43	Overcurrent protection devices	OCPDs
12	**Article 645**		
	645.27	Overcurrent protective devices, (OCPD)	OCPDs
	645.27	Overcurrent protective devices	OCPDs
12	**Article 646**		
	646.7. (X11)	Overcurrent Protection	Fine as is
12	**Article 647**		
	647.5	Overcurrent Protection	Fine as is
12	**Article 650**		
	650.9	Overcurrent Protection	Fine as is
	650.9	Overcurrent Device	OCPD
12	**Article 660**		
	660.7	Overcurrent Protection	Fine as is
	660.7(A)	Overcurrent protective devices	OCPDs
	660.7(B)	Overcurrent Devices	OCPDs
	660.7(B)	Overcurrent Protection	Fine as is
	660.9	Overcurrent Devices	OCPDs
12	**Article 665**		
	665.24	Overcurrent Protection	Fine as is
12	**Article 668**		
	668.4(C)(2)	Overcurrent Protection	Fine as is
	668.21	Overcurrent Protection	Fine as is

	668.21	Overcurrent Device	OCPD
12	**Article 669**		
	669.9	Overcurrent Protection	Fine as is
	669.9	be protected from Overcurrent	shall be provided with overcurrent protection
12	**Article 670**		
	670.1	Overcurrent Protection	Fine as is
	670.4(B). (X3)	Overcurrent Protection	Fine as is
	670.5. (X4)	Overcurrent Protection	Fine as is
	670.5(C). (X2)	Overcurrent protective device	OCPD
12	**Article 685**		
	685.10.	Overcurrent Devices	OCPDs

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-13			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
13	**Article 100**		
	Emerg.Power Supply Systems (EPSS)	overcurrent protection devices	overcurrent protective devices (OCPDs)
	Transfer-Switch B-C Emerg. Ltg.	branch-circuit overcurrent device	branch-circuit overcurrent protective device (OCPD)
13	**Article 130**		
	130.80(C)	overcurrent devices	OCPDs
	130.80(C)	branch-circuit overcurrent device	OCPD
13	**Article 445**		
	445.11	Overcurrent protective Relay	Fine as is
	445.12. Title	Overcurrent Protection	Fine as is
	445.12(A)	Overcurrent protective means	Overcurrent protection means
	445.12(B)	Overcurrent Protection	Fine as is
	445.12(B) (X2)	Overcurrent Device	OCPD
	445.12(C)	Overcurrent Device	OCPD
	445.12(D)	Overcurrent Devices	OCPDs
	445.12(E). (X3)	Overcurrent Devices	OCPDs
	445.13(A). (X2)	Overcurrent Protection	Fine as is
	445.13(B). Title	Overcurrent protection	Fine as is
	445.13(B).	Overcurrent protective device	OCPD
	445.13(B)	Overcurrent Relay	Fine as is
13	**Article 455**		
	455.7	Overcurrent Protection	Fine As Is
	455.7	protected from Overcurrent	shall be provided with overcurrent protection in accordance with
	455.7(A)	Overcurrent Protection	Fine As Is
	455.7(B)	Overcurrent Protection	Fine As Is
13	**Article 480**		
	480.4(B) IN.2	Overcurrent Protection	Fine As Is
	480.6. (X2)	Overcurrent Protection	Fine As Is
	480.7	Overcurrent Device	OCPD
13	**Article 695**		
	695.4(C)	Overcurrent protective devices	OCPDs
	695.4(H). Title	Overcurrent Device Selection	Overcurrent Protective Device Selection
	695.4(H)	Overcurrent Devices	OCPDs

	695.5	Overcurrent Device	OCPD
	695.5	Overcurrent protective devices	OCPDs
	695.5	Overcurrent Protection	Fine as is
	695.6	Overcurrent protective devices	OCPDs
	695.6	Overcurrent Devices	OCPD
	695.6	Overcurrent Protection	Fine as is
	695.7(A)(2)	Overcurrent Devices	OCPDs
	695.7	Overcurrent Protection	Fine as is
13	**Article 700**		
	700.4(F)(8)	Overcurrent protective devices, (OCPD)	OCPDs
	700.6(E)	Overcurrent protective device	OCPD
	700.10(B). (X6)	Overcurrent Protection	Fine as is
	700.10(B)(6)(b)(ii)	Overcurrent protective device	OCPD
	700.10(B)(6)(e)	Overcurrent protective devices	OCPDs
	Art. 700 Part VI	Overcurrent Protection	Fine as is
	700.30.	Branch-circuit overcurrent devices	OCPDs
	700.32(A)	Overcurrent protective devices, (OCPDs)	OCPDs
	700.32(A) In	Overcurrent Protection	Fine as is
	700.32(C)	Overcurrent Devices	OCPDs
13	**Article 701**		
	701.6(C)	Overcurrent protective device	OCPD
	701.10(B)(1). (X5)	Overcurrent Protection	Fine as is
	701.10(B)(1)	Overcurrent protective device	OCPD
	Art. 701. Part IV	Overcurrent Protection	OCPDs
	701.30.	Branch-Circuit Overcurrent devices	Branch-Circuit OCPDs
	701.32(A). (X2)	Overcurrent protective devices, OCPDs	OCPDs
	701.32(B). (X3)	OCPDs	Fine as is
	701.32(C). (X2)	OCPDs	Fine as is
	701.32(C)Ex	Overcurrent Devices	OCPDs
	701.32(C) In 2	OCPD and OCPDs	Fine as is
13	**Article 702**		
	702.5(C)	Overcurrent protective device	OCPD
13	**Article 706**		
	706.15(E)(1)	Overcurrent Device	OCPD
	706.30(B)	Overcurrent Devices	OCPDs

	706.31 Title	Overcurrent Protection	Fine as is
	706.31(A)	shall be protected at the source from overcurrent.	shall be provided with overcurrent protection at the source
	706.31(A)	shall be protected from overcurrent.	shall be provided with overcurrent protection
	706.31(A) In	Overcurrent Device	OCPD
	706.31(B). Title	Overcurrent Device	Overcurrent Protective Device
	706.31(B)	Overcurrent protective devices	OCPDs
	706.31(B)	Overcurrent devices	OCPDs
	706.31(C)	Overcurrent protective devices	OCPDs
	706.31(E)	Overcurrent Protection	Fine as is
	706.33(B)(2)	Overcurrent Device	OCPD
13	**Article 708**		
	708.10(B)	Overcurrent Protection	Fine as is
	708.24(E)	Overcurrent protective device	OCPD
	Art. 708. Part IV	Overcurrent Protection	Fine as is
	708.50.	Feeder- and Branch-circuit overcurrent devices	Feeder- and Branch-circuit OCPDs
	708.52(B)	Overcurrent Devices	OCPDs
	708.54(A)	Overcurrent protective devices, (OCPD)	OCPDs
	708.54(A). (B). (C)	OCPDs	Fine as is
	708.54	Overcurrent Devices	OCPDs

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-14			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
14	**Article 500**		
	500.30(A)(2)	Branch Circuit Overcurrent Protection	OCPD
	500.30.	Overcurrent Protection	Fine as is
14	**Article 501**		
	501.105(B)(5)	Overcurrent Protection	Fine as is
	501.125(B)(2)	Motor Overcurrent	Fine as is
14	**Article 502**		
	502.120(A)	Overcurrent Devices	OCPDs
	502.120(B)(1)	Overcurrent Devices	OCPDs
	502.125	Motor Overcurrent	Fine as is
14	**Article 505**		
	505.30(A)(2)	Branch Circuit Overcurrent Protection	OCPD
	505.30.	Overcurrent Protection	Fine as is
14	**Article 506**		
	506.30.	Branch Circuit Overcurrent Protection	OCPD
	506.30.	Overcurrent Protection	Fine as is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-15			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
15	**Article 100**		
	Bull Switch	Overcurrent protection	Fine as is
15	**Article 517**		
	517.17(B)	Overcurrent protective devices	OCPDs
	517.31(G). (X5)	Overcurrent protective devices	OCPDs
	517.31(G)	Overcurrent	Fine as is
	517.33((C). (X5)	Overcurrent protective devices	OCPDs
	517.42(F)	Overcurrent protective devices	OCPDs
	517.42(F)	Overcurrent	Fine as is
	517.73	Overcurrent Protection	Fine as is
	517.73(A)	Overcurrent protective devices	OCPDs
	517.73(B)	Overcurrent protective devices	OCPDs
	517.73(B)	Overcurrent Protection	Fine as is
	517.74(B)	Overcurrent protective devices	OCPDs
	517.160(A)(2)	Overcurrent Protection	Fine as is
	517.160(A)(2)	Overcurrent protective device	OCPD
	517.160(A)(2)	be protected against Overcurrent	be provided with overcurrent protection
	517.160(A)(3)	Overcurrent protective devices	OCPDs
	517.160(B)(1)	Overcurrent protective devices	OCPDs
15	**Article 518**		
	518.7(A)(1)	Overcurrent Protection	Fine as is
	518.17(A)(1) and (2)	Overcurrent Devices	OCPDs
15	**Article 520**		
	520.9	Branch Circuit Overcurrent Device	OCPD
	520.21	Overcurrent protective devices	OCPDs
	520.25. (X3)	Overcurrent Protection	Fine as is
	520.26	Overcurrent protective devices	OCPD
	520.26. (X3)	Overcurrent Protection	Fine as is
	520.27. (X2)	Overcurrent Device	OCPD
	520.44-T	Overcurrent Devices	OCPD
	520.50(C)	Overcurrent Protection	Fine as is
	520.50.	Branch-circuit overcurrent protective device	OCPDs
	520.52	Overcurrent Protection	Fine as is

	520.53(A)	Overcurrent protective devices	OCPDs
	520.53(D)	Overcurrent Protection	Fine as is
	520.54	Overcurrent Devices	OCPDs
	520.54(D)	Overcurrent Device	OCPD
	520.54(D)(1) and (2)	Overcurrent protective devices	OCPD
	520.54(E)	Overcurrent protective device	OCPD
	520.54(E). (X4)	Overcurrent protection device	OCPD
	520.54(E)	Overcurrent Devices	OCPDs
	520.54(K)	Overcurrent Device	OCPD
	520.68	Overcurrent protective device	OCPD
	520.68(3)	Overcurrent Device	OCPD
	520.68(4)	Overcurrent protective device	OCPD
	520.68(6)	Overcurrent Devices	OCPDs
	520.68(C)	Overcurrent Protection	Fine as is
15	**Article 522**		
	522.10(A)(2). (X3)	Overcurrent Devices	OCPDs
	522.10(A)(2	Overcurrent protective device	OCPD
	522.10(B). (X4)	Overcurrent Devices	OCPDs
	522.23. (X3)	Overcurrent Protection	Fine as is
15	**Article 525**		
	525.12	Overcurrent Device	OCPD
	525.23(B)	Overcurrent Device	OCPD
	525.23(C). (X2)	Overcurrent Protection	Fine as is
15	**Article 530**		
	530.9(A)	Branch-circuit overcurrent device	Branch-circuit OCPD
	530.10(C)	Overcurrent Protection	Fine as is
	530.23 and (A)	Overcurrent Protection	Fine as is
	530.23(B)	Overcurrent protective devices	OCPDs
	530.23(D)	Overcurrent Protection	Fine as is
	530.42	Overcurrent Protection	Fine as is
15	**Article 540**		
	540.11(B)	Overcurrent Devices	OCPDs

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-16			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
16	**Article 830**		
	830.15. (X4)	Overcurrent Protection	Fine as is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-17			
CMP	NEC Section (using First Draft of 2026 NEC)	Current Language	"New" Language
17	Article 422		
	422.5(C)	Branch-circuit overcurrent protective device	Branch-Circuit OCPD
	422.11. Title	Overcurrent Protection	Fine as is
	422.11	protected against overcurrent	shall be provided with overcurrent protection
	422.11(A)	Overcurrent Protection	Fine as is
	422.11(A)	Branch-circuit overcurrent protective device	Branch-Circuit OCPD
	422.11(B)	Overcurrent Protection	OCPDs
	422.11(C)	Overcurrent Protection	OCPDs
	422.11(D)	Overcurrent protective devices	OCPDs
	422.11(E)	Overcurrent Protection	Fine as is
	422.11(E)(1)	Overcurrent Protection	Fine as is
	422.11(E)(2)	Overcurrent Protection	Fine as is
	422.11(E)(3)	Overcurrent Protection	OCPD
	422.11(E)(3)	Overcurrent Device	OCPD
	422.11(F)(1)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	422.11(F)(1)	Overcurrent Protective Devices	OCPDs
	422.11(G)	Overcurrent Protective Devices	OCPDs
	422.13	Overcurrent Protection	Fine as is
	422.31(A)	Branch-circuit overcurrent protective device	Branch-Circuit OCPD
	422.60(A)	Overcurrent Protection	Fine as is
	422.62(B)(1). (X2)	Overcurrent protective device	OCPD
17	Article 424		
	424.19	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	424.19(A)	Supplementary Overcurrent Protection	Fine as is
	424.19(A)	Supplementary Overcurrent Protection	Fine as is
	424.19(A)	Supplementary Overcurrent Protective Device(s)	Supplementary OCPDs
	424.19(B)	Supplementary Overcurrent Protection	Fine as is
	424.22	Overcurrent Protection	Fine as is
	424.22(A)	Overcurrent Protection	Fine as is
	424.22(A)	protected against overcurrent	"..shall be permitted to have overcurrent protection.."
	424.22(B)	Supplementary Overcurrent Protective Device	Supplementary OCPD
	424.22(C). Title	Overcurrent Protective Devices	Fine as is
	424.22(C)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs

	424.22(C)	Overcurrent Protection	Fine as is
	424.22(C)	Supplementary Overcurrent Protection	Fine as is
	424.22(D) (X2)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	424.22(E). (X3)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	424.72	Overcurrent Protection	Fine as is
	424.72(A)	Overcurrent protective device	OCPD
	424.72(B)	Overcurrent protective device	OCPD
	424.72(C). Title	Supplementary Overcurrent Protective Devices	Fine as is
	424.72(C)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	424.72(C)	Overcurrent Protection	Fine as is
	424.72(D). Title	Supplementary Overcurrent Protective Devices	Fine as is
	424.72(D).	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	424.72(D)	Overcurrent protective device	OCPD
	424.72(E)	Supplementary Overcurrent Protective Devices. (X3)	Supplementary OCPDs
	424.82	Overcurrent protective devices	OCPDs
17	**Article 425**		
	425.19	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	425.19(A). (X2)	Supplementary Overcurrent Protection	Fine as is
	425.19(A)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	425.19(B)	Supplementary Overcurrent Protection	Fine as is
	425.22. Title	Overcurrent Protection	Fine as is
	425.22(A)	Overcurrent Protection	Fine as is
	425.22(A)	protected against overcurrent	"..shall be permitted to have overcurrent protection.."
	425.22(B)	Supplementary Overcurrent Protective Device	Supplementary OCPD
	425.22(C). Title	Overcurrent Protective Devices	Fine as is
	425.22(C)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	425.22(C). (X2)	Supplementary Overcurrent Protection	Fine as is
	425.22(D). Title	Supplementary Overcurrent Protective Devices	Fine as is
	425.22(D). (X2)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	425.22(E) (X3)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	425.72	Overcurrent Protection	Fine as is
	425.72(A)	Overcurrent protective device	OCPD
	425.72(B)	Overcurrent protective device	OCPD
	425.72(C). Title	Supplementary Overcurrent Protective Devices	Fine as is
	425.72(C)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs

	425.72(C)	Overcurrent Protection	Fine as is
	425.72(D)	Overcurrent protection	Fine as is
	425.72(E). Title	Supplementary Overcurrent Protective Devices	Fine as is
	425.72(E)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	425.72(E)	Overcurrent Protective Devices	OCPD
	425.72(F). (X3)	Supplementary Overcurrent Protective Devices	Supplementary OCPDs
	425.82	Overcurrent protective devices	OCPDs
17	**Article 427**		
	427.57	Overcurrent Protection	Fine as is
	427.57	considered protected against Overcurrent	considered to have overcurrent protection
17	**Article 680**		
	680.10.(A)& (B)(2)	Overcurrent protective devices	OCPDs
	680.23(F)(2)	Overcurrent Protection	Fine as is

CMP-10 TG-4 Review of Overcurrent Language for the Articles undeer the purview of CMP-18			
CMP	**NEC Section (using First Draft of 2026 NEC)**	**Current Language**	**"New" Language**
18	**Article 393**		
	393.45. Title	Overcurrent ...... Protection	Overcurrent Protection ....
	393.45(A)	Overcurrent Protection	Fine as is
18	**Article 406**		
	406.46(F)	Overcurrent Device	OCPD
18	**Article 410**		
	410.59(A)	Branch-circuit overcurrent devices	Branch-Circuit OCPD
	410.153	Overcurrent Protection	Fine as is
18	**Article 600**		
	600.41	Overcurrent	CMP to Review

Public Comment No. 1707-NFPA 70-2024 [New Article after 100]

Ampacity, Standard

The ampacity of a conductor under the standard conditions of use as specified in the ampacity table pertaining to the conductor, without application of any adjustment or correction factors.

Statement of Problem and Substantiation for Public Comment

The definition of "ampacity" in the NEC refers to the maximum current "under the conditions of use" of the conductor, and as such properly refers to a value that includes ampacity adjustment and correction to reflect those conditions of use. However, many sections in the NEC, such as 110.14(C), 210.19, 215.2, 310.15(A), etc. currently use the word "ampacity" to refer both to such adjusted and corrected values as well as to the ampacity table entries directly without any adjustment and correction, even within the same sentence. This overloading of the term "ampacity" is a source of considerable confusion for those learning to use the NEC and even for those with many years of experience.

Therefore I suggest that the NEC should adopt two different terms, one term for referring to the table entries themselves, and one for the final value after adjustment and correction. If the CMP agrees, I will propose a PI for the 2029 NEC reflecting this change. But as this would require considerable effort, this Public Comment is my attempt to ask the CMP:

1) Whether the CMP agrees that the use of two different terms would improve clarity.
2) What pair of terms the CMP would like to use. I am proposing "Standard Ampacity" and "Ampacity". Many alternatives are reasonable, such as "Starting Ampacity" and "Final Ampacity," or "Standard Ampacity" and "Adjusted Ampacity," etc.

Related Item

• 471-NFPA 70-2023 • 472-NFPA 70-2023 • 473-NFPA 70-2023

Submitter Information Verification

Submitter Full Name: Wayne Whitney
Organization: Whitney
Street Address:
City:
State:
Zip:

Submittal Date: Mon Aug 26 13:56:54 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: Adding this definition could create more confusion. There are many locations in the NEC that already specify whether the ampacity value to be used includes or excludes the correction and adjustment factors.

Public Comment No. 537-NFPA 70-2024 [Section No. 310.3]

310.3 Conductors.

(A) Minimum Size of Conductors.

The minimum size of conductors for voltage ratings up to and including 2000 volts shall be 16 AWG copper, 14 AWG copper-clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in this code.

(B) Conductor Material.

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

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

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

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

(C) Stranded Conductors.

Where installed in raceways, conductors 8 AWG and larger shall be stranded, unless specifically permitted or required elsewhere in this *Code* to be solid.

(D) Insulated.

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

Informational Note: See 270.27 for insulation of neutral conductors of a solidly grounded high-voltage system.

Additional Proposed Changes

File Name	Description	Approved
CN_269.pdf		

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 269 appeared in the First Draft Report on First Revision No. 8228 and First Revision No. 7930.

The Correlating Committee directs the CMP-6 to review FR 8228 and FR 7930 with respect to relocating the requirements in 310.3 “Conductors” to comply with the NEC Style Manual Section 2.2.1 on parallel numbering. If the article does not contain reconditioning requirements, the subdivisions shall not be included in the article.

Related Item

• First Revision No. 8228 • First Revision No. 7930

Submitter Information Verification

Submitter Full Name: CC Notes

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jul 30 23:27:38 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8425-NFPA 70-2024

Statement: A second revision was created that renumbers section 310.3 to 310.5. This action was taken to comply with the NEC Style Manual Section 2.2.1 on parallel numbering.

Correlating Committee Note No. 269-NFPA 70-2024 [Section No. 310.3]

Submitter Information Verification

Committee: NEC-AAC

Submittal Date: Thu May 09 18:01:42 EDT 2024

Committee Statement

Committee Statement: The Correlating Committee directs the CMP-6 to review FR 8228 and FR 7930 with respect to relocating the requirements in 310.3 “Conductors” to comply with the NEC Style Manual Section 2.2.1 on parallel numbering. If the article does not contain reconditioning requirements, the subdivisions shall not be included in the article.

First Revision No. 8228-NFPA 70-2024 [Section No. 310.3(A)]

First Revision No. 7930-NFPA 70-2024 [Section No. 310.3(B)]

Ballot Results

✔ **This item has passed ballot**

12 Eligible Voters
1 Not Returned
11 Affirmative All
0 Affirmative with Comments
0 Negative with Comments
0 Abstention

Not Returned

McDaniel, Roger D.

Affirmative All

Ayer, Lawrence S.

Bowmer, Trevor N.

Hickman, Palmer L.

Holub, Richard A.

Jackson, Peter D.

Kendall, David H.

Manche, Alan

Osborne, Robert D.

Porter, Christine T.

Schultheis, Timothy James

Williams, David A.

Public Comment No. 1388-NFPA 70-2024 [Section No. 310.3(A)]

(A) Minimum Size of Conductors.

1) The minimum size of conductors for voltage ratings up to and including 2000 volts shall be 16 AWG copper, 14 AWG copper-clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in this code.

2) The minimum size of conductors shall comply with one or both of the following

a) be large enough to limit voltage drop to five percent or less from the service point to each outlet

b) be no longer than the lengths indicated in Table 310.3(A)

Additional Proposed Changes

File Name	Description	Approved
voltdroptable_310.pdf	Table 310.3(A) Maximum Conductor Lengths	

Statement of Problem and Substantiation for Public Comment

Excessive voltage drop can prevent overcurrent protective devices from opening within the parameters shown in the device's time-current curve. Limiting the conductor length, especially for smaller conductors, will result in an installation that allows the overcurrent protective devices to operate as expected to safeguard persons and property. A table with lengths limiting the voltage drop to approximately 5% on the branch circuit is attached to create a straightforward, enforceable requirement for installers and inspectors.

Related Item

- PI 2861

Submitter Information Verification

Submitter Full Name: Christel Hunter

Organization: Cerro Wire

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 21 17:11:14 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but held

Resolution: Additional time is needed to review the information provided during the meeting in support of adding a voltage drop requirement or conductor length limitation for conductors. Proposed requirements should be written in a way that can be enforced for a wide variety of applications. As part of the discussion during the meeting, additional information/data/statistics is requested regarding fires caused by branch circuit impedance effects on OCPD operation. CMP-06 recommends that the CC put together a task group to review the impact of branch circuit impedance on the OCPD ecosystem.

Table 310.3(A) Maximum Conductor Lengths		
	Copper	Aluminum or Copper-Clad Aluminum
Size (AWG or kcmil)		
16	90	n/a
14	100	90
12	110	100
10	125	110
8	125	125
6	n/a	125

Public Comment No. 1395-NFPA 70-2024 [Section No. 310.3(A)]

(A) Minimum Size of Conductors.

The minimum size of conductors for voltage ratings up to and including 2000 volts shall be ~~16~~ 14 AWG copper, ~~14 AWG~~ 12 AWG copper-clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in this code.

Statement of Problem and Substantiation for Public Comment

Testing was described and requested in the panel statement with Committee Comment No. 8404 in the 2023 NEC Second Draft report. That testing was not performed, nor was any comparable testing performed to justify the allowance of smaller branch circuit conductors. The committee statement included the following information, which is still valid and should be considered before lowering the allowable conductor size in Article 310:

Multiple test reports were presented to the panel as substantiation for the public comments in the 2023 revision cycle covering 14 AWG copper-clad aluminum conductor heating at certain ampacity levels under insulation to replicate a real-world installation. The reports point to the need for a deeper understanding of the performance of 14 AWG copper-clad aluminum.

During the 2023 NEC revision cycle, the panel received reports and presentations from:

1) the Bimetallics Task Group (conducted at an Eaton facility)

2) the Copper Development Association (conducted at a Hampton Tedder facility)

3) the Southwire company (conducted at the DB Cofer laboratory)

4) the Cable Technologies Laboratory (conducted at their facility)

5) the Cerrowire company (conducted at the Marmon Innovation and Technology Center)

The Panel also considered reports from the 2020 NEC revision cycle, including the NSF International report.

After considering all the information and results presented in the reports, public inputs, and public comments, concerns were recognized about conductor overheating in common, everyday installations that need to be addressed prior to reducing the allowable branch circuit conductor size. Primarily, the evidence of excessive heat rise that occurs when wiring methods are installed in thermal insulation needs to be addressed. Voltage drop was also identified as a concern and needs to be addressed.

To determine the appropriate code requirements to ensure the installation of reduced branch circuit conductor sizes is both practical and safe, additional information is required. The panel requests public input that includes the following information obtained from credible sources and qualified testing laboratories:

1) Testing of representative wiring methods with 14 AWG copper-clad aluminum and 16 AWG copper shall be performed. Representative wiring methods could include those with non-metallic jackets, metallic sheaths, and those in metallic and non-metallic raceway systems.

2) Each wiring method shall have three current-carrying conductors.

3) At a minimum, testing of 16 AWG copper and 14 AWG copper-clad aluminum in thermal insulation is required. To address questions that were raised about existing branch circuit conductor sizes and heat

rise in thermal insulation, the panel is also requesting testing of:

a. 14 AWG copper and 12 AWG copper-clad aluminum

b. 12 AWG copper and 10 AWG copper-clad aluminum

4) Equivalent testing of aluminum conductors is also welcomed.

5) For each wiring method, testing shall be performed at the 60C, 75C, and 90C ampacity values as appropriate as indicated or proposed in Table 310.16. Each test shall continue for a minimum of 3 hours or until thermal stability is reached, unless the temperature exceeds 150C at which point the test will be terminated. Conductor temperature shall be no more than 2C above ambient when each test begins.

6) At a minimum, testing shall include one continuous 100-foot length of wiring between the supply and load connections. Thermal insulation R-values and types shall comply with International Residential Code (IRC) Table N1102.1.3 minimum values for climate zone 5. A minimum of 90% of the wiring method shall be placed inside the thermal insulation. Testing that provides comparisons of differing thermal insulation types and R-values is encouraged.

7) Testing shall include installations that are representative of both attic and wall locations.

8) Thermocouples shall be affixed in contact with the insulation of a current-carrying conductor inside the wiring method. For cable wiring methods the jacket or sheath shall be replaced/restored over the thermocouple.

9) Thermocouples shall not be placed on or next to framing members or any other building components other than thermal insulation and the conductor insulation. Thermocouples shall be placed no less than every 10 feet along the wire within the wiring method and temperature data values shall be recorded no less than every 30 seconds. Thermocouples shall be placed on the conductor insulation within one foot of the supply and load connections. Ambient temperature shall be recorded continuously.

10) Voltage and current at the supply and load connections shall be monitored and values shall be recorded at a minimum of every 30 seconds.

11) All conductors shall be tested under equivalent conditions.

The panel has also identified remediating actions that could be taken to prevent overheating in this type of installation, including installation restrictions, reduced ampacity values in the Article 310 tables, or ampacity adjustment requirements.

Related Item

• FR 8228

Submitter Information Verification

Submitter Full Name:	Christel Hunter
Organization:	Cerro Wire
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Aug 21 22:13:09 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected
Resolution:	The CMP 6 action on 310.3(A) at their first draft meeting was supported by data submitted in public inputs and the discussion on the reports provided during the first draft meeting. Review of the substantiation in the public comments on this section did not provide sufficient new data or test reports that supports changing the panel's first draft action.

Public Comment No. 1806-NFPA 70-2024 [Section No. 310.3(A)]

(A) Minimum Size of Conductors.

The minimum size of conductors for voltage ratings up to and including 2000 volts shall be ~~16 AWG copper,~~ 14 AWG copper or 12 AWG aluminum or copper -clad aluminum, ~~or 12 AWG aluminum,~~ except as permitted elsewhere in this code.

Statement of Problem and Substantiation for Public Comment

This proposal seeks to restore this section to the language of the 2023 National Electrical Code. When this section was modified during the 2026 NEC First Draft process, the discussions in favor of the modification were based upon whether the maximum temperature encountered during testing exceeded 90°C. The underlying assumption is that the maximum allowable temperature for Type NM-B Cable is 90°C (likely based upon the requirements in NEC 334.112 and UL 719 Section 1.1 which refers to the use of conductors with 90°C insulation). Nowhere in the NEC or in UL 719 is the maximum temperature for the complete Type NM-B Cable (not just the conductors) directly stated. Given this, the temperature rating for the overall cable jacket (sheath) should be considered in the determination of the maximum temperature for the complete cable assembly.

Section 5.2.1 of UL 719 (Nonmetallic-Sheathed Cable) requires compliance with the requirements in the “Physical properties of NM Cable PVC jacket” table in UL 1581 (Table 50.179). This testing involves aging the jacket material at 100°C for 240 hours before performing tensile and elongation tests. It is the aging of the test specimens at a specified time and temperature that determines the temperature rating of the material. The aging parameters in Table 50.179 (100°C for 240 hours) do not match those required for material rated 90°C.

Table 50.182 in UL 1581 includes the correlation of the temperature rating of the material with the specified oven time and temperature. In this table, aging at 100°C for 240 hours corresponds to a temperature rating of 75°C, not 90°C.

Given this, it is reasonable to conclude the maximum allowable temperature for Type NM-B Cable is not 90°C. It is also reasonable to conclude the maximum allowable temperature is 75°C or less.

Related Item

• FR 8228 • PI 1008

Submitter Information Verification

Submitter Full Name:	Dave Watson
Organization:	Southwire
Affiliation:	Southwire
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Aug 27 13:30:59 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected
Resolution:	The CMP 6 action on 310.3(A) at their first draft meeting was supported by data submitted in public inputs and the discussion on the reports provided during the first draft meeting. Review of the substantiation in the public comments on this section did not provide sufficient new data or test reports that supports changing the panel’s first draft action. The substantiation provided is focused primarily on NM cable which is one instance in which this may be used, but not the only one.

Public Comment No. 1861-NFPA 70-2024 [Section No. 310.3(A)]

(A) Minimum Size of Conductors.

The minimum size of conductors for voltage ratings up to and including 2000 volts shall be 16 AWG copper, 14 AWG copper-clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in this code.

Informational Note: See 210.23 for permissible loading of branch-circuits

Statement of Problem and Substantiation for Public Comment

With the addition of 10A OCPD and use of copper-clad aluminum it is important to point the user to Section 210.23 so they understand the limited application of a 10A branch-circuit.

Related Item

- FR-8228

Submitter Information Verification

Submitter Full Name: Jeff Noren
Organization: National Electrical Contractors Association
Street Address:
City:
State:
Zip:

Submittal Date: Tue Aug 27 18:34:55 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8471-NFPA 70-2024

Statement: The pointer provides a good reference for inspectors and installers in the field for permissible loads based on overcurrent protective device rating.

Public Comment No. 543-NFPA 70-2024 [Section No. 310.3(A)]

(A) Minimum Size of Conductors.

The minimum size of conductors for voltage ratings up to and including 2000 volts shall be ~~16 AWG copper,~~ 14 AWG copper and copper -clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in this code.

Statement of Problem and Substantiation for Public Comment

Unlike the size of 14 AWG CCA, the size of 16 AWG copper should be removed from section 310.3(A) for the following reasons. No forethought was ever given to 16 AWG as a branch circuit conductor by its proponents. Therefore, a proposal for applying 16 AWG copper as a branch circuit conductor has never been submitted as a Public Input in any cycle. Thorough technical substantiation is unavailable to CMP6. Further, 16 AWG copper was never subjected to the testing protocol spelled out by the NFPA Research Foundation report, a point upon which CMP6 insisted for all new small branch circuit conductors. To give 16 AWG copper "a free pass" is at odds with the will of CMP6. Although 16 AWG copper may be a worthy candidate for investigation, this panel should not assume it to be safe for use as a branch circuit conductor. It should be a PI for the 2029 cycle, and supported by the prescribed technical substantiation.

Related Item

• FR 8228 • PI 1008

Submitter Information Verification

Submitter Full Name: Peter Graser

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Affiliation: ABA

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jul 31 08:21:41 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: Copper conductors sized 16 AWG are currently listed for use with many electrical products and are currently used in other similar applications in the NEC.

Public Comment No. 1380-NFPA 70-2024 [Section No. 310.4]

310.4 Conductor Constructions and Applications.

Insulated conductors shall comply with Table 310.4(1) and Table 310.4(2).

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(1) Conductor Applications and Insulations Rated 600 Volts

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation: AWG or kcmil	mm		m…
Fluorinated ethylene propylene	FEP or FEPB	90°C (194°F)	Dry and damp locations	Fluorinated ethylene propylene	14–10	0.51		2
					8–2	0.76		3
					14–8	0.36		1
		200°C (392°F)	Dry locations — special applications[2]	Fluorinated ethylene propylene	6–2	0.36		1
Mineral insulation (metal sheathed)	MI	90°C (194°F)	Dry and wet locations	Magnesium oxide	18–16[3]	0.58		2
					16–10	0.91		3
		250°C (482°F)	For special applications[2]		9–4	1.27		5
					3–500	1.40		5
Moisture-, heat-, and oil-resistant thermoplastic	MTW	60°C (140°F)	Machine tool wiring in wet locations	Flame-retardant, moisture-, heat-, and oil-resistant thermoplastic	-		(A)	(B)
		90°C (194°F)	Machine tool wiring in dry locations.		22–12	0.76	0.38	30
					10	0.76	0.51	30
					-	8	1.14	0.76
			-		Informational Note: See NFPA 79-2021, *Electrical Standard for Industrial Machinery*.	6	1.52	0.76
			-			4–2	1.52	1.02
			-			1–4/0	2.03	1.27
			-			213–500	2.41	1.52
			-			501–1000	2.79	1.78
Paper	-		85°C (185°F)	For underground service conductors, or by special permission	Paper	-	-	
Perfluoro-alkoxy	PFA	90°C (194°F)	Dry and damp locations	Perfluoro-alkoxy	14–10	0.51		2
					8–2	0.76		3
		200°C (392°F)	Dry locations — special applications[2]		1–4/0	1.14		4
					-	-		-
Perfluoro-alkoxy	PFAH	250°C (482°F)	Dry locations only. Only for leads within apparatus or within	Perfluoro-alkoxy	14–10	0.51		2
					8–2	0.76		3

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	AWG or kcmil	mm	m
			raceways connected to apparatus (nickel or nickel-coated copper only)		1–4/0	1.14	4
Thermoset	RHH	90°C (194°F)	Dry and damp locations	-		~~14~~ 16 -10	1.14
						8–2	1.52
						1–4/0	2.03
						213–500	2.41
						501–1000	2.79
						1001–2000	3.18
Moisture-resistant thermoset	RHW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	~~14–10~~ 16–10	1.14	4
					8–2	1.52	6
					1–4/0	2.03	8
	RHW-2	90°C (194°F)			213–500	2.41	9
					501–1000	2.79	11
					1001–2000	3.18	12
Silicone	SA	90°C (194°F)	Dry and damp locations	Silicone rubber	~~14–10~~ 16–10	1.14	4
					8–2	1.52	6
					1–4/0	2.03	8
		200°C (392°F)	For special application[2]		213–500	2.41	9
					501–1000	2.79	11
					1001–2000	3.18	12
Thermoset	SIS	90°C (194°F)	Switchboard and switchgear wiring only	Flame-retardant thermoset	14–10	0.76	3
					8–2	1.14	4
					1–4/0	1.40	5
Thermoplastic and fibrous outer braid	TBS	90°C (194°F)	Switchboard and switchgear wiring only	Thermoplastic	14–10	0.76	3
					8	1.14	4
					6–2	1.52	6
					1–4/0	2.03	8
Extended polytetra-fluoro-ethylene	TFE	250°C (482°F)	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus, or as open wiring (nickel or nickel-	Extruded polytetra-fluoroethylene	14–10	0.51	2
					8–2	0.76	3

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation AWG or kcmil	mm	m
			coated copper only)		1–4/0	1.14	4
Heat-resistant thermoplastic	THHN	90°C (194°F)	Dry and damp locations	Flame-retardant, heat-resistant thermoplastic	~~14–12~~ 16–12	0.38	1
					10	0.51	2
					8–6	0.76	3
					4–2	1.02	4
					1–4/0	1.27	5
					250–500	1.52	6
					501–1000	1.78	7
Moisture- and heat-resistant thermoplastic	THHW	75°C (167°F)	Wet location	Flame-retardant, moisture- and heat-resistant thermoplastic	~~14–10~~ 16–10	0.76	3
					8	1.14	4
					6–2	1.52	6
		90°C (194°F)	Dry location		1–4/0	2.03	8
					213–500	2.41	9
					501–1000	2.79	11
					1001–2000	3.18	12
Moisture- and heat-resistant thermoplastic	THW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	~~14–10~~ 16–10	0.76	3
					8	1.14	4
		90°C (194°F)	Special applications within electric discharge lighting equipment. Limited to 1000 open-circuit volts or less. (Size 14-8 only as permitted in 410.68.)		6–2	1.52	6
					1–4/0	2.03	8
					213–500	2.41	9
					501–1000	2.79	11
					1001–2000	3.18	12
	-	THW-2	90°C (194°F)	Dry and wet locations	-	-	-
Moisture- and heat-resistant thermoplastic	THWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	~~14–12~~ 16–12	0.38	1
					10	0.51	2
					8–6	0.76	3
					4–2	1.02	4
	THWN-2	90°C (194°F)			1–4/0	1.27	5
					250–500	1.52	6
					501–1000	1.78	7
Moisture-resistant thermoplastic	TW	60°C	Dry and wet locations	Flame-retardant, moisture-	~~14–10~~ 16–10	0.76	3

Trade Name	**Type Letter**	**Maximum Operating Temperature**	**Application Provisions**	**Insulation**	**Thickness of Insulation**		
					AWG or kcmil	**mm**	**m**
				resistant thermoplastic	8	1.14	4
					6–2	1.52	6
		(140°F)			1–4/0	2.03	8
					213–500	2.41	9
					501–1000	2.79	11
					1001–2000	3.18	12
Underground feeder and branch-circuit cable — single conductor (for Type UF cable employing more than one conductor, see Article 340, Part II).	UF	60°C	See Article 340, Part II.		~~14–10~~ 16–10	1.52	60
		(140°F)		Moisture-resistant	8–2	2.03	80
		75°C		Moisture- and heat-resistant	1–4/0	2.41	95
		(167°F)[4]					
Underground service-entrance cable — single conductor (for Type USE cable employing more than one conductor, seeArticle 338, Part II).	USE	75°C	See Article 338, Part II.	Heat- and moisture-resistant	~~14–10~~ 16–10	1.14	4
		(167°F)[4]			8–2	1.52	6
					1–4/0	2.03	8
					213–500	2.41	95
					501–1000	2.79	11
	USE-2	90°C (194°F)	Dry and wet locations		1001–2000	3.18	12
Thermoset	XHH	90°C	Dry and damp locations	Flame-retardant thermoset	~~14–10~~ 16–10	0.76	3
					8–2	1.14	4
					1–4/0	1.40	5
		(194°F)			213–500	1.65	6
					501–1000	2.03	8
					1001–2000	2.41	9
Thermoset	XHHN	90°C	Dry and damp locations	Flame-retardant thermoset	~~14–12~~ 16–12	0.38	1
					10	0.51	2
					8–6	0.76	3
		(194°F)			4–2	1.02	4
					1–4/0	1.27	5
					250–500	1.52	6
					501–1000	1.78	7

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	m
Moisture-resistant thermoset	XHHW	90°C (194°F)	Dry and damp locations	Flame-retardant, moisture-resistant thermoset	~~14–10~~ 16–10	0.76	3
					8–2	1.14	4
		75°C (167°F)	Wet locations		1–4/0	1.40	5
					213–500	1.65	6
					501–1000	2.03	8
					1001–2000	2.41	9
Moisture-resistant thermoset	XHHW-2	90°C (194°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	~~14–10~~ 16–10	0.76	3
					8–2	1.14	4
					1–4/0	1.40	5
					213–500	1.65	6
					501–1000	2.03	8
					1001–2000	2.41	9
Moisture-resistant thermoset	XHWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	~~14–12~~ 16–12	0.38	1
					10	0.51	2
					8–6	0.76	3
	XHWN-2	90°C (194°F)			4–2	1.02	4
					1–4/0	1.27	5
					250–500	1.52	6
					501–1000	1.78	7
Modified ethylene tetrafluoro-ethylene	Z	90°C (194°F)	Dry and damp locations	Modified ethylene tetrafluoro-ethylene	14–12	0.38	1
					10	0.51	2
		150°C (302°F)	Dry locations — special applications[2]		8–4	0.64	2
					3–1	0.89	3
					1/0–4/0	1.14	4
Modified ethylene tetrafluoro-ethylene	ZW	75°C (167°F)	Wet locations	Modified ethylene tetrafluoro-ethylene	14–10	0.76	3
		90°C (194°F)	Dry and damp locations				
		150°C (302°F)	Dry locations — special applications[2]		8–2	1.14	4
	ZW-2	90°C (194°F)	Dry and wet locations				

Note: Conductors in Table 310.4(1) shall be permitted to be rated up to 1000 volts if listed and marked.

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

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

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

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

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

[6]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(2) Thickness of Insulation for Nonshielded Types RHH and RHW Solid Dielectric Insulated Conductors Rated 2000 Volts

Conductor Size	-	Column A[1]		-	Column B[2]	
(AWG or kcmil)	-	mm	mils	-	mm	mils
~~14–10~~ 16–10	-	2.03	80	-	1.52	60
8	-	2.03	80	-	1.78	70
6–2	-	2.41	95	-	1.78	70
1–2/0	-	2.79	110	-	2.29	90
3/0–4/0	-	2.79	110	-	2.29	90
213–500	-	3.18	125	-	2.67	105
501–1000	-	3.56	140	-	3.05	120
1001–2000	-	3.56	140	-	3.56	140

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

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

Statement of Problem and Substantiation for Public Comment

To correlate with the conductor size changes in 310.3 made in FR-8228, applicable conductor size changes were made in this table to include an insulation thickness requirement for 16 AWG copper conductors.

Related Item

- FR 8228

Submitter Information Verification

Submitter Full Name: Christel Hunter

Organization: Cerro Wire

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 21 16:50:45 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8416-NFPA 70-2024

Statement: This correlates with the conductor size changes in 310.3, applicable conductor size changes were made in this table to include an insulation thickness requirement for 16 AWG copper conductors.

Public Comment No. 362-NFPA 70-2024 [Section No. 310.4]

310.4 Conductor Constructions and Applications.

Insulated conductors shall comply with Table 310.4(1) and Table 310.4(2).

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(1) Conductor Applications and Insulations Rated 600 Volts

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation				
					AWG or kcmil	mm		mils	
Fluorinated ethylene propylene	FEP or FEPB	90°C (194°F)	Dry and damp locations	Fluorinated ethylene propylene	14–10	0.51		20	
					8–2	0.76		30	
		200°C (392°F)	Dry locations — special applications[2]	Fluorinated ethylene propylene	14–8	0.36		14	
					6–2	0.36		14	
Mineral insulation (metal sheathed)	MI	90°C (194°F)	Dry and wet locations	Magnesium oxide	18–16[3]	0.58		23	
					16–10	0.91		36	
		250°C (482°F)	For special applications[2]		9–4	1.27		50	
					3–500	1.40		55	
Moisture-, heat-, and oil-resistant thermoplastic	MTW	60°C (140°F)	Machine tool wiring in wet locations	Flame-retardant, moisture-, heat-, and oil-resistant thermoplastic	-		(A)	(B)	(A
		90°C (194°F)	Machine tool wiring in dry locations.		22–12	0.76	0.38	30	15
					10	0.76	0.51	30	20
					-	8	1.14	0.76	45
			-		Informational Note: See NFPA 79-2021, *Electrical Standard for Industrial Machinery*.	6	1.52	0.76	60
			-			4–2	1.52	1.02	60
			-			1–4/0	2.03	1.27	80
			-			213–500	2.41	1.52	95
			-			501–1000	2.79	1.78	11
Paper	-		85°C (185°F)	For underground service conductors, or by special permission	Paper	-	-		-
Perfluoro-alkoxy	PFA	90°C (194°F)	Dry and damp locations	Perfluoro-alkoxy	14–10	0.51		20	
					8–2	0.76		30	
		200°C (392°F)	Dry locations — special applications[2]		1–4/0	1.14		45	
					-	-		-	
Perfluoro-alkoxy	PFAH	250°C (482°F)	Dry locations only. Only for leads within apparatus or within	Perfluoro-alkoxy	14–10	0.51		20	
					8–2	0.76		30	

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	mils
			raceways connected to apparatus (nickel or nickel-coated copper only)		1–4/0	1.14	45
Thermoset	RHH	90°C (194°F)	Dry and damp locations	-		14-10	1.14
						8–2	1.52
						1–4/0	2.03
						213–500	2.41
						501–1000	2.79
						1001–2000	3.18
Moisture-resistant thermoset	RHW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	1.14	45
					8–2	1.52	60
					1–4/0	2.03	80
	RHW-2	90°C (194°F)			213–500	2.41	95
					501–1000	2.79	110
					1001–2000	3.18	125
Silicone	SA	90°C (194°F)	Dry and damp locations	Silicone rubber	14–10	1.14	45
					8–2	1.52	60
					1–4/0	2.03	80
		200°C (392°F)	For special application[2]		213–500	2.41	95
					501–1000	2.79	110
					1001–2000	3.18	125
Thermoset	SIS	90°C (194°F)	Switchboard and switchgear wiring only	Flame-retardant thermoset	14–10	0.76	30
					8–2	1.14	45
					1–4/0	1.40	55
Thermoplastic and fibrous outer braid	TBS	90°C (194°F)	Switchboard and switchgear wiring only	Thermoplastic	14–10	0.76	30
					8	1.14	45
					6–2	1.52	60
					1–4/0	2.03	80
~~Extended~~ Extruded polytetra-fluoro-ethylene	TFE	250°C (482°F)	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus, or as open wiring (nickel or nickel-	Extruded polytetra-fluoroethylene	14–10	0.51	20
					8–2	0.76	30

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	mils
			coated copper only)		1–4/0	1.14	45
Heat-resistant thermoplastic	THHN	90°C (194°F)	Dry and damp locations	Flame-retardant, heat-resistant thermoplastic	14–12	0.38	15
					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	70
Moisture- and heat-resistant thermoplastic	THHW	75°C (167°F)	Wet location	Flame-retardant, moisture- and heat-resistant thermoplastic	14–10	0.76	30
					8	1.14	45
					6–2	1.52	60
		90°C (194°F)	Dry location		1–4/0	2.03	80
					213–500	2.41	95
					501–1000	2.79	110
					1001–2000	3.18	125
Moisture- and heat-resistant thermoplastic	THW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	14–10	0.76	30
					8	1.14	45
		90°C (194°F)	Special applications within electric discharge lighting equipment. Limited to 1000 open-circuit volts or less. (Size 14-8 only as permitted in 410.68.)		6–2	1.52	60
					1–4/0	2.03	80
					213–500	2.41	95
					501–1000	2.79	110
					1001–2000	3.18	125
	-	THW-2	90°C (194°F)	Dry and wet locations	-	- -	-
Moisture- and heat-resistant thermoplastic	THWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	14–12	0.38	15
					10	0.51	20
					8–6	0.76	30
					4–2	1.02	40
	THWN-2	90°C (194°F)			1–4/0	1.27	50
					250–500	1.52	60
					501–1000	1.78	70
Moisture-resistant thermoplastic	TW	60°C (140°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoplastic	14–10	0.76	30
					8	1.14	45
					6–2	1.52	60
					1–4/0	2.03	80
					213–500	2.41	95

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	mils
					501–1000	2.79	110
					1001–2000	3.18	125
Underground feeder and branch-circuit cable — single conductor (for Type UF cable employing more than one conductor, see Article 340, Part II).	UF	60°C (140°F)	See Article 340, Part II.	Moisture-resistant	14–10	1.52	60[5]
					8–2	2.03	80[5]
		75°C (167°F)[4]		Moisture- and heat-resistant	1–4/0	2.41	95[5]
Underground service-entrance cable — single conductor (for Type USE cable employing more than one conductor, seeArticle 338, Part II).	USE	75°C (167°F)[4]	See Article 338, Part II.	Heat- and moisture-resistant	14–10	1.14	45
					8–2	1.52	60
					1–4/0	2.03	80
					213–500	2.41	95 [6]
					501–1000	2.79	110
	USE-2	90°C (194°F)	Dry and wet locations		1001–2000	3.18	125
Thermoset	XHH	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–10	0.76	30
					8–2	1.14	45
					1–4/0	1.40	55
					213–500	1.65	65
					501–1000	2.03	80
					1001–2000	2.41	95
Thermoset	XHHN	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–12	0.38	15
					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	70
Moisture-resistant thermoset	XHHW	90°C (194°F)	Dry and damp locations	Flame-retardant, moisture-resistant thermoset	14–10	0.76	30
					8–2	1.14	45
		75°C (167°F)	Wet locations		1–4/0	1.40	55
					213–500	1.65	65
					501–1000	2.03	80

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation		
					AWG or kcmil	mm	mils
					1001–2000	2.41	95
Moisture-resistant thermoset	XHHW-2	90°C (194°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	0.76	30
					8–2	1.14	45
					1–4/0	1.40	55
					213–500	1.65	65
					501–1000	2.03	80
					1001–2000	2.41	95
Moisture-resistant thermoset	XHWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–12	0.38	15
					10	0.51	20
					8–6	0.76	30
	XHWN-2	90°C (194°F)			4–2	1.02	40
					1–4/0	1.27	50
					250–500	1.52	60
					501–1000	1.78	70
Modified ethylene tetrafluoro-ethylene	Z	90°C (194°F)	Dry and damp locations	Modified ethylene tetrafluoro-ethylene	14–12	0.38	15
					10	0.51	20
		150°C (302°F)	Dry locations — special applications[2]		8–4	0.64	25
					3–1	0.89	35
					1/0–4/0	1.14	45
Modified ethylene tetrafluoro-ethylene	ZW	75°C (167°F)	Wet locations	Modified ethylene tetrafluoro-ethylene	14–10	0.76	30
		90°C (194°F)	Dry and damp locations		8–2	1.14	45
		150°C (302°F)	Dry locations — special applications[2]				
	ZW-2	90°C (194°F)	Dry and wet locations				

Note: Conductors in Table 310.4(1) shall be permitted to be rated up to 1000 volts if listed and marked.

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

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

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

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

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

[6]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(2) Thickness of Insulation for Nonshielded Types RHH and RHW Solid Dielectric Insulated Conductors Rated 2000 Volts

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

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

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

Statement of Problem and Substantiation for Public Comment

Correct a typo by changing 'extended' to 'extruded' for TFE in Table 310.4(1)

Related Item

- FR7931

Submitter Information Verification

Submitter Full Name: Susan Stene
Organization: UL Solutions
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jul 30 11:38:42 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-8472-NFPA 70-2024
Statement: A second revision was created to correct a misspelled word in the “TFE” column. The term “extended” will be replaced with “extruded.”

Public Comment No. 728-NFPA 70-2024 [Section No. 310.6]

~~**310.6** Conductor Identification.~~

~~**(A)** Grounded Conductors.~~

~~Insulated or covered grounded conductors shall be identified in accordance with 200.7 .~~

~~**(B)** Equipment Grounding Conductors.~~

~~Equipment grounding conductors shall be identified in accordance with 250.119 .~~

~~**(C)** Ungrounded Conductors.~~

~~**(1)** General.~~

~~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 conductors and equipment grounding conductors. Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1) .~~

~~**(2)** Branch Circuit(s).~~

~~Branch-circuit ungrounded conductors supplied from more than one nominal voltage system shall be identified in accordance with 210.5(C) .~~

~~**(3)** Feeder(s).~~

~~Feeders supplied from more than one nominal voltage system shall be identified in accordance with 215.12(C)~~

~~*Exception: Conductor identification shall be permitted in accordance with 200.8 .*~~

Statement of Problem and Substantiation for Public Comment

There is nothing in this section that is not already addressed in a more apporpriate article in the code. None of the requirements that this section points to (200.7, 210.5, 215.12, etc.) are optional, so why does this section need to exist?

Related Item

• FR 7958

Submitter Information Verification

Submitter Full Name: Ryan Jackson
Organization: Self-employed
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 04 12:27:57 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action:	Rejected
Resolution:	Not all of the information in 310.6 is located elsewhere in the standard. For example, 310.6(C) is found nowhere else in the code. This also provides pointers for users to the other relevant sections of the code.

Public Comment No. 1386-NFPA 70-2024 [Section No. 310.10(D)]

(D) Conductors Exposed to Direct Sunlight.

Conductors exposed to the rays of the sun shall comply with one of the following:

(1) Be insulated and listed as being sunlight resistant

(2) Be covered with insulating material, such as tape or sleeving, that is listed as being sunlight resistant

(3) Be bare or have insulation or covering that ~~is~~ shall not be required to be sunlight resistant where bare conductors are permitted elsewhere in this code

Statement of Problem and Substantiation for Public Comment

The text changes are intended to clarify that any insulation or covering present, either with or without sunlight resistance, is permitted where the conductors would normally be permitted to be bare.

Related Item

- FR 7934

Submitter Information Verification

Submitter Full Name: Christel Hunter

Organization: Cerro Wire

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 21 17:02:09 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8420-NFPA 70-2024

Statement: This editorial revision provides clarity that any insulation or covering present, either with or without sunlight resistance, is permitted where the conductors would normally be permitted to be bare.

Public Comment No. 1001-NFPA 70-2024 [Section No. 310.12(D)]

(D) Grounded Conductors.

Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, if the requirements of 120.61 and 230.42 for service conductors or the requirements of 215.4 and 120.61 for feeder conductors are met.

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

Informational Note No. 1: See 240.6(A) for standard ampere ratings for fuses and inverse time circuit breakers.

Informational Note No. 2: See Informative Annex D, Example D7.

Statement of Problem and Substantiation for Public Comment

This language has been relocated to the parent text of 310.12 and should have been deleted from 310.12(D)

Related Item

• First Revision No. 8031-NFPA 70-2024

Submitter Information Verification

Submitter Full Name: Don Ganiere

Organization: none

Street Address:

City:

State:

Zip:

Submittal Date: Sat Aug 10 12:50:44 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8473-NFPA 70-2024

Statement: The language was relocated from 310.12(D) to 310.12 during the first draft cycle so it would be applicable to all sections of 310.12 and should have been removed from 310.12(D).

Public Comment No. 559-NFPA 70-2024 [Section No. 310.14(A)(3)]

(3) Temperature Limitation of Conductors.

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

Informational Note No. 1: See Table 310.4(1) and Table 315.10(A) for the temperature rating of a conductor that is the maximum temperature, at any location along its length, that the conductor can withstand over a prolonged time period without serious degradation. The ampacity tables of Article 310 and the ampacity tables of Informative Annex B, the ambient temperature correction factors in 310.15(B), and the notes to the tables provide guidance for coordinating conductor sizes, types, ampacities, ambient temperatures, and number of associated conductors. The principal determinants of operating temperature are as follows:

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

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

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

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

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

Additional Proposed Changes

File Name	Description	Approved
CN_274.pdf		

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 274 appeared in the First Draft Report.

The Correlating Committee requests CMP 6 to review their action and reconsider PI 993. Because the tables are found within the same article as this section, it is appropriate to delete “Article 310” and replace it with “this article” as proposed.

Related Item

• Correlating Committee Note No. 274

Submitter Information Verification

Submitter Full Name: CC Notes

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jul 31 17:05:37 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8433-NFPA 70-2024
Statement:	A second revision was created to delete “Article 310” and replace it with “this article”. This action was taken to comply with the NEC Style Manual Section 4.1.4. The reference to Table 315.10(A) was removed because conductors over 2000 volts were put into a separate article.

Correlating Committee Note No. 274-NFPA 70-2024 [Section No. 310.14(A)(3)]

Submitter Information Verification

Committee: NEC-AAC
Submittal Date: Thu May 09 21:24:24 EDT 2024

Committee Statement

Committee Statement: The Correlating Committee requests CMP 6 to review their action and reconsider PI 993. Because the tables are found within the same article as this section, it is appropriate to delete “Article 310” and replace it with “this article” as proposed.

Ballot Results

This item has passed ballot

12 Eligible Voters
1 Not Returned
11 Affirmative All
0 Affirmative with Comments
0 Negative with Comments
0 Abstention

Not Returned

McDaniel, Roger D.

Affirmative All

Ayer, Lawrence S.
Bowmer, Trevor N.
Hickman, Palmer L.
Holub, Richard A.
Jackson, Peter D.
Kendall, David H.
Manche, Alan
Osborne, Robert D.
Porter, Christine T.
Schultheis, Timothy James
Williams, David A.

Public Comment No. 1704-NFPA 70-2024 [Section No. 310.15(A)]

(A) General.

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

The temperature correction and adjustment factors shall be permitted to be applied to the ~~ampacity~~ <u>table entry</u> for the temperature rating of the conductor, ~~if~~ <u>but</u> the corrected and adjusted ampacity ~~does~~ <u>may</u> not exceed the ~~ampacity~~ <u>table entry</u> for the temperature rating of the termination in accordance with 110.14(C).

Informational Note No. 1: Table 310.16 through Table 310.19 are application tables for use in determining conductor sizes on loads calculated in accordance with Article 120, Part II, Part III, Part IV, or Part V. Ampacities result from consideration of one or more of the following:

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

(2) Coordination with circuit and system overcurrent protection

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

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

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

Informational Note No. 3: See 400.5 for the ampacities of flexible cords and cables. See 402.5 for the ampacities of fixture wires.

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

Statement of Problem and Substantiation for Public Comment

Article 100 defines "ampacity" as "The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating." Thus the table entries in Tables 310.16 through 310.19 are only ampacities when the conditions (1) through (4) at the head of the table are satisfied. The table notes instruct us on how to modify the table entries to find the ampacity when one or more of those conditions are not met.

Therefore, using the word "ampacity" to refer to the table entry in conditions where at least one of the conditions is not met (where ampacity adjustment or correction is required) is confusing. Proper exposition requires a different term to refer to the table value itself (with no ampacity adjustment or correction applied). Here I am suggesting the simple phrase "table entry", since this text is already talking about the tables in question.

Also, the current language in this sentence suggests that if the calculation starting with the table entry according to the temperature rating of the conductor results in a value higher than the table entry for the termination temperature, rather than taking the minimum of those two numbers as the ampacity, one must go back and redo the adjustment and correction calculation starting with the termination temperature table entry. As this is not the end, the revised language avoids this possible misinterpretation, which I have encountered multiple times with electricians.

Related Item

- 450-NFPA 70-2023

Submitter Information Verification

Submitter Full Name: Wayne Whitney

Organization: Whitney

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 26 13:37:19 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: The recommendation to change the term “ampacity” to “table entry” was rejected because 310.15(A) is for general ampacities for conductors and identifies the various tables in the National Electrical Code where ampacities would apply, changing the wording to “table entry” may cause confusion due to the fact that the term “ampacities” is included the title of the tables to reflect the values provided in the tables and the use of the term “entry” may suggest the need for additional measures to be performed to receive the ampacity value needed to perform the calculation.

Public Comment No. 731-NFPA 70-2024 [Section No. 310.15(E)]

(E) Neutral Conductor.

When applying 310.15(C), neutrals shall comply with 310.15(~~A)~~ ~~or~~ E)(1) or 310.15(~~B~~ E)(2) .

(1) Current-Carrying.

A neutral conductor shall be considered as current-carrying in any of the following circuits:

(1) A 2 wire circuit consisting of one ungrounded and one neutral conductor

(2) A 3 wire circuit consisting of two ungrounded conductors and the neutral conductor of a 4-wire, 3 phase, wye connected system

Informational Note: When two ungrounded conductors and a neutral originate from a 4-wire, 3 phase, wye connected system, the neutral conductor carries approximately the same current as the line-to-neutral load current of the other conductors.

(3) A 4-wire, 3-phase wye circuit where the major portion of the load consists of nonlinear loads

Informational Note: Where the major portion of the loads consists of nonlinear loads in a 4-wire, 3 phase wye circuit, harmonic currents are present in the neutral conductor.

(2) Non-Current-Carrying.

~~A neutral~~ For circuits not covered in 310.15(E)(1), a neutral conductor that carries only the unbalanced current from the other conductors of the same circuit shall not be considered current-carrying.

Statement of Problem and Substantiation for Public Comment

I applaud CMP 6 for these changes, which I think will help code users. It seems that the first sentence is misnumbered, however, as it points back to 310.15(A) and (B) instead of the two options included in this section [(E)(1) and (E)(2)].
Section (E)(2) needs to be revised because, as written in the first draft, it is a blanket exception that can be used for essentially every neutral conductor, including those specified in (E)(1).

Related Item

• FR 8035

Submitter Information Verification

Submitter Full Name: Ryan Jackson
Organization: Self-employed
Street Address:
City:
State:
Zip:

Submittal Date: Sun Aug 04 12:41:18 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8440-NFPA 70-2024

Statement: A second revision was created to correct the misnumbered references to 310.15(E)(1) and 310.15(E)(2). Editorial revisions were also made to 310.15(E)(2) to provide distinction between current-carrying and non-current-carrying neutral conductors.

Public Comment No. 132-NFPA 70-2024 [Section No. 310.16]

310.16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried).

The ampacities shall be as specified in Table 310.16 where all of the following conditions apply:

(1) Conductors are rated 0 volts through 2000 volts.

(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(1)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	10	—	18	—	—	—	—
14*	15~~20~~	15 ~~25~~	15	10†	—	—	14†
12*	20~~25~~	20 ~~30~~	20	15	20	25	12*
10*	30~~35~~	30 ~~40~~	30	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800

900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the code.

†Ampacity shall be applicable only to copper-clad aluminum conductors.

Statement of Problem and Substantiation for Public Comment

I have seen many times, DIY homeowners and pool guys installing the wrong breaker size due to this table. They are not aware of the * referring to article 240.4. I feel this chart needs to be changed to reflect the overcurrent amps and change the * to show how the wire can be used for higher voltages outside the overcurrent requirments.

Related Item

• Contractor

Submitter Information Verification

Submitter Full Name: Douglas Brown
Organization: Brown's Electrical Services
Affiliation: Customer
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jul 21 13:15:55 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: Replacing the ampacity values which are used for adjustment and correction factors with the ratings of overcurrent protection devices for specific small conductors will create confusion and set a limitation on the allowable ampacity of those specific small conductors in applications that would require the application of correction and adjustment factors.

Public Comment No. 2021-NFPA 70-2024 [Section No. 310.16]

310.16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried).

The ampacities shall be as specified in Table 310.16 where all of the following conditions apply:

(1) Conductors are rated 0 volts through 2000 volts.

(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(1)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	10	—	18	—	—	—	—
14*	15	20	25~~10~~	~~†~~ -	—	—	~~14~~ ~~†~~ -
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800

900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the code.

† ~~Ampacity shall be applicable only to copper-clad aluminum conductors.~~

Statement of Problem and Substantiation for Public Comment

This proposal seeks to restore this section to the language of the 2023 National Electrical Code. When this section was modified during the 2026 NEC First Draft process, the discussions in favor of the modification were based upon whether the maximum temperature encountered during testing exceeded 90°C. The underlying assumption is that the maximum allowable temperature for Type NM-B Cable is 90°C (likely based upon the requirements in NEC 334.112 and UL 719 Section 1.1 which refers to the use of conductors with 90°C insulation). Nowhere in the NEC or in UL 719 is the maximum temperature for the complete Type NM-B Cable (not just the conductors) directly stated. Given this, the temperature rating for the overall cable jacket (sheath) should be considered in the determination of the maximum temperature for the complete cable assembly.

Section 5.2.1 of UL 719 (Nonmetallic-Sheathed Cable) requires compliance with the requirements in the “Physical properties of NM Cable PVC jacket” table in UL 1581 (Table 50.179). This testing involves aging the jacket material at 100°C for 240 hours before performing tensile and elongation tests. It is the aging of the test specimens at a specified time and temperature that determines the temperature rating of the material. The aging parameters in Table 50.179 (100°C for 240 hours) do not match those required for material rated 90°C.

Table 50.182 in UL 1581 includes the correlation of the temperature rating of the material with the specified oven time and temperature. In this table, aging at 100°C for 240 hours corresponds to a temperature rating of 75°C, not 90°C.

Given this, it is reasonable to conclude the maximum allowable temperature for Type NM-B Cable is not 90°C. It is also reasonable to conclude the maximum allowable temperature is 75°C or less.

Related Item

• FR 8257

Submitter Information Verification

Submitter Full Name: Dave Watson

Organization: Southwire

Affiliation: Southwire

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 28 15:55:14 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: The CMP 6 action on Table 310.16 at their first draft meeting was supported by data submitted in public inputs and the discussion on the reports provided during the first draft meeting. Review of the substantiation in the public comments on this section did not provide sufficient new data or test reports that supports changing the panel’s first draft action.

Public Comment No. 238-NFPA 70-2024 [Section No. 310.16]

310.16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried).

The ampacities shall be as specified in Table 310.16 where all of the following conditions apply:

(1) Conductors are rated 0 volts through 2000 volts.

(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(1)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	10	—	18	—	—	—	—
14*	15	20	25	10† —	15 ‡ —	20 ‡	14†
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800

900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the code.

†Ampacity shall be applicable only to copper-clad aluminum conductors.

Statement of Problem and Substantiation for Public Comment

Derating conductors in circuits through adjustment and correction factors ensures that circuits are kept at temperatures below that of the thermal rating of their conductors' insulation. Not having ampacity values for 14 AWG CCA in the 75C and 90C columns does not allow for the performance of adjustment and correction calculations (done to ensure safety) when more than three current carrying conductors are together in circuits, or when ambient temperatures require conductors to be derated. The guidance and allowance for use of the 90C column for adjustment and correction is in accordance with section 310.15(A), and to permit 14 AWG CCA an ampacity rating is equivalent to what has been allowed for 16 AWG copper in Table 310.16 for many cycles (16 AWG copper has long had an ampacity value of 18 amperes in the 90C column of Table 310.16). Also, for conductors rated 75C for use in wet locations, such as THHW, the 75C column is used to make adjustment and correction calculations. Both Table 310.16 and UL 83 reference CCA for use with THHW type insulation. Further, the 75C column is used for sizing conductors where the conductor insulation, terminals and connections are rated 75C in accordance with 240.4(E) and (G) and 110.14(C)(1)(a)(3). Examples of this would be small motors or specific appliances.

Related Item

- PI 1016

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld Bimetallics, LLC.
Affiliation: ABA
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jul 25 06:46:03 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: CC-8481-NFPA 70-2024

Statement: The NEC now allows conductor sizes of 16 AWG copper and 14 AWG copper-clad aluminum; therefore values were added to the ampacity table for making ampacity adjustments and corrections.

Public Comment No. 544-NFPA 70-2024 [Section No. 310.16]

310.16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried).

The ampacities shall be as specified in Table 310.16 where all of the following conditions apply:

(1) Conductors are rated 0 volts through 2000 volts.

(2) Conductors are rated 60°C (140°F), 75°C (167°F), or 90°C (194°F).

(3) Wiring is installed in a 30°C (86°F) ambient temperature.

(4) There are not more than three current-carrying conductors.

Table 310.16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(1)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18*	—	—	14	—	—	—	—
16*	~~10~~		—	18	—	—	—
14*	15	20	25	10† —	15‡ —	20‡	14†
12*	20	25	30	15	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800

900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.

3. Section 310.16 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the code.

†Ampacity shall be applicable only to copper-clad aluminum conductors.

Statement of Problem and Substantiation for Public Comment

Unlike the size of 14 AWG CCA, the size of 16 AWG copper should be removed from section 310.3(A) for the following reasons. No forethought was ever given to 16 AWG as a branch circuit conductor by its proponents. Therefore, a proposal for applying 16 AWG copper as a branch circuit conductor has never been submitted as a Public Input in any cycle. Thorough technical substantiation is unavailable to CMP6. Further, 16 AWG copper was never subjected to the testing protocol spelled out by the NFPA Research Foundation report, a point upon which CMP6 insisted for all new small branch circuit conductors. To give 16 AWG copper “a free pass” is at odds with the will of CMP6. Although 16 AWG copper may be a worthy candidate for investigation, this panel should not assume it to be safe for use as a branch circuit conductor. It should be a PI for the 2029 cycle and supported by the prescribed technical substantiation.

Related Item

• PI 1016 • FR 8036

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld Bimetallics, LLC.
Affiliation: ABA
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jul 31 08:29:34 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution:	Copper conductors sized 16 AWG are currently listed for use with many electrical products and are currently used in other similar applications in the NEC.

Public Comment No. 1161-NFPA 70-2024 [Section No. 320.2]

320.2 Listing Requirements.

The following shall be listed and identified:

(1) Type AC cable

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type AC cable to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an “approved” method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4’s has been used for decades without incident. It would be very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

Related Item

- FR7993

Submitter Information Verification

Submitter Full Name: Megan Hayes

Organization: NEMA

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 16 10:23:17 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8470-NFPA 70-2024

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 1265-NFPA 70-2024 [Section No. 320.2]

320.2 Listing Requirements.

The following shall be listed and identified:

(1) Type AC cable

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type AC cable to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This change is a solution in search of a problem. There was no technical substantiation provided to require that all securing and supporting devices be listed products. In addition the term "hardware" is very broad and undefined in the code. The currently accepted language would require the use of listed screws, nails, or other items to securely fasten the supporting device to the building's structural components.
More consideration should be given to Mr. Watson's negative comment.
Panel 8 resolved similar Pubic Inputs for raceway support with the following panel statement.
"No safety issues have been identified to justify the listing of support and securement hardware."

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 1603-NFPA 70-2024 [Section No. 330.2]	
Public Comment No. 1605-NFPA 70-2024 [Section No. 334.2]	

Related Item

- Public Input No. 2881-NFPA 70-2023

Submitter Information Verification

Submitter Full Name: Don Ganiere

Organization: none

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 19 09:38:21 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8470-NFPA 70-2024

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 1163-NFPA 70-2024 [Section No. 330.2]

330.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type MC cable

(2) ~~Support and securement hardware~~

(3) <u>Fittings used for connecting Type MC cable to boxes, cabinets, or other equipment</u>

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an “approved” method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4’s has been used for decades without incident. It would be very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

<u>Related Item</u>

- FR8038

Submitter Information Verification

Submitter Full Name: Megan Hayes

Organization: NEMA

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 16 10:45:54 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: <u>SR-8474-NFPA 70-2024</u>

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 1603-NFPA 70-2024 [Section No. 330.2]

330.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type MC cable

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type MC cable to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This change is a solution in search of a problem. There was no technical substantiation provided to require that all securing and supporting devices be listed products. In addition the term "hardware" is very broad and undefined in the code. The currently accepted language would require the use of listed screws, nails, or other items to securely fasten the supporting device to the building's structural components.
More consideration should be given to Mr. Watson's negative comment.
Panel 8 resolved similar Pubic Inputs for raceway support with the following panel statement.
"No safety issues have been identified to justify the listing of support and securement hardware."

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 1265-NFPA 70-2024 [Section No. 320.2]	
Public Comment No. 1605-NFPA 70-2024 [Section No. 334.2]	

Related Item

• Public Input No. 2883-NFPA 70-2023

Submitter Information Verification

Submitter Full Name:	Don Ganiere
Organization:	none
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Sat Aug 24 13:47:24 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8474-NFPA 70-2024
Statement:	To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of

cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 1255-NFPA 70-2024 [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 <u>a corrosion-resistant jacket is provided over the metallic covering and</u> any of the following conditions are met:

(12) <u>The metallic covering is impervious to moisture.</u>

(13) <u>A moisture-impervious jacket is provided under the metal covering.</u>

(14) <u>The insulated conductors under the metallic covering are listed for use in wet locations.</u>

(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 Comment

Although Terra made it a bit difficult to read, this comment seeks to put the requirement for a corrosion resistant jacket over the cable armor back in place. The language accepted in the First Draft allows for regular MC cable that you buy at Home Depot to be installed outdoors as long as it has THWN conductors in it! Obviously the cable armor itself needs to be suitable for wet locations and for corossion. What is the point in having the wires in a cable if we are just going to let the armor get destroyed by the environmental conditions? We may as well be allowing THWN to be stapled to the side of a building.

<u>Related Item</u>

• FR 8039

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Self-employed

Affiliation: Steel Tube Institute

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 18 17:29:21 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8535-NFPA 70-2024

Statement: Language was added back into the charging sentence of (11) to make sure that the metallic armor is protected from deterioration in damp and wet locations. An exception was added for copper-alloy covered cable because its construction is already impervious to moisture and resistant to corrosion.

Public Comment No. 2019-NFPA 70-2024 [Section No. 330.104]

330.104 Conductors.

For ungrounded, grounded, and equipment grounding conductors, the minimum conductor sizes shall be ~~16 AWG~~ 14 AWG copper, nickel, or nickel-coated copper ~~, 14 AWG~~ 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, ~~16 AWG~~ 14 AWG copper-clad aluminum, and 12 AWG aluminum.

Statement of Problem and Substantiation for Public Comment

This proposal seeks to restore this section to the language of the 2023 National Electrical Code. When this section was modified during the 2026 NEC First Draft process, the discussions in favor of the modification were based upon whether the maximum temperature encountered during testing exceeded 90°C. The underlying assumption is that the maximum allowable temperature for Type NM-B Cable is 90°C (likely based upon the requirements in NEC 334.112 and UL 719 Section 1.1 which refers to the use of conductors with 90°C insulation). Nowhere in the NEC or in UL 719 is the maximum temperature for the complete Type NM-B Cable (not just the conductors) directly stated. Given this, the temperature rating for the overall cable jacket (sheath) should be considered in the determination of the maximum temperature for the complete cable assembly.

Section 5.2.1 of UL 719 (Nonmetallic-Sheathed Cable) requires compliance with the requirements in the "Physical properties of NM Cable PVC jacket" table in UL 1581 (Table 50.179). This testing involves aging the jacket material at 100°C for 240 hours before performing tensile and elongation tests. It is the aging of the test specimens at a specified time and temperature that determines the temperature rating of the material. The aging parameters in Table 50.179 (100°C for 240 hours) do not match those required for material rated 90°C.

Table 50.182 in UL 1581 includes the correlation of the temperature rating of the material with the specified oven time and temperature. In this table, aging at 100°C for 240 hours corresponds to a temperature rating of 75°C, not 90°C.

Given this, it is reasonable to conclude the maximum allowable temperature for Type NM-B Cable is not 90°C. It is also reasonable to conclude the maximum allowable temperature is 75°C or less.

Related Item

- FR 8230

Submitter Information Verification

Submitter Full Name: Dave Watson
Organization: Southwire
Affiliation: Southwire
Street Address:
City:
State:
Zip:

Submittal Date: Wed Aug 28 15:41:16 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: The CMP 6 action on 330.104 at their first draft meeting was supported by data submitted in public inputs and the discussion on the reports provided during the first draft meeting. Review of the substantiation in the public comments on this section did not provide sufficient new data or test reports that supports changing the panel's first draft action.

Public Comment No. 1166-NFPA 70-2024 [Section No. 332.2]

332.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type MI cable

(2) ~~Support and securement hardware~~

(3) <u>Fittings used for connecting Type MI cables to boxes, cabinets, or other equipment</u>

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an “approved” method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4’s has been used for decades without incident. It would be very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

Related Item

- FR8053

Submitter Information Verification

Submitter Full Name: Megan Hayes

Organization: NEMA

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 16 11:04:02 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8475-NFPA 70-2024

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 1167-NFPA 70-2024 [Section No. 334.2]

334.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type NM and Type NMC cables

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type NM and Type NMC cables to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an “approved” method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4’s has been used for decades without incident. It would be very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

Related Item

• FR8061

Submitter Information Verification

Submitter Full Name:	Megan Hayes
Organization:	NEMA
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Fri Aug 16 11:15:48 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8476-NFPA 70-2024
Statement:	To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of

Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 1605-NFPA 70-2024 [Section No. 334.2]

334.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type NM and Type NMC cables

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type NM and Type NMC cables to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This change is a solution in search of a problem. There was no technical substantiation provided to require that all securing and supporting devices be listed products. In addition the term "hardware" is very broad and undefined in the code. The currently accepted language would require the use of listed screws, nails, or other items to securely fasten the supporting device to the building's structural components.
More consideration should be given to Mr. Watson's negative comment.
Panel 8 resolved similar Pubic Inputs for raceway support with the following panel statement.
"No safety issues have been identified to justify the listing of support and securement hardware."

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 1265-NFPA 70-2024 [Section No. 320.2]	same issue
Public Comment No. 1603-NFPA 70-2024 [Section No. 330.2]	same issue

Related Item

- Public Input No. 2886-NFPA 70-2023

Submitter Information Verification

Submitter Full Name: Don Ganiere
Organization: none
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 24 13:54:56 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8476-NFPA 70-2024

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 557-NFPA 70-2024 [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 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: See NFPA 220-2024, *Standard on Types of Building Construction*, or the applicable building code, or both for types of building construction and occupancy classification definitions.

Informational Note No. 2: See Informative Annex E for determination of building types.

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note No. 3: 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, 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

Additional Proposed Changes

File Name	Description	Approved
CN_271.pdf		

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 271 appeared in the First Draft Report.

The Correlating Committee directs CMP 6 to review 334.10(3) Informational Note No. 2 and either remove the reference to Annex E or add a reference to NFPA 5000.

Related Item

- Correlating Committee Note No. 271

Submitter Information Verification

Submitter Full Name:	CC Notes
Organization:	NEC Correlating Committee
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Jul 31 17:02:17 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8595-NFPA 70-2024
Statement:	Corrected reference per CC request.

Correlating Committee Note No. 271-NFPA 70-2024 [Section No. 334.10]

Submitter Information Verification

Committee: NEC-AAC

Submittal Date: Thu May 09 21:15:36 EDT 2024

Committee Statement

Committee Statement: The Correlating Committee directs CMP 6 to review 334.10(3) Informational Note No. 2 and either remove the reference to Annex E or add a reference to NFPA 5000.

Ballot Results

✔ **This item has passed ballot**

12 Eligible Voters
1 Not Returned
11 Affirmative All
0 Affirmative with Comments
0 Negative with Comments
0 Abstention

Not Returned

McDaniel, Roger D.

Affirmative All

Ayer, Lawrence S.
Bowmer, Trevor N.
Hickman, Palmer L.
Holub, Richard A.
Jackson, Peter D.
Kendall, David H.
Manche, Alan
Osborne, Robert D.
Porter, Christine T.
Schultheis, Timothy James
Williams, David A.

Public Comment No. 1318-NFPA 70-2024 [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.

Exception to (3): Other non-habitable grade level storage garages less than 1500 square feet, shall be permitted to use Type NM cables without the 15- minute thermal barrier in Type V construction.

Informational Note No. 1: See NFPA 220-2024, *Standard on Types of Building Construction*, or the applicable building code, or both for types of building construction and occupancy classification definitions.

Informational Note No. 2: See Informative Annex E for determination of building types.

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note No. 3: 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 Comment

This comment is being submitted on behalf of the Minnesota Department of Labor and Industry. Currently, the Department's inspection staff includes 14-office/field staff, 50-state field inspectors, 4-virtual inspectors and 22 plus contract electrical inspectors that complete over 170,000 electrical inspections annually.

Please revisit PI 1895. Small non-habitable storage garages and storage buildings should be allowed to use NM cable without the 15-minute thermal barrier. If an installer wanted to use NM cable in a storage garage, the requirements would fall under (3). (3) requires the cable to be installed behind a 15- minute thermal barrier. The thermal barrier is used mainly to allow the occupants time to exit a building in the event of a fire without inhaling toxins from the cable jacket. Typically, the grade level detached storage garage and storage building(s) have minimal provisions for receptacles and/or lights, and are small enough to allow people to exit is seconds, so requirements for a thermal barrier in non-habitable building(s) does not compromise electrical safety nor would it be more concerning than the flammable contents being stored in the building. NM cable has a proven track record of being a safe, and less expensive wiring method if installed properly.

Related Item

• Public Input No. 1895-NFPA 70-2023 Section No. 334.10

Submitter Information Verification

Submitter Full Name: Dean Hunter
Organization: Minnesota Department of Labor
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 20 14:50:58 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8594-NFPA 70-2024

Statement: Non-habitable storage buildings were added as an exception for the installation of NM cable in Type V construction due to its similarity to other locations where NM cable is permitted without a thermal barrier. The exception permits a limited square footage and is required to be at grade level, which allows for a quick means of egress.

Public Comment No. 295-NFPA 70-2024 [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~~ 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.

Informational Note No. 1: See NFPA 220-2024, *Standard on Types of Building Construction*, or the applicable building code, or both for types of building construction and occupancy classification definitions.

Informational Note No. 2: See Informative Annex E for determination of building types.

(4) Cable trays in structures permitted to be Types III, IV, or V where the cables are identified for the use.

Informational Note No. 3: 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 Comment

This Public Comment is related to Public Input No. 68.

This revision is needed to allow NM cables to be installed in walls, ceilings and floors where located behind building items such as a hinged, fire-rated access panel that commonly get installed in sheetrock ceilings to provide access to plumbing shut-off valves and other systems where access may be needed. NM cables installed in the ceiling space above one or several of these panels in a sheetrock ceiling may not meet the Article 100 definition of "concealed". It meets the definition of "exposed" but would still be provided with a protective thermal barrier of at least 15 minutes.

See graphics showing 1 ½ hour fire-rated hatches in sheetrock ceiling.

The Committee Statement on Public Input No. 68 had 3 sentences. The first sentence stated, “The majority of the installation is concealed throughout its entire length, EXCEPT for short portions temporarily visible through an access port.” This seemingly supports the revisions proposed by PI 68 and this Public Comment.

But then the 2nd sentence states, “A cable is still considered to be concealed even when a mechanical or plumbing access is provided.” This seemingly contradicts the first sentence of the Committee Statement. It most certainly contradicts the Article 100 definition of “Exposed (as applied to wiring methods)” which is defined as “On or attached to the surface or behind panels designed to allow access.”

Both sentences of the Committee Statement cannot be true simultaneously.
You can’t state the wiring is concealed throughout its entire length EXCEPT at the hatch and then also

say the wiring at the hatch is considered CONCEALED too! Please clarify! Which is it? Is the wiring at the hatch “Concealed” as the committee states or is the wiring at the hatch “Exposed’ as defined in Article 100. It can’t be both “concealed” and “exposed” simultaneously! It has to be one or the other! There is no way to suggest that wiring behind the hatch is considered anything but “exposed’ as defined by Article 100. In fact, it aligns perfectly with that definition! It does not align with the definition of “concealed” at all! Concealed is defined as “Rendered inaccessible by the structure or finish of the building.” The wiring behind these hatches is accessible but well protected by the building construction.

Related Item

- PI 68

Submitter Information Verification

Submitter Full Name:	Russ Leblanc
Organization:	LeBlanc Consulting Services
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Sun Jul 28 09:09:02 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8551-NFPA 70-2024
Statement:	NM Cables installed behind items such as fire-rated access panels are considered as exposed rather than concealed per the Article 100 definition of Exposed (as applied to wiring methods). Based on global 649, the text “to be installed” is redundant and has been removed to increase clarity.

Public Comment No. 256-NFPA 70-2024 [Section No. 334.19]

334.19 Cable Entries.

The sheath on nonmetallic-sheathed cable shall extend not less than 6 mm (¼ in.) ~~and not greater than 25.4 mm (1 in.)~~ beyond any cable clamp or cable entry in the enclosure.

Statement of Problem and Substantiation for Public Comment

There was no real substantiation for adding this requirement. Of course, there couldn't be because it is not a real safety issue. This type of change only upsets installers. If 1 1/4" of cable sheath is inside the enclosure, so what? And how does the electrician fix it if it gets written up? They have to put their razor knife on the sheath to strip it further and likely damage the conductors. So now we have people creating a safety issue becuase they are trying to address an issue that never even existed in the first place. Of the literal millions of boxes that do not satisfy this new rule, how many incidents are there?

Related Item

- RF 8085

Submitter Information Verification

Submitter Full Name:	Ryan Jackson
Organization:	Self-employed
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jul 25 18:04:33 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8554-NFPA 70-2024
Statement:	The 1 inch limitation was removed to address the concerns of the submitter that attempting to remove excess sheath could result in damaging the conductors. The requirement in 300.14 to start the 6" measurement of free conductor at the point of emergence from the sheath will tend to limit the amount of sheath that is left in the box, if enforced. The following text "inside the enclosure, outlet, device, pull, or junction box" was added to provide inspectors enforceable text for making sure the end of the sheath properly extends into the enclosure, outlet, device, pull, or junction box.

Public Comment No. 138-NFPA 70-2024 [Section No. 334.30 [Excluding any Sub-Sections]]

> Nonmetallic-sheathed cable shall be supported and secured by cable ties listed and identified for securement and support, or ~~listed~~ staples, 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.

Statement of Problem and Substantiation for Public Comment

There was no substantiation provided that unlisted staples presented a hazard at all. The code already requires that staples be installed as not to damage the cable, a listed staple will do nothing to stop a cable from being damaged.

Related Item

- FR-8094

Submitter Information Verification

Submitter Full Name:	Jesse Duvuvei
Organization:	North Strabane Township
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Mon Jul 22 08:48:41 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected
Resolution:	To avoid damage to cable and undue stress on electrical connections, the use of listed staples for securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago.

Public Comment No. 1609-NFPA 70-2024 [Section No. 334.80(A)]

(A) General.

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, <u>or for termination requirements,</u> 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).

Statement of Problem and Substantiation for Public Comment

The CMP's informative response to PI 494-NFPA 70-2023 has led me to the understanding that the issue raised in that PI is best addressed by amending this section of Article 334. The purpose of this change is to allow the use of NM with equipment with a termination temperature requirement above 60C, in recognition of the 90C rated conductors within the NM cable, without changing the overall limit of NM cable to the 60C ampacity.

So consider a 48A continuous load (such as an EVSE, an increasingly common new installation) installed with a 60A overcurrent device with 60C/75C rated terminations, and supplied by NM cable. What size NM cable is required?

The conductor size selected is driven by the requirements of 210.19(A)(1)(a) and (b), as well as 240.4. According to 334.80(A), the calculated ampacity of a 6/2 NM cable is limited to 55A, and that of a 4/2 NM cable is limited to 70A, per the 60C column of Table 310.16. Whenever this limit controls, rather than the ampacity being even lower due to the necessary adjustment and correction starting with the 90C Table 310.16 ampacity, 6/2 NM cable complies with 210.19(A)(1)(b), as its 55A ampacity exceeds the load of 48A. In such circumstances it also complies with 240.4(B) with respect to the 60A OCPD required by 210.20, as that is next standard OCPD size larger than its ampacity of 55A.

But as currently understood, 6/2 NM would never comply with 210.19(A)(1)(a), which calls for a conductor with an ampacity of 60A before ampacity adjustment and correction. This causes such installations to require 4/2 NM cable.

However, what is the idea behind 210.19(A)(1)(a)? This is a termination requirement, and it recognizes that equipment terminations may rely on the heat-sinking effect of the connected conductors to control termination temperature. The listing standard for equipment, such as UL 489 for circuit breakers, specifies the size of conductor to use in the heat rise test based on the termination temperature rating of the equipment. For a 60A OCPD, if the termination is rated 60C, it requires testing with #4 copper conductors, while if the termination is rated 75C, it requires testing with #6 copper conductors.

So a breaker with 60C/75C terminations has been tested with #6 copper conductors not to overheat. The terminations may rise in temperature to 75C, but as per the allowance for NM ampacity adjustment and correction based on the 90C rating, NM and its conductors are rated for such a temperature. [In a sufficiently hot attic, where the 90C ampacity after adjustment and correction controls, if the conductor is loaded to its full ampacity, the conductor temperature is allowed to rise to 90C.]

Thus we see that using 6/2 NM cable on a 60A breaker rated 60C/75C with a 48A continuous load will provide the necessary level of heat sinking at the breaker termination as per the UL testing standard and will not cause the NM conductors to exceed their rated temperature. Moreover, the load is still less than the 60C ampacity as required by 334.80(A).

Therefore this installation with a 60C/75C rated breaker and 6/2 NM cable should not be prohibited by the combination of 210.19(A)(1)(a) and 334.80(A); the prohibition is not supported by the physics or by testing limitations. Given the reasons behind 210.19(A)(1)(a) the best way to allow this installation is to adjust 334.80(A) to allow the higher temperature rating to be used for termination requirements. Note that the proposed change would still require 4/2 NM cable to be used where the equipment termination temperature rating is 60C.

With the ongoing electrification of the US automotive fleet over the next two decades, literally hundreds of thousands of 48A EVSEs will be installed on 60A circuits, many of which will be supplied by NM cable. Enacting this change will provide significant economic savings and a reduction in unnecessary resource utilization.

Now the 55A rating is a continuous rating, and greater than the 48A continuous load, so the cable will not be overloaded during normal operating conditions. This complies with 210.19(A)(1)(b).

Related Item

- Public Input No. 494-NFPA 70-2023

Submitter Information Verification

Submitter Full Name: Wayne Whitney
Organization: Whitney
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 24 14:14:57 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: The relationship between the cable/conductor temperature and the termination temperature is addressed in section 110.14(C). Section 310.14 governs ampacities and does not have an adjustment for termination requirements. See Informational Note No. 1 of section 310.14(A)(3).

Public Comment No. 2016-NFPA 70-2024 [Section No. 334.104]

334.104 Conductors.

The 600-volt insulated power conductors shall be sizes 14 AWG through 2 AWG copper conductors or sizes 12 AWG through 2 AWG aluminum or copper-clad aluminum conductors. Control and signaling conductors shall be no smaller than 18 AWG copper.

Statement of Problem and Substantiation for Public Comment

This proposal seeks to restore this section to the language of the 2023 National Electrical Code. When this section was modified during the 2026 NEC First Draft process, the discussions in favor of the modification were based upon whether the maximum temperature encountered during testing exceeded 90°C. The underlying assumption is that the maximum allowable temperature for Type NM-B Cable is 90°C (likely based upon the requirements in NEC 334.112 and UL 719 Section 1.1 which refers to the use of conductors with 90°C insulation). Nowhere in the NEC or in UL 719 is the maximum temperature for the complete Type NM-B Cable (not just the conductors) directly stated. Given this, the temperature rating for the overall cable jacket (sheath) should be considered in the determination of the maximum temperature for the complete cable assembly.

Section 5.2.1 of UL 719 (Nonmetallic-Sheathed Cable) requires compliance with the requirements in the “Physical properties of NM Cable PVC jacket” table in UL 1581 (Table 50.179). This testing involves aging the jacket material at 100°C for 240 hours before performing tensile and elongation tests. It is the aging of the test specimens at a specified time and temperature that determines the temperature rating of the material. The aging parameters in Table 50.179 (100°C for 240 hours) do not match those required for material rated 90°C.

Table 50.182 in UL 1581 includes the correlation of the temperature rating of the material with the specified oven time and temperature. In this table, aging at 100°C for 240 hours corresponds to a temperature rating of 75°C, not 90°C.

Given this, it is reasonable to conclude the maximum allowable temperature for Type NM-B Cable is not 90°C. It is also reasonable to conclude the maximum allowable temperature is 75°C or less.

Related Item

- FR 8231

Submitter Information Verification

Submitter Full Name: Dave Watson

Organization: Southwire

Affiliation: Southwire

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 28 15:37:09 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: The CMP 6 action on 334.104 at their first draft meeting was supported by data submitted in public inputs and the discussion on the reports provided during the first draft meeting. Review of the substantiation in the public comments on this section did not provide sufficient new data or test reports that supports changing the panel's first draft action.

Public Comment No. 240-NFPA 70-2024 [Section No. 334.104]

334.104 Conductors.

The 600-volt insulated power conductors shall be sizes 14 AWG through 2 AWG copper and copper-clad aluminum conductors or sizes 12 AWG through ~~2 AWG aluminum or copper-clad aluminum~~ 2 AWG aluminum conductors. ~~Control~~

For control and signaling conductors minimum conductor sizes shall be no smaller than 18 AWG copper, 16 AWG copper-clad aluminum and 12 AWG aluminum .

Additional Proposed Changes

File Name	Description	Approved
G150875569_Final_Report_Rev1.pdf	Dielectric Testing of THHN Insulation	
CI_2_Testing_Report_Final_Submittal_w_App.pdf	Thermal Modeling Study of Small Circuit Conductors in R-43 Insulation	

Statement of Problem and Substantiation for Public Comment

Over three cycles, the size 14 AWG copper-clad aluminum (CCA) for use in the NM cable wiring method (Article 334) has been thoroughly vetted. And based upon the knowledge gained from 8 years of study by this committee, CMP6 in the First Revision accepted by 2/3 majority 14 AWG CCA for two wiring methods - MC Cable (FR 8230) and Tray Cable (FR 8232). The wiring methods of MC and Tray Cable, like with NM-B cable, employ THHN 90°C rated thermoplastic insulation (or equivalent), which is an important point when judging the safety of 14 AWG CCA NM-B. They all utilize the same 90°C PVC. 14 AWG CCA was also added to section 310.3(A) for use in conductors up to 2000 volts (while the NM cable wiring method is limited to only 600 volts), as well as given an ampacity rating of 10 amperes in Table 310.16. These facts support the idea that due to NM's derating, to use 14 AWC CCA in NM cable is even less of a concern than it would be for MC and Tray cable.

For the Second Revision of the 2026 cycle, a team of scientists, electrical engineers and accreditors on behalf of Copperweld Bimetallics continued its research of small branch circuits based upon the recommendations of the NFPA Research Foundation. The team took both analytical and experimental approaches to the question, resulting in a multi-physics forecast modeling program for copper and CCA conductors that may be used for future projects to predict conductor performance under variable conditions. The knowledge gained from that effort is being used as substantiation in support of this Public Comment. The study concluded that 14 AWG CCA poses no more threat to public safety in terms of overheating as a branch circuit conductor of NM cable than would any other size.

According to the NFPA Fire Protection Research Foundation report published in August of 2023, the acceptance criteria for small circuit conductors "should be based on insulation ampacity temperature ratings outlined in the Article 310 ampacity tables within the 2023 edition of the NEC," which for the THHN of NM-B cable is 90°C. As stated in the NRTL Intertek letter report 105885650CSLT-001 attached to this PC, NM-B cable was tested under test conditions within a 10' x 21' wall panel, using circuit lengths of 100 feet within R-43 wall insulation (as recommended by the FPRF report), while carrying current to the full ampacity rating of the wiring method. The conditions set by the test plan were designed to simulate the extreme NEC-permitted limits of what a conductor might encounter in a real installation. The maximum heating of 14 AWG NM-B CCA was reported to be 61.4C, a value well within the rating of the THHN insulation, 90C, which is the pass/fail line set by the FPRF report.

A dielectric is a material, such as a thermoplastic (PVC) insulation, that resists electrical voltage potential. To test for dielectric breakdown in a conductor's insulation (cracks or pin holes caused by aging and degradation), a rising voltage is applied to a piece of the conductor while its insulation is submerged in water. If the insulation were to be compromised by overheating or aging, the rising voltage will force a failure in the insulation (allowing current to pass through it causing a short). A second Intertek NRTL letter report provided with this Public Comment (Letter Report G150875569) provides insight into the dielectric performance profile of 90C rated THHN insulation. Using UL 83 as a guide (UL 83 is the industry standard for thermoplastic insulated wire and cable), hundreds of cut samples of THHN conductors were placed into three separate ovens and heated over 43 days. One of the ovens was set to 90°C, the second to 125°C and the third to 150°C. Every two days three samples were removed from each of the ovens and tested for their dielectric properties by applying rising voltage from 1 volt up to 22,000 volts. A set of control samples was also tested along with them, conductors left at lab ambient. If the rising voltage caused a dielectric breakdown in a sample, that point was recorded instantaneously by a data logger.

In the report, the experiment proved that even at 150°C of constant heating over 43 days (a level of heating no conductor would ever see given properly functioning circuit protection), the insulation remained functional. The dielectric properties of the 90°C rated THHN insulation never broke down below 2,000 volts, the pass/fail line per UL 83. Further, by applying the Arrhenius equation for predicting the service life of products like electrical wire and cable, this equates to roughly 682 years of normal service life of the THHN insulation. The study showed that there was little difference between the dielectric breakdown of those conductors baked at 90C for 43 days, and the control samples that were tested along with them. The control samples were left at an average of 21C. In other words, the safety factors built into 90°C rated THHN insulation further assure the safety of NM-B cables, regardless of whether they are large or small circuits.

These two NRTL accredited test reports are a further testament to the safety of 14 AWG CCA for use in NM cables for the three 10-ampere branch circuit applications cited in section 210.23(A), one of which is for use in LED lighting circuits. Because of the tight restrictions placed upon 10-ampere branch circuits by CMP2 for residential applications (all three allowances use extremely light loads), to exceed 10-amperes is highly unlikely. But even so, the THHN insulation is very resilient. These limitations in themselves ensure safety for residential usage. Regardless of material type or product category, however, human error and calamity are impossible to regulate in any location -- residential included. But the safety factors built into 14 AWG CCA NM-B cable in terms of its required limitations and 90C insulation type make it remarkably forgiving and able to survive worst-case scenarios without creating a hazard.

Related Item

• PI 1010 • PI 1021

Submitter Information Verification

Submitter Full Name:	Peter Graser
Organization:	Copperweld Bimetallics, LLC.
Affiliation:	ABA
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jul 25 06:59:17 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8565-NFPA 70-2024

Statement: Based on the data provided 14 AWG copper-clad aluminum is added as a smaller sized branch circuit conductor for NM cable. 16 AWG copper is added as a branch circuit conductor based on its historical use. 16 AWG copper-clad aluminum is being added as a smaller remote control and signal wire for use in NM cable.

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Copperweld Satellite Compliance Lab Final Report

Intertek Project G150875569

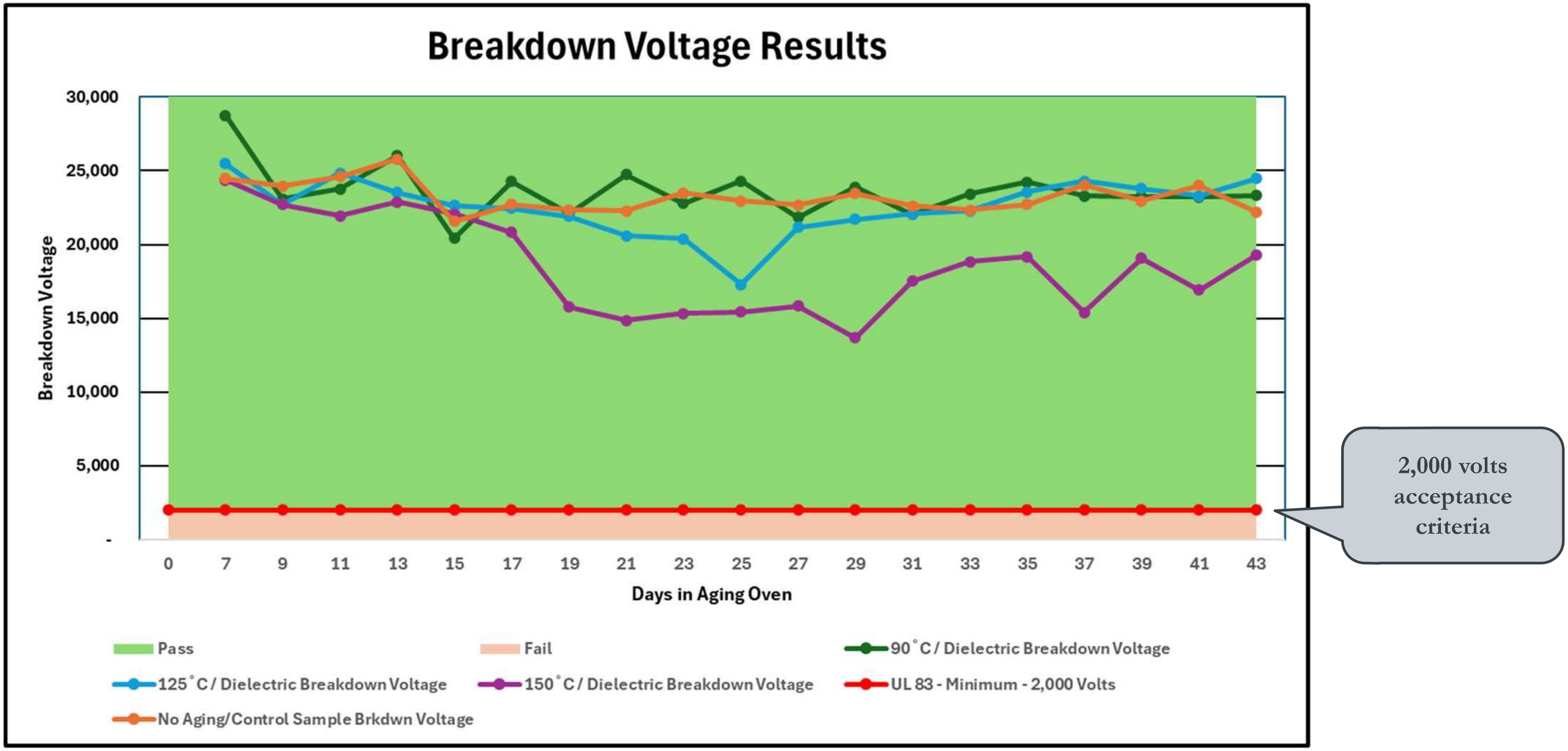
August 2024

Table of Contents

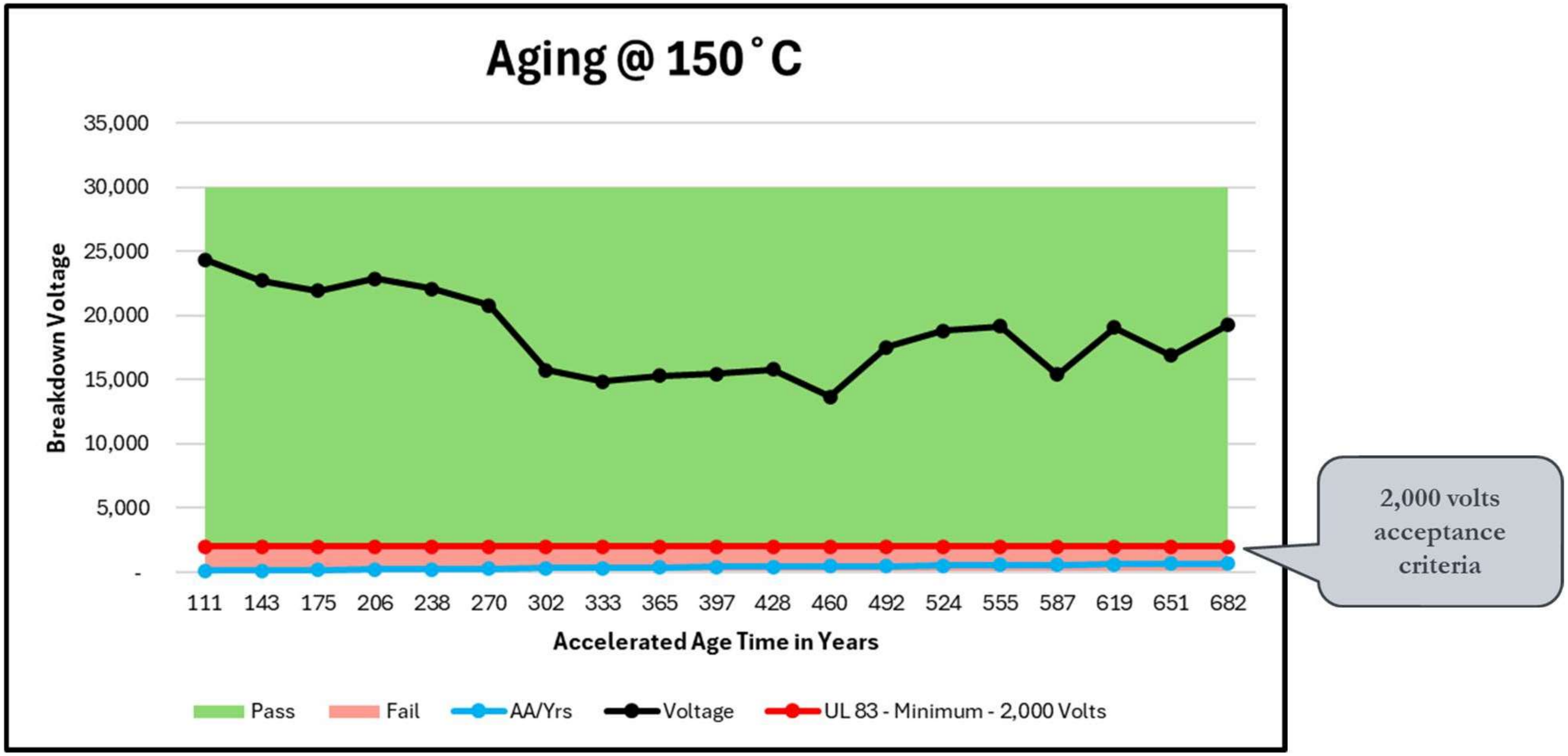
Objectives

1. **Determine the effects of accelerated aging on the dielectric properties of 90°C rated THHN insulation (components of NM Cable).**
2. **Gain knowledge about the service life of THHN insulation.**
3. **Understand the effects of heating on THHN conductors at temperatures of 90°C, 125°C, and 150°C.**
4. **Compare the aged samples to control samples that were unaged and held within ambient lab temperatures.**

Acceptance Criteria Established of 2,000 Volts



Estimated Performance Life of THHN Insulation



Note: Accelerated Aging is calculated via the Arrhenius Equation (see Appendix A).

Conclusions

1. Conductors aged at 90˚C showed negligible degradation of insulation dielectric properties when compared to the control samples. (Control samples remained at lab average ambient of 21.4˚C for the duration of testing).
2. Insulated conductors perform well above UL 83 withstand minimum of 2,000 volts while showing little degradation of breakdown voltage after accelerated aging @ 150˚C over 43 days.
3. Even at the extreme condition of 150˚C for 43 days, the insulation dielectric properties of the test conductors never fell below the 2,000-volt UL 83 withstand requirements – zero samples failed. (The lowest recorded breakdown result was 13,825 volts.).
4. Based upon the data in this report, the Arrhenius Equation predicts a service life of the THHN insulation of 682 years.
5. In terms of heat aging of THHN conductors, the results of this testing are consistent with the report published on November 16, 2012, from Underwriters Laboratories (UL), "Influence of Damage and Degradation on Breakdown Voltage of NM Cables" authored by Fan He, PhD, and Paul W. Brazis Jr., PhD. The UL test program also subjected the THHN of test NM-B cables to 150˚C temperatures, but only for a period of 15 days.

Appendix A

Calculating Aging Duration

In general, the Arrhenius Equation is basis for calculating aging duration. While the details of activation energy that equation can be discussed, those details are not necessary for the majority of people. So, the equation below is how we typically calculated accelerated aging durations.

$$Accelerated\ Aging\ Duration = \frac{Real\ Time\ Duration}{Q_{10}^{\frac{T_{AA}-T_S}{10}}}$$

where:

- T_{AA} is the accelerated aging temperature
- T_S is the standard temperature
- Q_{10} is the aging rate per 10°C.

Constants used in calculations for this project:

1. Q_{10} - aging rate = 2
2. T_S - standard temp = 25°C
3. T_{AA} – Aging Oven Temp setting (90°C, 125°C, 150°C)

Accelerated Aging is calculated via the Arrhenius Equation by multiple industries such as Wire & Cable, Medical, Food, and the National Regulatory Commission (NRC). ASTM F1980 provides guidance for accelerated aging.

References:

1. https://rationalengineering.blogspot.com/2014/08/accelerated-aging-of-medical-devices.html
2. https://keystonepackage.com/accelerated-aging-calculator/
3. https://ebi.bio/accelerated-aging/

Appendix B

Equipment List

Description	Make	Gage ID	Cal due
Hipot 955i	Vitrek	37408	12/25/2024
Hipot AC-30	Vitrek	37409	12/25/2024
Oven 90	Cascade TEK	QL-06010622	5/20/2025
Oven 125	Cascade TEK	QL-06010722	5/20/2025
Oven 150	Cascade TEK	QL-06010822	5/20/2025
Time/Temp/RH	Traceable	QL-221731943	5/20/2025

Appendix B continued

VITREK

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ACCREDITED CALIBRATION LABORATORY

Certificate of Calibration

Manufacturer:	Vitrek Corporation	**Cal. And Issue Date:**	6/28/2024
Description:	Electrical Safety Tester	**Cal. Due Date:**	
Model No.:	955i	**Report No.:**	98033C26
Serial No.:	037408	**Procedure No.:**	950PW-011011
Temperature:	23 ± 5 °C	**Incoming Status:**	N/A (New/Repair Unit)
Humidity:	50 ± 30% RH	**Outgoing Status:**	In Tolerance
Report Prepared For:		**Options Installed:**	

Copperweld Bimetallics LLC
254 Cotton Mill Rd
Fayetteville,TN 37334

Standards Used	Serial Number	Cal Date	Cal Due	Traceability No.
Vitrek 4700 Precision HV Meter	017893	08/04/23	08/04/24	9951832E
Fluke 8808A Multimeter	1187007	10/14/20	10/14/24	551220083877939
Vitrek 50 mOhm Resistance Std.	017109	10/20/23	10/20/24	99B6BC7D
Vitrek SR502 Low Resistance Std.	015788	10/20/23	10/20/24	99B6B9D6
ESI RS925C Resistance Std.	920004	10/20/23	10/20/24	99B680D8

Vitrek, LLC certifies that the referenced instrument listed above by model number and serial number was tested and calibrated in compliance with ISO17025:2017 and ANSI/NCSL Z540-1-1994. The standards used are traceable to the International System of Units (SI) via national metrology institutes (e.g. NIST, NRC, etc.) within the limitations of their own respective calibration service, or have been derived from accepted values of natural physical constants, or by the ratio of transfer self-calibration techniques. No limitations of use apply to the calibrated unit unless otherwise specified.

Where applicable the expanded uncertainty of measurement at the time of test is given in the following pages.They are calculated in accordance with the method described in the ISO Guide to the expression of Uncertainty in Measurement (GUM). Unless otherwise indicated, the reported uncertainty ofmeasurement is stated as the standard uncertainty of measurement multiplied by the coverage factor of k (k=2). This represents a coverageprobability of approximately 95% for a normal distribution. Uncertainties stated with units of parts per million (ppm) are given in fundamental units.

The test limits stated in the report correspond to the published manufacturer's specifications of the equipment, at the points tested.

Technician: R. Owen Workstation: 2

Comments:

Calibration results relate only to above referenced serial number. Technician certifies that the standards reflected on this data sheet are the standards used for calibration.

R. Owen, Technician

Auditor

This Certificate shall not be reproduced, except in full, without the written approval of Vitrek, LLC

Page: 1 of 2

VITREK

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Report #: 98033C26
Model #: 955i
Serial #: 37408

Outgoing Measurement Results

DC Output (Unloaded)

NOMINAL OUTPUT LEVEL	MEASURED	DIFFERENCE	TOLERANCE	UNCERTAINTY	STATUS
10000 V	9996 V	4 V	26 V	360 ppm	PASS
6000 V	5999 V	1 V	16 V	360 ppm	PASS
4000 V	4000 V	0 V	11 V	360 ppm	PASS
1900 V	1899.8 V	0.2 V	5.3 V	370 ppm	PASS
1000 V	999.9 V	0.1 V	3.0 V	380 ppm	PASS
500 V	499.9 V	0.1 V	1.75 V	420 ppm	PASS
100 V	100.0 V	0.0 V	0.8 V	690 ppm	PASS

DC Current

NOMINAL INPUT LEVEL	MEASURED	DIFFERENCE	TOLERANCE	UNCERTAINTY	STATUS
100 mA (no output)	99.99 mA	0.01 mA	0.3 mA	450 ppm	PASS
10 mA (no output)	10.00 mA	0.00 mA	0.03 mA	710 ppm	PASS
1 mA (no output)	1.0000 mA	0.0000 mA	0.003 mA	300 ppm	PASS
100 µA (no output)	100.00 µA	0.00 µA	0.3 µA	430 ppm	PASS
0 nA (no output)	0.1 nA	0.1 nA	0.5 nA	N/A ppm	PASS
0 nA (5000V output)	0.1 nA	0.1 nA	0.5 nA	N/A ppm	PASS

AC Output (Unloaded)

NOMINAL OUTPUT LEVEL	MEASURED	DIFFERENCE	TOLERANCE	UNCERTAINTY	STATUS
10000 V @60Hz	9999 V	1 V	62 V	1400 ppm	PASS
6000 V @60Hz	6000 V	0 V	32 V	1400 ppm	PASS
1900 V @60Hz	1900.0 V	0.0 V	11.0 V	1500 ppm	PASS
1000 V @60Hz	1000.2 V	0.2 V	6.5 V	1500 ppm	PASS
1000 V @400Hz	1003.4 V	3.4 V	36.5 V	4700 ppm	PASS
300 V @60Hz	300.0 V	0.0 V	3.0 V	1800 ppm	PASS
100 V @60Hz	100.0 V	0.0 V	2.0 V	2500 ppm	PASS

AC Current

NOMINAL INPUT LEVEL	MEASURED	DIFFERENCE	TOLERANCE	UNCERTAINTY	STATUS
0 nArms (100V 60Hz output)	0.0 nA	0.0 nA	10 nA	N/A ppm	PASS
0 nArms (2000V 60Hz output)	6.8 nA	6.8 nA	28 nA	N/A ppm	PASS
0 nAinphs (2000V 60Hz output)	6.5 nA	6.5 nA	11.2 nA	N/A ppm	PASS
0 nArms (5000V 60Hz output)	19.0 nA	19.0 nA	55 nA	N/A ppm	PASS
0 nArms (9000V 60Hz output)	41.0 nA	41.0 nA	141 nA	N/A ppm	PASS

Lo Ohms (4-Wire)

NOMINAL INPUT LEVEL	MEASURED	DIFFERENCE	TOLERANCE	UNCERTAINTY	STATUS
100 kΩ	99.8 kΩ	0.2 kΩ	1.5 kΩ	87 ppm	PASS
10 kΩ	10.000 kΩ	0.000 kΩ	0.08 kΩ	270 ppm	PASS
100 Ω	100.0 Ω	0.0 Ω	0.8 Ω	36 ppm	PASS
1 Ω	998.4 mΩ	1.6 mΩ	10 mΩ	1000 ppm	PASS
0 Ω	0.1 mΩ	0.1 mΩ	2 mΩ	N/A ppm	PASS

Lo Ohms (2-Wire)

NOMINAL INPUT LEVEL	MEASURED	DIFFERENCE	TOLERANCE	UNCERTAINTY	STATUS
0 Ω	4.0 mΩ	4.0 mΩ	20 mΩ	N/A ppm	PASS

* : Indicates possibility of falling within or outside of the specified limits due to the measurement uncertainty.

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Appendix B continued

VITREK

Vitrek, LLC
12169 Kirkham Road
Poway, CA 92064
Voice: 858 689 2755 • Fax: 858 689 2760
Web: www.vitrek.com • E-mail: info@vitrek.com

ACCREDITED CALIBRATION LABORATORY CERT# 3878.01

Certificate of Calibration

Manufacturer:	Vitrek Corporation	**Cal. And Issue Date:**	6/28/2024
Description:	Electrical Safety Tester	**Cal. Due Date:**	
Model No.:	AC-30	**Report No.:**	980340D7
Serial No.:	037409	**Procedure No.:**	AC30-PW-0610
Temperature:	23 ± 5 °C	**Incoming Status:**	N/A (New/Repair Unit)
Humidity:	50 ± 30% RH	**Outgoing Status:**	In Tolerance
Report Prepared For:		**Options Installed:**	

Copperweld Bimetallics LLC
254 Cotton Mill Rd
Fayetteville, TN 37334

Standards Used	Serial Number	Cal Date	Cal Due	Traceability No.
Vitrek 4700 Precision HV Meter	017893	08/04/23	08/04/24	9951832E
Fluke 8808A Multimeter	1187007	10/14/20	10/14/24	551220083877939
Vitrek HVL-70 HV Probe	27626	08/04/23	08/04/24	99518908

Vitrek, LLC certifies that the referenced instrument listed above by model number and serial number was tested and calibrated in compliance with ISO17025:2017 and ANSI/NCSL Z540-1-1994. The standards used are traceable to the International System of Units (SI) via national metrology institutes (e.g. NIST, NRC, etc.) within the limitations of their own respective calibration service, or have been derived from accepted values of natural physical constants, or by the ratio of transfer self-calibration techniques. No limitations of use apply to the calibrated unit unless otherwise specified.

Where applicable the expanded uncertainty of measurement at the time of test is given in the following pages.They are calculated in accordance with the method described in the ISO Guide to the expression of Uncertainty in Measurement (GUM). Unless otherwise indicated, the reported uncertainty ofmeasurement is stated as the standard uncertainty of measurement multiplied by the coverage factor of k (k=2). This represents a coverageprobability of approximately 95% for a normal distribution. Uncertainties stated with units of parts per million (ppm) are given in fundamental units.

The test limits stated in the report correspond to the published manufacturer's specifications of the equipment, at the points tested.

Technician: R. Owen Workstation: 2

Calibration results relate only to above referenced serial number. Technician certifies that the standards reflected on this data sheet are the standards used for calibration.

Comments:

R. Owen, Technician

Auditor

VITREK

Vitrek Corporation
12169 Kirkham Road
Poway, CA 92064
Voice: 858 689 2755 • Fax: 858 689 2760 • www.vitrek.com

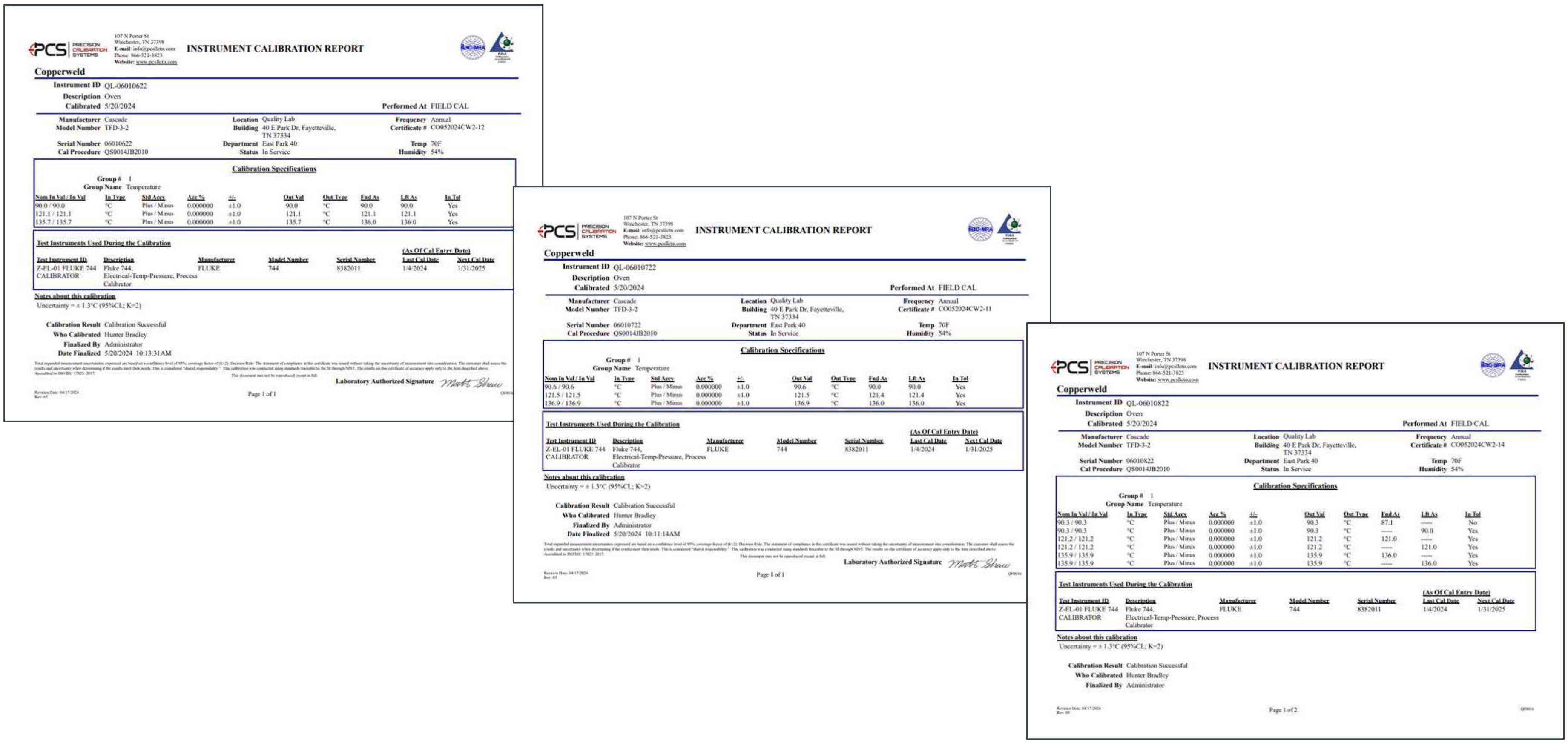
Report #: 980340D7
Model #: AC-30
Serial #: 37409

Outgoing Measurement Results

Driver Source:	Model:	955i	Serial Number:	37408

AC Output					
NOMINAL OUTPUT LEVEL	MEASURED	DIFFERENCE	TOLERANCE	UNCERTAINTY	STATUS
10000 V @50Hz	10016 V	16 V	155 V	1239 ppm	PASS
20000 V @50Hz	20038 V	38 V	305 V	1286 ppm	PASS
30000 V @50Hz	30083 V	83 V	455 V	1348 ppm	PASS
10000 V @60Hz	10012 V	12 V	155 V	1239 ppm	PASS
20000 V @60Hz	20028 V	28 V	305 V	1286 ppm	PASS
30000 V @60Hz	30055 V	55 V	455 V	1348 ppm	PASS

Appendix B continued



INSTRUMENT CALIBRATION REPORT

PCS Precision Calibration Systems
107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

Copperweld

Instrument ID QL-06010622
Description Oven
Calibrated 5/20/2024
Performed At FIELD CAL

Manufacturer Cascade
Model Number TFD-3-2
Serial Number 06010622
Cal Procedure QS0014JB2010
Location Quality Lab
Building 40 E Park Dr, Fayetteville, TN 37334
Department East Park 40
Status In Service
Frequency Annual
Certificate # CO052024CW2-12
Temp 70F
Humidity 54%

Calibration Specifications

Group # 1
Group Name Temperature

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
90.0 / 90.0	°C	Plus / Minus	0.000000	±1.0	90.0	°C	90.0	90.0	Yes
121.1 / 121.1	°C	Plus / Minus	0.000000	±1.0	121.1	°C	121.1	121.1	Yes
135.7 / 135.7	°C	Plus / Minus	0.000000	±1.0	135.7	°C	136.0	136.0	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	Last Cal Date	Next Cal Date
Z-EL-01 FLUKE 744 CALIBRATOR	Fluke 744, Electrical-Temp-Pressure, Process Calibrator	FLUKE	744	8382011	1/4/2024	1/31/2025

(As Of Cal Entry Date)

Notes about this calibration
Uncertainty = ± 1.3°C (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated Hunter Bradley
Finalized By Administrator
Date Finalized 5/20/2024 10:13:31AM

Laboratory Authorized Signature

Page 1 of 1

INSTRUMENT CALIBRATION REPORT

PCS Precision Calibration Systems
107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

Copperweld

Instrument ID QL-06010722
Description Oven
Calibrated 5/20/2024
Performed At FIELD CAL

Manufacturer Cascade
Model Number TFD-3-2
Serial Number 06010722
Cal Procedure QS0014JB2010
Location Quality Lab
Building 40 E Park Dr, Fayetteville, TN 37334
Department East Park 40
Status In Service
Frequency Annual
Certificate # CO052024CW2-11
Temp 70F
Humidity 54%

Calibration Specifications

Group # 1
Group Name Temperature

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
90.6 / 90.6	°C	Plus / Minus	0.000000	±1.0	90.6	°C	90.0	90.0	Yes
121.5 / 121.5	°C	Plus / Minus	0.000000	±1.0	121.5	°C	121.4	121.4	Yes
136.9 / 136.9	°C	Plus / Minus	0.000000	±1.0	136.9	°C	136.0	136.0	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	Last Cal Date	Next Cal Date
Z-EL-01 FLUKE 744 CALIBRATOR	Fluke 744, Electrical-Temp-Pressure, Process Calibrator	FLUKE	744	8382011	1/4/2024	1/31/2025

(As Of Cal Entry Date)

Notes about this calibration
Uncertainty = ± 1.3°C (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated Hunter Bradley
Finalized By Administrator
Date Finalized 5/20/2024 10:11:14AM

Laboratory Authorized Signature

Page 1 of 1

INSTRUMENT CALIBRATION REPORT

PCS Precision Calibration Systems
107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

Copperweld

Instrument ID QL-06010822
Description Oven
Calibrated 5/20/2024
Performed At FIELD CAL

Manufacturer Cascade
Model Number TFD-3-2
Serial Number 06010822
Cal Procedure QS0014JB2010
Location Quality Lab
Building 40 E Park Dr, Fayetteville, TN 37334
Department East Park 40
Status In Service
Frequency Annual
Certificate # CO052024CW2-14
Temp 70F
Humidity 54%

Calibration Specifications

Group # 1
Group Name Temperature

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
90.3 / 90.3	°C	Plus / Minus	0.000000	±1.0	90.3	°C	87.1	-----	No
90.3 / 90.3	°C	Plus / Minus	0.000000	±1.0	90.3	°C	-----	90.0	Yes
121.2 / 121.2	°C	Plus / Minus	0.000000	±1.0	121.2	°C	121.0	-----	Yes
121.2 / 121.2	°C	Plus / Minus	0.000000	±1.0	121.2	°C	-----	121.0	Yes
135.9 / 135.9	°C	Plus / Minus	0.000000	±1.0	135.9	°C	136.0	-----	Yes
135.9 / 135.9	°C	Plus / Minus	0.000000	±1.0	135.9	°C	-----	136.0	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	Last Cal Date	Next Cal Date
Z-EL-01 FLUKE 744 CALIBRATOR	Fluke 744, Electrical-Temp-Pressure, Process Calibrator	FLUKE	744	8382011	1/4/2024	1/31/2025

(As Of Cal Entry Date)

Notes about this calibration
Uncertainty = ± 1.3°C (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated Hunter Bradley
Finalized By Administrator

Page 1 of 2

Appendix B continued

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 QL-221731943
Description Traceable Temp/Humidity
Calibrated 5/20/2024
Performed At FIELD CAL

Manufacturer Traceable
Model Number NA
Serial Number NA
Cal Procedure QS0043JT2015
Location Quality Lab
Building 40 E Park Dr, Fayetteville, TN 37334
Department Quality
Status In Service
Frequency Annual
Certificate # CO052024CW2-20
Temp 70F
Humidity 50%

Calibration Specifications

Group # 1
Group Name Temperature

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
20.35 / 20.35	°C	Plus / Minus	0.000000	±2.0	20.4	°C	20.0	20.0	Yes

Group # 2
Group Name Humidity

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
49.89 / 49.89	%	Pct of Reading	4.000000	0.0	49.9	%	51.0	51.0	Yes

Group # 3
Group Name Time

Nom In Val / In Val	In Type	Std Accy	Acc %	+/-	Out Val	Out Type	Fnd As	Lft As	In Tol
1 / 1	min	Pct of Reading	0.100000	0.00	1.00	min	1.00	1.00	Yes
30 / 30	min	Pct of Reading	0.100000	0.00	30.00	min	30.00	30.00	Yes

Test Instruments Used During the Calibration

Test Instrument ID	Description	Manufacturer	Model Number	Serial Number	(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-ST-007 STOPWATCH	Stopwatch	Control Company	8788T52	221625050	6/30/2022	6/30/2024
Z-TE-038 THERMOHYGROMETER	Vaisala HM40 Temperature & Humidity Meter	Vaisala	HM40	P3640184 w/ P3420005 Probe	11/22/2023	11/30/2024

Revision Date: 04/17/2024
Rev: 05

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PCS PRECISION CALIBRATION SYSTEMS

107 N Porter St
Winchester, TN 37398
E-mail: info@pcsllctn.com
Phone: 866-521-3823
Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

Copperweld

Instrument ID QL-221731943
Description Traceable Temp/Humidity
Calibrated 5/20/2024
Performed At FIELD CAL

Notes about this calibration

Humidity Uncertainty = ± 1.79% RH (95%CL; K=2)
Temperature Uncertainty = ± 0.15°C (95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated Connor Whetzel
Finalized By Administrator
Date Finalized 5/20/2024 11:46:18AM

Total expanded measurement uncertainties expressed are based on a confidence level of 95%; coverage factor of (k=2). Decision Rule: The statement of compliance in this certificate was issued without taking the uncertainty of measurement into consideration. The customer shall assess the results and uncertainty when determining if the results meet their needs. This is considered "shared responsibility." This calibration was conducted using standards traceable to the SI through NIST. The results on this certificate of accuracy apply only to the item described above. Accredited to ISO/IEC 17025: 2017.

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Laboratory Authorized Signature Matt Shaw

Revision Date: 04/17/2024
Rev: 05

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QF0016

Appendix C (Non-Aging/Control Sample)

			No Aging/Control Sample Brkdwn Voltage									
Date		Day	Sample 1	Sample 2	Sample 3	Average	Oven Temp(˚C)	Lab Temp(˚C)	Lab RH	Hrs	Start 15m Dwell	Test Time
7/2/24	Tues	0										
7/9/24	Tues	7	24,280	25,657	23,512	24,483	N/A	22	50%	168	N/A	9:17
7/11/24	Thur	9	24,672	23,257	23,933	23,954	N/A	20.5	47%	216	N/A	9:12
7/13/24	Sat	11	23,813	24,750	25,202	24,588	N/A	20.5	48%	264	N/A	9:05
7/15/24	Mon	13	26,818	25,480	25,035	25,778	N/A	22	48%	312	N/A	9:10
7/17/24	Wed	15	22,620	20,679	21,391	21,563	N/A	22	50%	360	N/A	9:12
7/19/24	Fri	17	23,442	23,082	21,665	22,730	N/A	22	48%	408	N/A	9:09
7/21/24	Sun	19	22,686	22,715	21,608	22,336	N/A	20	50%	456	N/A	9:05
7/23/24	Tues	21	22,460	21,993	22,387	22,280	N/A	21.5	52%	504	N/A	9:19
7/25/24	Thur	23	23,001	23,631	23,835	23,489	N/A	20	48%	552	N/A	9:09
7/27/24	Sat	25	21,464	25,411	22,007	22,961	N/A	20	48%	600	N/A	9:14
7/29/24	Mon	27	22,687	21,729	23,646	22,687	N/A	22	46%	648	N/A	9:18
7/31/24	Wed	29	24,006	22,851	23,543	23,467	N/A	20	48%	696	N/A	8:48
8/2/24	Fri	31	22,541	23,399	21,948	22,629	N/A	20	48%	744	N/A	9:21
8/4/24	Sun	33	21,908	23,927	21,208	22,348	N/A	20.5	52%	792	N/A	9:21
8/6/24	Tues	35	23,561	21,901	22,680	22,714	N/A	20.5	48%	840	N/A	9:18
8/8/24	Thur	37	24,999	24,386	22,659	24,015	N/A	22	50%	888	N/A	9:12
8/10/24	Sat	39	22,348	23,352	23,121	22,940	N/A	22	49%	936	N/A	9:02
8/12/24	Mon	41	22,694	24,005	25,248	23,982	N/A	22	51%	984	N/A	9:02
8/14/24	Wed	43	22,359	22,685	21,558	22,201	N/A	22	49%	1032	N/A	9:02

Appendix C (90˚C Samples)

			90˚C / Dielectric Breakdown Voltage									
		Day	Sample 1	Sample 2	Sample 3	Average	Oven Temp(˚C)	Lab Temp(˚C)	Lab RH	Oven Hrs	Start 15m Dwell	Test Time
7/2/2024	Tues	0					90	21	50%	0	N/A	9:10
7/9/24	Tues	7	30,000	26,840	29,382	28,741	90	22	50%	168	9:43	9:47
7/11/24	Thur	9	23,510	22,548	23,170	23,076	90	20.5	47%	216	9:16	9:45
7/13/24	Sat	11	24,126	24,134	23,023	23,761	90	20.5	48%	264	9:02	9:17
7/15/24	Mon	13	26,656	26,719	24,703	26,026	90	22	48%	312	9:03	9:18
7/17/24	Wed	15	19,875	20,850	20,568	20,431	90	22	50%	360	9:10	9:25
7/19/24	Fri	17	24,945	24,462	23,403	24,270	90	22	48%	408	9:07	9:26
7/21/24	Sun	19	21,353	22,112	22,753	22,073	90	20	50%	456	N/A	9:15
7/23/24	Tues	21	25,326	25,340	23,555	24,740	90	21.5	52%	504	N/A	9:45
7/25/24	Thur	23	21,310	23,806	23,218	22,778	90	21.5	49%	552	N/A	11:25
7/27/24	Sat	25	23,833	25,839	23,237	24,303	90	21.5	49%	600	N/A	11:38
7/29/24	Mon	27	22,627	22,684	20,176	21,829	90	22	46%	648	N/A	4:27
7/31/24	Wed	29	24,049	24,131	23,461	23,880	90	22	46%	696	N/A	4:43
8/2/24	Fri	31	19,342	23,435	23,381	22,053	90	20	48%	744	N/A	8:51
8/4/24	Sun	33	22,380	23,122	24,798	23,433	90	20.5	52%	792	9:07	9:25
8/6/24	Tues	35	24,041	24,622	24,061	24,241	90	21	48%	840	9:06	9:30
8/8/24	Thur	37	21,666	23,769	24,437	23,291	90	22	50%	888	9:02	9:20
8/10/24	Sat	39	23,245	22,788	23,683	23,239	90	22	49%	936	9:00	9:15
8/12/24	Mon	41	21,731	22,657	25,311	23,233	90	22	51%	984	9:01	9:16
8/14/24	Wed	43	23,942	23,956	22,066	23,321	90	22	49%	1032	9:01	9:16

Appendix C (125˚C Samples)

			125˚C / Dielectric Breakdown Voltage									
		Day	Sample 1	Sample 2	Sample 3	Average	Oven Temp(˚C)	Lab Temp(˚C)	Lab RH	Oven Hrs	Start 15m Dwell	Test Time
7/2/2024	Tues	0					125	21	50%	0	N/A	9:14
7/9/24	Tues	7	24,942	27,054	24,403	25,466	125	22	50%	168	9:43	10:13
7/11/24	Thur	9	22,299	24,136	21,760	22,732	125	20.5	47%	216	9:16	9:35
7/13/24	Sat	11	23,790	25,424	25,267	24,827	125	20.5	48%	264	9:02	9:20
7/15/24	Mon	13	25,237	23,228	22,121	23,529	125	22	48%	312	9:03	9:23
7/17/24	Wed	15	22,925	22,496	22,526	22,649	125	22	50%	360	9:10	9:30
7/19/24	Fri	17	21,391	22,591	23,327	22,436	125	22	48%	408	9:07	9:32
7/21/24	Sun	19	22,156	21,744	21,787	21,896	125	20	50%	456	8:59	9:20
7/23/24	Tues	21	20,606	21,477	19,667	20,583	125	21.5	52%	504	N/A	9:50
7/25/24	Thur	23	19,524	21,093	20,534	20,384	125	21.5	49%	552	N/A	11:28
7/27/24	Sat	25	11,315	20,366	20,202	17,294	125	21.5	49%	600	N/A	11:42
7/29/24	Mon	27	21,648	20,550	21,262	21,153	125	22	46%	648	N/A	16:32
7/31/24	Wed	29	21,970	21,235	21,933	21,713	125	22	46%	696	N/A	4:47
8/2/24	Fri	31	22,432	22,138	21,688	22,086	125	20	48%	744	N/A	8:56
8/4/24	Sun	33	24,216	20,213	22,394	22,274	125	20.5	52%	792	9:07	9:31
8/6/24	Tues	35	23,164	23,842	23,713	23,573	125	21	48%	840	9:06	9:35
8/8/24	Thur	37	24,045	25,827	23,053	24,308	125	22	50%	888	9:02	9:25
8/10/24	Sat	39	24,345	23,518	23,478	23,780	125	22	49%	936	9:00	9:20
8/12/24	Mon	41	22,640	22,754	24,499	23,298	125	22	51%	984	9:01	9:20
8/14/24	Wed	43	24,015	24,912	24,529	24,485	125	22	49%	1032	9:01	9:19

Appendix C (150˚C Samples)

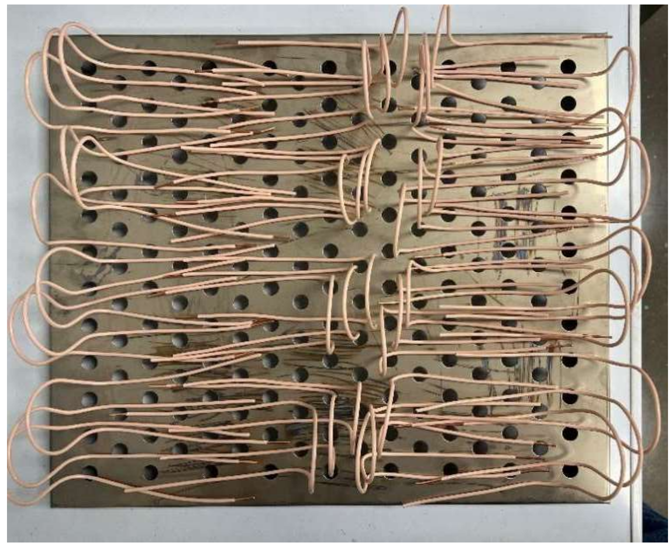
			150˚C / Dielectric Breakdown Voltage									
		Day	Sample 1	Sample 2	Sample 3	Average	Oven Temp(˚C)	Lab Temp(˚C)	Lab RH	Oven Hrs	Start 15m Dwell	Test Time
7/2/2024	Tues	0					150	21	50%	0	N/A	9:21
7/9/24	Tues	7	23,804	24,067	25,214	24,362	150	22	50%	168	9:43	10:21
7/11/24	Thur	9	21,845	22,763	23,551	22,720	150	20.5	47%	216	9:16	9:32
7/13/24	Sat	11	23,029	22,806	20,000	21,945	150	20.5	48%	264	9:02	9:23
7/15/24	Mon	13	23,115	23,157	22,377	22,883	150	22	48%	312	9:03	9:28
7/17/24	Wed	15	22,956	21,179	22,125	22,087	150	22	50%	360	9:10	9:36
7/19/24	Fri	17	21,051	20,480	20,941	20,824	150	22	48%	408	9:07	9:37
7/21/24	Sun	19	15,799	15,929	15,587	15,772	150	20	50%	456	N/A	9:30
7/23/24	Tues	21	15,056	14,706	14,800	14,854	150	21.5	52%	504	N/A	9:56
7/25/24	Thur	23	15,647	14,480	15,878	15,335	150	21.5	49%	552	N/A	11:33
7/27/24	Sat	25	15,994	14,518	15,829	15,447	150	21.5	49%	600	N/A	11:47
7/29/24	Mon	27	15,948	15,422	16,108	15,826	150	22	46%	648	N/A	4:37
7/31/24	Wed	29	13,825	13,218	14,031	13,691	150	22	46%	696	N/A	4:52
8/2/24	Fri	31	17,344	18,674	16,580	17,533	150	20	48%	744	N/A	9:04
8/4/24	Sun	33	16,411	19,987	20,066	18,821	150	20.5	52%	792	9:07	9:36
8/6/24	Tues	35	19,490	18,766	19,318	19,191	150	21	48%	840	9:06	9:40
8/8/24	Thur	37	14,117	16,456	15,655	15,409	150	22	50%	888	9:02	9:34
8/10/24	Sat	39	17,870	19,708	19,627	19,068	150	22	49%	936	9:00	9:25
8/12/24	Mon	41	16,553	18,701	15,462	16,905	150	22	51%	984	9:01	9:27
8/14/24	Wed	43	18,891	18,854	20,122	19,289	150	22	49%	1032	9:01	9:24

Appendix D

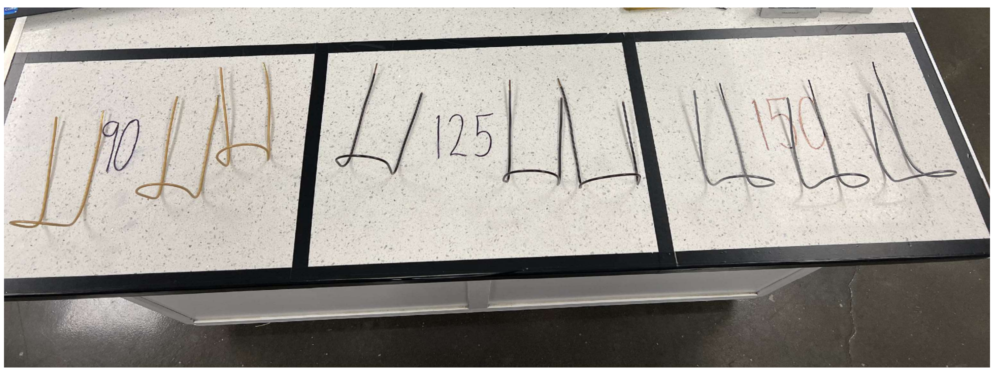
Test Plan Detail (per UL 2556 section 6.3 Dielectric Breakdown) by Step:

1. Obtain sample material of enough quantity to complete testing. Approximately (500) feet.
2. Cut sample lengths of (18) inches.
3. Bend around mandrel (180) degrees at mid length.
4. Bend (90) degrees, approximately (2) inches from sample end with radius.
5. Strip 1/2 inch of insulation from one terminal end of sample.
6. Remove oven shelf from oven and load samples such to prevent/minimize any touching of samples.
7. Preheat oven to temperature.
8. Load samples/shelf into oven and record: begin time, oven temp, lab temp, age hours, relative humidity, and test time.
9. Complete initial (7) day period of aging before testing of samples begins.
10. Complete steps 11-21 every two days until reaching 43 days.
11. Select (3) samples from lab control group and record: begin time, oven temp, lab temp, age hours, relative humidity, and test time.
12. Remove (3) samples from each oven and record: begin time, oven temp, lab temp, age hours, relative humidity, and test time.
13. Complete the 15-minute dwell/normalize time prior to insulation breakdown testing using Hipot equipment.
14. Place sample in water keeping terminated ends well above the water level (soak ~ 1min total with test).
15. Connect the Hipot lead to the terminated end of the sample suspending in the water per Step 12 above.
16. Connect the other Hipot lead to the bare wire in water container.
17. Conduct the Hipot test elevating voltage at 500v/sec until failure occurs.
18. Record voltage level at current fault and/or breakdown.
19. Repeat Step 16 for all three samples from oven.
20. Record Average of the three samples.
21. Repeat the above steps for all three ovens/temperatures (9 samples/day).
22. Empty water container, rinse, and refill to (3) inch level for next day testing.

Appendix E



Appendix E (continued)



Appendix F

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Testing Site Acceptance

SATELLITE™

Be an insider outside of our lab.

The following organization has been assessed and found to comply with the relevant requirements of ISO/IEC 17025 and the Intertek Global Satellite Program Manual and accepted by Intertek as a Level 3

Recognized SATELLITE™ Laboratory

for Test Data Acceptance through the Utilization of Customer Test Facilities (CTF Stage 3) for the ETL mark and is authorized to perform test work for the product types identified on the endorsement to this Testing Site Acceptance.

Intertek Satellite Program
Our data acceptance testing program allows a qualified client to perform product testing at their site, with the same validity as if it were conducted in an Intertek laboratory. By combining their existing testing resources with Intertek's global recognition, our clients can reduce their costs and time-to-market while verifying the accuracy of their test results.

Organization:

Copperweld Bimetallics, LLC
40 East Park Drive
Fayetteville, TN 37334 USA

Acceptance Number	L3-US-3482
Issue Number	00003
Issue Date	9 August 2023
Expiration Date	9 September 2024

The Testing Site Acceptance is comprised of this front sheet and 1 endorsement.

Intertek Testing Services NA, Inc., 3933 US Rt 11, Cortland NY 13045

Page 1 of 3

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Testing Site Acceptance

SATELLITE™

Be an insider outside of our lab.

Endorsement to Acceptance No: L3-US-3482
The details below define the conditions applicable to the Testing Site Acceptance granted to the Laboratory. The acceptance is subject to the laboratory's continuing compliance with the applicable rules according to Intertek's SATELLITE™ Laboratory Program.

Scope of Acceptance:

Standards :

Standard	Description	Date & Edition
UL 83	Thermoplastic-Insulated Wires and Cables	16th Ed., rev Apr 10, 2020
UL 719	Nonmetallic-Sheathed Cables	13th Ed., rev Jan 12, 2023
UL 1569	Metal-Clad Cables	5th Ed., Dated May 4, 2018
UL 493	Thermoplastic-Insulated Underground Feeder and Branch-Circuit Cables	10th Ed., rev Nov 7, 2023

Intertek Testing Services NA, Inc., 3933 US Rt 11, Cortland NY 13045

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Testing Site Acceptance

SATELLITE™

Be an insider outside of our lab.

Conditions applicable to the Acceptance:
Refer to annex agreement

The Testing Site Acceptance is comprised of the front sheet and 1 endorsement.

Signature:
Name: James Diescher
Title: Satellite Technical Lead

Intertek Testing Services NA, Inc., 3933 US Rt 11, Cortland NY 13045

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Appendix G (Intertek Validation of Data Report)

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COPPERWELD BIMETALLICS LLC
LETTER REPORT

SCOPE OF WORK
EXPEDITE - Performance Test plan review (not for certification) and report - Copperweld Satellite lab

REPORT NUMBER
105875569CRT-001b

ISSUE DATE
19-Aug-2024

REVISED DATE
21-Aug-2024

PAGES
4+Appendix

DOCUMENT CONTROL NUMBER
GFT-OP-10a (21-June-2019)

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2933 US Rt. 11
Cortland NY 13045

Telephone: 607-758-6613
www.intertek.com

LETTER REPORT

19-Aug-2024

Intertek Report No. 105875569CRT-001b
Intertek Project No. G105875569

Chad Smith
Copperweld Bimetallics, LLC
254 Cotton Mill Road
Fayetteville, TN 37334
csmith@copperweld.com

Ph: (325) 430-9669

Subject: Performance Test report of non-standard client specific Dielectric Breakdown tests after aging on 12 AWG CCA THHN insulated conductors.

Dear Mr. Smith,

This letter report represents the results of our evaluation of the above referenced product(s) to the requirements contained in the following standards:

Non-standard Dielectric Breakdown Tests

SECTION 1
SUMMARY

This investigation was authorized by signed proposal number Qu-01463261, dated 25-Jun-2024.
The test was conducted at Copperweld Bimetallics. The test plan, Test equipment and Test results have all been approved and reviewed by Intertek.

Revision History

21-Aug-24 Revised test description to Dielectric Breakdown test

SECTION 2
NON-CONFORMANCES

NA

SECTION 3
CRITICAL COMPONENTS & MATERIALS

The following critical components or materials have not been able to be identified as appropriately certified...

1. None

Appendix G (Intertek Validation of Data Report) continued

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Copperweld Bimetallics, LLC
Intertek Report: 105875569CRT-001b

LETTER REPORT

SECTION 4
TESTING

The below listed represents a summary of the tests & results, including any which are pending completion or have yet to be conducted.
Completed Tests:
Test Location:

Test Description	Standard	Section	Results
Dielectric Breakdown Unaged.	NA	NA	NA
Dielectric Breakdown aged at 90°C	NA	NA	NA
Dielectric Breakdown aged at 125°C	NA	NA	NA
Dielectric Breakdown aged at 150°C	NA	NA	NA

SECTION 5
PHOTOGRAPHS
Please see APPENDIX A of this report for Sample, Chamber and set up photos.

SECTION 6

PROJECT STATUS & ACTION

Issuance of this letter report completes the evaluation and reporting covered by Intertek Project No. G105875569.

IMPORTANT – CLIENT DECISION:

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact your dedicated Intertek Project Manager.

Completed by:	Matthew Morgan	Reviewed by:	Joshua O'Connor
Title:	Associate Engineer	Title:	Senior Project Engineer
Signature:	[signature]	Signature	[signature]
Date	8/21/2024	Date:	8/21/2024

Please note: this Letter Report does not represent authorization for the use of any Intertek certification marks.

Version: 21-June-2019 Page 3 of 4 GFT-OP-10a

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Copperweld Bimetallics, LLC
Intertek Report: 105875569CRT-001b

LETTER REPORT

APPENDIX A

Version: 21-June-2019 Page 4 of 4 GFT-OP-10a

Appendix G (Intertek Validation of Data Report) continued

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Document Version Date: 10/17/2023

Job Information					
Client:	Copperweld Bimetallics, LLC	**Engineer:**	Matthew Morgan	**Date:**	8/19/2024
Job Number:	G105875569	**Tested By:**	Chad Smith	**Date:**	8/19/2024
Quote:	Qu-01463261	**Tested By:**	Jared DeRight	**Date:**	8/19/2024
Product:	12 AWG CCA THHN	**Reviewer:**	Joshua O'Connor	**Date:**	
		Control Number:	FG2758934		
Standard:	Client Specific Dielectric Breakdown Aging R&D Comparison				
Insulation:	PVC	**Jacket:**	Nylon		

Test Samples		
Identification	**Markings/Model**	**Length or Qty**
A	12 AWG CCA White THHNN FG2758934 - Unaged Control	45 - 18" lengths
B	12 AWG CCA White THHNN FG2758934 - 90°C Conditioning	45 - 18" lengths
C	12 AWG CCA White THHNN FG2758934 - 125°C Conditioning	45 - 18" lengths
D	12 AWG CCA White THHNN FG2758934 - 150°C Conditioning	45 - 18" lengths

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Customer: G105875569
Project Number: Copperweld Bimetallics, LLC

Document Version Date: 10/17/2023

Test Summary				
Page	**Test Name**	**Clause**	**Completed Date**	**Pass/Fail**
8	Dielectric Breakdown Unaged	NA	8/14/2024	NA
10	Dielectric Breakdown aged at 90°C	NA	8/14/2024	NA
12	Dielectric Breakdown aged at 125°C	NA	8/14/2024	NA
14	Dielectric Breakdown aged at 150°C	NA	8/14/2024	NA

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Appendix G (Intertek Validation of Data Report) continued

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Customer: Copperweld Bimetallics, LLC
Project Number: G105875569

Document Version Date: 10/17/2023

Equipment			
Item	Description	Asset Tag	Cal. Due Date
1	Hipot 955i	37408	12/25/2024
2	Hipot AC-30	37409	12/25/2024
3	90°C Oven - Cascade TEK	QL-06010622	5/20/2025
4	125°C Oven - Cascade TEK	QL-06010722	5/20/2025
5	150°C Oven - Cascade TEK	QL-06010822	5/20/2025
6	Time/Temp/RH - Traceable	QL-221731943	5/20/2025

CBU - Calibrate Before Use
VBU - Verify Before Use
NA - Not Applicable

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Customer: Copperweld Bimetallics, LLC
Project Number: G105875569

Document Version Date: 10/17/2023

Sample Photo	
ID	
B, D & C Prepped Samples	

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Appendix G (Intertek Validation of Data Report) continued

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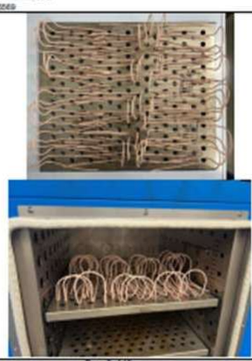
Customer: Copperweld Bimetallics, LLC 0
Project Number: G105875569

ID	
Oven setup	

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Customer: Copperweld Bimetallics, LLC 0
Project Number: G105875569

ID	
Ovens	

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Appendix G (Intertek Validation of Data Report) continued

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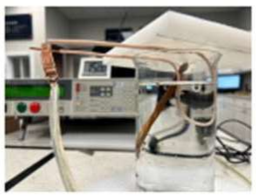
Customer: Copperweld Bimetallics, LLC 0
Project Number: G105875569

ID	
Test setup	

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Appendix G (Intertek Validation of Data Report) continued

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Breakdown Unaged

Parameters:	
Sample Requirement:	45 - 18" samples. A
Conditioning:	Room temperature for atleast 15 minutes prior to test.
Test Potential Required:	500V/Sec Until Failure or Fault occurs
Test Duration Required:	60 seconds

Sample Prep:
Cut samples to length - 18 Inches
Strip one end of insulation - 1/2" to 1"
Bend specimen to optimize oven space:
1) 180° bend 1" radius mid length of sample
2) 2" from mid section, bend both legs 90°
3) Load oven (45) samples per photo

Test procedure (unaged control samples):
Place sample in water keeping terminated ends well above the water level
Connect the Hipot lead to the terminated end of the sample suspending in the water
Connect the Hipot Lead to the bare wire in water tank
Conduct the Hipot test elevating voltage at 500v/sec until failure occurs
Conduct this series on all three samples per test interval. (0 Days, Day 7 and every 2 days thereafter for a total of 43 days)
After each test interval the water shall be emptied and replaced.

Reporting:
Record voltage level at current fault and/or breakdown
Conduct this test on three samples Record voltage level at current fault and/or breakdown
Record Fault Condition (Flashover or Breakdown)

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Breakdown Unaged

Results:Unaged Control Samples A

Date	Interval (day)	Recoreded Voltage at Fault			Average Voltage	Conditioning			Fault Condition		
		Sample A:1	Sample A:2	Sample A:3		Oven Temp(°C)	Lab Temp(°C)	Lab RH	Sample A:1	Sample A:2	Sample A:3
7/2/24	0										
7/9/24	7	24,280	25,657	23,512	24,483	N/A	22	50%	Flashover	Flashover	Flashover
7/11/24	9	24,672	23,257	23,933	23,954	N/A	20.5	47%	Flashover	Flashover	Flashover
7/13/24	11	23,813	24,750	25,202	24,588	N/A	20.5	48%	Flashover	Flashover	Flashover
7/15/24	13	26,818	25,480	25,035	25,778	N/A	22	48%	Flashover	Flashover	Flashover
7/17/24	15	22,620	20,679	21,391	21,563	N/A	22	50%	Flashover	Flashover	Flashover
7/19/24	17	23,442	23,082	21,665	22,730	N/A	22	48%	Flashover	Flashover	Flashover
7/21/24	19	22,686	22,715	21,608	22,336	N/A	20	50%	Flashover	Flashover	Flashover
7/23/24	21	22,460	21,993	22,387	22,280	N/A	21.5	52%	Flashover	Flashover	Flashover
7/25/24	23	23,001	23,631	23,835	23,489	N/A	20	48%	Flashover	Flashover	Flashover
7/27/24	25	21,464	25,411	22,007	22,961	N/A	20	48%	Flashover	Flashover	Flashover
7/29/24	27	22,687	21,729	23,646	22,687	N/A	22	46%	Flashover	Flashover	Flashover
7/31/24	29	24,006	22,851	23,543	23,467	N/A	20	48%	Flashover	Flashover	Flashover
8/2/24	31	22,541	23,399	21,948	22,629	N/A	20	48%	Flashover	Flashover	Flashover
8/4/24	33	21,908	23,927	21,208	22,348	N/A	20.5	52%	Flashover	Flashover	Flashover
8/6/24	35	23,561	21,901	22,680	22,714	N/A	20.5	48%	Flashover	Flashover	Flashover
8/8/24	37	24,999	24,386	22,659	24,015	N/A	22	50%	Flashover	Flashover	Flashover
8/10/24	39	22,348	23,352	23,121	22,940	N/A	22	49%	Flashover	Flashover	Flashover
8/12/24	41	22,694	24,005	25,248	23,982	N/A	22	51%	Flashover	Flashover	Flashover
8/14/24	43	22,359	22,685	21,558	22,201	N/A	22	49%	Flashover	Flashover	Flashover

Test Date: 7/9/024 - 8/14/2024 **Tested By:** Chad Smith,Jared DeRight
Approved Date: 8/19/2024 **Engineer:** Matthew Morgan

Equipment Used (See Page 3): 1 | 2 | 6

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Appendix G (Intertek Validation of Data Report) continued

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Breakdown aged at 90°C

Parameters:	
Sample Requirement:	45 - 18" samples. B
Conditioning:	90°C
Test Potential Required:	500V/Sec Until Failure or Fault occurs
Test Duration Required:	60 seconds

Sample Prep:
Cut samples to length - 18 Inches
Strip one end of insulation - 1/2" to 1"
Bend specimen to optimize oven space:
1) 180° bend 1" radius mid length of sample
2) 2" from mid section, bend both legs 90°
3) Load oven (45) samples per photo

Test procedure (unaged control samples):
Remove three Samples and let normalize for atleast 15 minutes prior to testing.
Place sample in water keeping terminated ends well above the water level
Connect the Hipot lead to the terminated end of the sample suspending in the water
Connect the Hipot Lead to the bare wire in water tank
Conduct the Hipot test elevating voltage at 500v/sec until failure occurs
Conduct this series on all three samples per test interval. (0 Days, Day 7 and every 2 days thereafter for a total of 43 days)
After each test interval the water shall be emptied and replaced.

Reporting:
Record voltage level at current fault and/or breakdown
Conduct this test on three samples Record voltage level at current fault and/or breakdown
Record Fault Condition (Flashover or Breakdown)

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Breakdown aged at 90°C

Results:90°C Aged Samples (Sample B)

Date	Interval (day)	Recoreded Voltage at Fault			Average Voltage	Conditioning			Fault Condition		
		Sample B:1	Sample B:2	Sample B:3		Oven Temp(°C)	Lab Temp(°C)	Lab RH	Sample B:1	Sample B:2	Sample B:3
7/2/24	0					90	21	50%			
7/9/24	7	30,000	26,840	29,382	28,741	90	22	50%	Breakdown	Flashover	Breakdown
7/11/24	9	23,510	22,548	23,170	23,076	90	20.5	47%	Flashover	Flashover	Flashover
7/13/24	11	24,126	24,134	23,023	23,761	90	20.5	48%	Flashover	Flashover	Flashover
7/15/24	13	26,656	26,719	24,703	26,026	90	22	48%	Flashover	Flashover	Flashover
7/17/24	15	19,875	20,850	20,568	20,431	90	22	50%	Flashover	Flashover	Flashover
7/19/24	17	24,945	24,462	23,403	24,270	90	22	48%	Flashover	Flashover	Flashover
7/21/24	19	21,353	22,112	22,753	22,073	90	20	50%	Flashover	Flashover	Flashover
7/23/24	21	25,326	25,340	23,555	24,740	90	21.5	52%	Flashover	Flashover	Flashover
7/25/24	23	21,310	23,806	23,218	22,778	90	21.5	49%	Flashover	Flashover	Flashover
7/27/24	25	23,833	25,839	23,237	24,303	90	21.5	49%	Flashover	Flashover	Flashover
7/29/24	27	22,627	22,684	20,176	21,829	90	22	46%	Flashover	Flashover	Flashover
7/31/24	29	24,049	24,131	23,461	23,880	90	22	46%	Flashover	Flashover	Flashover
8/2/24	31	19,342	23,435	23,381	22,053	90	20	48%	Flashover	Flashover	Flashover
8/4/24	33	22,380	23,122	24,798	23,433	90	20.5	52%	Flashover	Flashover	Flashover
8/6/24	35	24,041	24,622	24,061	24,241	90	21	48%	Flashover	Flashover	Flashover
8/8/24	37	21,666	23,769	24,437	23,291	90	22	50%	Flashover	Flashover	Flashover
8/10/24	39	23,245	22,788	23,683	23,239	90	22	49%	Flashover	Flashover	Flashover
8/12/24	41	21,731	22,657	25,311	23,233	90	22	51%	Flashover	Flashover	Flashover
8/14/24	43	23,942	23,956	22,066	23,321	90	22	49%	Flashover	Flashover	Flashover

Test Date: 7/9/024 - 8/14/2024 **Tested By:** Chad Smith,Jared DeRight
Approved Date: 8/19/2024 **Engineer:** Matthew Morgan

Environmental Conditions During Testing: Humidity: ___ % RH Ambient: ___ °C

Equipment Used (See Page 3): 1 | 2 | 3 | 4 | 5 | 6

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Appendix G (Intertek Validation of Data Report) continued

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Breakdown aged at 125°C

Parameters:	
Sample Requirement:	45 - 18" samples. C
Conditioning:	125°C
Test Potential Required:	500V/Sec Until Failure or Fault occurs
Test Duration Required:	60 seconds

Sample Prep:
Cut samples to length - 18 Inches
Strip one end of insulation - 1/2" to 1"
Bend specimen to optimize oven space:
1) 180° bend 1" radius mid length of sample
2) 2" from mid section, bend both legs 90°
3) Load oven (45) samples per photo

Test procedure (unaged control samples):
Remove three Samples and let normalize for atleast 15 minutes prior to testing.
Place sample in water keeping terminated ends well above the water level
Connect the Hipot lead to the terminated end of the sample suspending in the water
Connect the Hipot Lead to the bare wire in water tank
Conduct the Hipot test elevating voltage at 500v/sec until failure occurs
Conduct this series on all three samples per test interval. (0 Days, Day 7 and every 2 days thereafter for a total of 43 days)
After each test interval the water shall be emptied and replaced.

Reporting:
Record voltage level at current fault and/or breakdown
Conduct this test on three samples Record voltage level at current fault and/or breakdown
Record Fault Condition (Flashover or Breakdown)

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Breakdown aged at 125°C

Results:125°C Aged Samples (Sample C)

Date	Interval (day)	Recoreded Voltage at Fault			Average Voltage	Conditioning			Fault Condition		
		Sample C:1	Sample C:2	Sample C:3		Temp(C)	Temp(C)	Lab RH	Sample C:1	Sample C:2	Sample C:3
7/2/24	0					125	21	50%			
7/9/24	7	24,942	27,054	24,403	25,466	125	22	50%	Flashover	Flashover	Flashover
7/11/24	9	22,299	24,136	21,760	22,732	125	20.5	47%	Flashover	Flashover	Flashover
7/13/24	11	23,790	25,424	25,267	24,827	125	20.5	48%	Flashover	Flashover	Flashover
7/15/24	13	25,237	23,228	22,121	23,529	125	22	48%	Flashover	Flashover	Flashover
7/17/24	15	22,925	22,496	22,526	22,649	125	22	50%	Flashover	Flashover	Flashover
7/19/24	17	21,391	22,591	23,327	22,436	125	22	48%	Flashover	Breakdown	Flashover
7/21/24	19	22,156	21,744	21,787	21,896	125	20	50%	Flashover	Flashover	Flashover
7/23/24	21	20,606	21,477	19,667	20,583	125	21.5	52%	Flashover	Flashover	Flashover
7/25/24	23	19,524	21,093	20,534	20,384	125	21.5	49%	Flashover	Flashover	Breakdown
7/27/24	25	11,315	20,366	20,202	17,294	125	21.5	49%	Flashover	Flashover	Flashover
7/29/24	27	21,648	20,550	21,262	21,153	125	22	46%	Flashover	Flashover	Flashover
7/31/24	29	21,970	21,235	21,933	21,713	125	22	46%	Flashover	Flashover	Flashover
8/2/24	31	22,432	22,138	21,688	22,086	125	20	48%	Breakdown	Breakdown	Flashover
8/4/24	33	24,216	20,213	22,394	22,274	125	20.5	52%	Breakdown	Flashover	Flashover
8/6/24	35	23,164	23,842	23,713	23,573	125	21	48%	Breakdown	Flashover	Flashover
8/8/24	37	24,045	25,827	23,053	24,308	125	22	50%	Flashover	Flashover	Flashover
8/10/24	39	24,345	23,518	23,478	23,780	125	22	49%	Flashover	Flashover	Breakdown
8/12/24	41	22,640	22,754	24,499	23,298	125	22	51%	Flashover	Breakdown	Flashover
8/14/24	43	24,015	24,912	24,529	24,485	125	22	49%	Flashover	Flashover	Breakdown

Test Date: 7/9/024 - 8/14/2024
Approved Date: 8/19/2024
Tested By: Chad Smith,Jared DeRig
Engineer: Matthew Morgai

Environmental Conditions During Testing: Humidity: % RH Ambient: °C

Equipment Used (See Page 3): 1 | 2 | 3 | 4 | 5 | 6

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Appendix G (Intertek Validation of Data Report) continued

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Voltage-withstand aged at 150°C

Parameters:	
Sample Requirement:	45 - 18" samples. D
Conditioning:	150°C
Test Potential Required:	500V/Sec Until Failure or Fault occurs
Test Duration Required:	60 seconds

Sample Prep:
Cut samples to length - 18 Inches
Strip one end of insulation - 1/2" to 1"
Bend specimen to optimize oven space:
1) 180˚ bend 1" radius mid length of sample
2) 2" from mid section, bend both legs 90˚
3) Load oven (45) samples per photo

Test procedure (unaged control samples):
Remove three Samples and let normalize for atleast 15 minutes prior to testing.
Place sample in water keeping terminated ends well above the water level
Connect the Hipot lead to the terminated end of the sample suspending in the water
Connect the Hipot Lead to the bare wire in water tank
Conduct the Hipot test elevating voltage at 500v/sec until failure occurs
Conduct this series on all three samples per test interval. (0 Days, Day 7 and every 2 days thereafter for a total of 43 days)
After each test interval the water shall be emptied and replaced.

Reporting:
Record voltage level at current fault and/or breakdown
Conduct this test on three samples Record voltage level at current fault and/or breakdown
Record Fault Condition (Flashover or Breakdown)

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ClientCopperweld Bimetallics, LLC
Project Number: G105875569

Dielectric Voltage-withstand aged at 150°C

Results: 150°C Aged Samples (Sample D)

Date	Interval (day)	Recoreded Voltage at Fault			Average Voltage	Conditioning			Fault Condition		
		Sample D:1	Sample D:2	Sample D:3		Oven Temp(˚C)	Lab Temp(˚C)	Lab RH	Sample D:1	Sample D:2	Sample D:3
7/2/24	0					150	21	50%			
7/9/24	7	23,804	24,067	25,214	24,362	150	22	50%	Breakdown	Flashover	Flashover
7/11/24	9	21,845	22,763	23,551	22,720	150	20.5	47%	Flashover	Breakdown	Flashover
7/13/24	11	23,029	22,806	20,000	21,945	150	20.5	48%	Flashover	Flashover	Breakdown
7/15/24	13	23,115	23,157	22,377	22,883	150	22	48%	Breakdown	Breakdown	Breakdown
7/17/24	15	22,956	21,179	22,125	22,087	150	22	50%	Breakdown	Breakdown	Breakdown
7/19/24	17	21,051	20,480	20,941	20,824	150	22	48%	Breakdown	Breakdown	Breakdown
7/21/24	19	15,799	15,929	15,587	15,772	150	20	50%	Breakdown	Breakdown	Breakdown
7/23/24	21	15,056	14,706	14,800	14,854	150	21.5	52%	Breakdown	Breakdown	Breakdown
7/25/24	23	15,647	14,480	15,878	15,335	150	21.5	49%	Breakdown	Breakdown	Breakdown
7/27/24	25	15,994	14,518	15,829	15,447	150	21.5	49%	Breakdown	Breakdown	Breakdown
7/29/24	27	15,948	15,422	16,108	15,826	150	22	46%	Breakdown	Breakdown	Breakdown
7/31/24	29	13,825	13,218	14,031	13,691	150	22	46%	Breakdown	Breakdown	Breakdown
8/2/24	31	17,344	18,674	16,580	17,533	150	20	48%	Breakdown	Breakdown	Breakdown
8/4/24	33	16,411	19,987	20,066	18,821	150	20.5	52%	Breakdown	Breakdown	Breakdown
8/6/24	35	19,490	18,766	19,318	19,191	150	21	48%	Breakdown	Breakdown	Breakdown
8/8/24	37	14,117	16,456	15,655	15,409	150	22	50%	Breakdown	Breakdown	Breakdown
8/10/24	39	17,870	19,708	19,627	19,068	150	22	49%	Breakdown	Breakdown	Breakdown
8/12/24	41	16,553	18,701	15,462	16,905	150	22	51%	Breakdown	Breakdown	Breakdown
8/14/24	43	18,891	18,854	20,122	19,289	150	22	49%	Breakdown	Breakdown	Breakdown

Test Date: 7/9/024 - 8/14/2024
Approved Date: 8/19/2024
Tested By: Chad Smith,Jared DeRigh
Engineer: Matthew Morgan

Environmental Conditions During Testing: Humidity: See above Ambient: See above

Equipment Used (See Page 3): 1 | 2 | 3 | 4 | 5 | 6

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Small Branch Circuit Conductor Performance in Thermal Insulation

For

Copperweld Bimetallics, LLC.

Performed at

Construction Instruction
6850 Argonne St, Unit 100
Denver, Colorado
and

Report Prepared by

Chuck Mello
Dr. David Pope, PhD
Dr. Mark Licurse, PhD
Justin Wilson

Testing Witnessed and Report Reviewed by

Harry van der Meer - Intertek
John Kovacik – Trusted Safety Solutions LLC

Date: August 27, 2024

Intertek Report No. 105885650CSLT-001

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Appendices

Executive Summary

In August of 2023, the Fire Protection Research Foundation published a report *Evaluation of Electrical Conductors in Thermal Insulation: Literature Review, Gap Analysis, & Development of a Research Plan,* (K-712000-RA-0001 R03), authored by Lindsay Vasilak, Peter Dick and Ehsan Azordegan of Kinectrics AES (FPRF report). The scope for this project was to evaluate electrical cables, with particular attention to "small circuit" cables installed in thermal insulation. The scope of work included a literature review, a gap analysis of the known research on the subject, as well as developing a comprehensive research plan:

> *"that can be universally applied to assess small branch conductors."*

A project technical panel was assembled by NFPA staff to assist the Kinectrics team and oversee the project. Its membership consisted of four past and present members of NEC Code Making Panel 6, one member of the NEC Correlating Committee (who also presided as Chair of the NEC Correlating Committee's Bimetals Task Group), as well as two other members representing the NFPA and Canadian Standards Association.

In the summer of 2024, and in continuance of its experimental research of small branch circuit conductors, Copperweld Bimetallics assembled a team of individuals with expertise from relevant scientific disciplines to further advance the knowledge on the performance of small branch circuit conductors, including 14 AWG copper-clad aluminum (CCA) NM-B cables. The team used the FPRF report as the design basis of its experimental research. However, the guidance provided by the FPRF report was not at the detailed level of a testing procedure or standard, so the description of its test protocols was general in nature and subject to interpretation. Little explanation was provided for the reasoning behind the design limits. Separate communications with the FPRF staff provided clarification on several points of the test design.

The only acceptance criteria provided by the FPRF report was the temperature rating when tested at the ampacity ratings of the conductors used in the experiment.

> *"Acceptance criteria should be based on insulation ampacity temperature ratings outlined in the Article 310 ampacity tables within the 2023 edition of the NEC."*

Perhaps also recognizing the prospect of impracticality of some aspects of its guidance, the FPRF report does grant some latitude to those organizations who endeavor to perform actual testing. The FPRF report states that:

> *"The experimental plan outlined in this section is expected and designed to be refined in the future by laboratories who may perform such testing."*

Notwithstanding, the Copperweld team designed and executed the experimental portion of its analysis while staying true to the spirit set by the FPRF report.

As specified by section 5 of the FPRF report, for example, R-43 insulation and 100-foot circuits were used in the evaluation. The disciplines of building science, electrical engineering, materials science and thermodynamics were all utilized to design experiments that would provide relevant data and give the report reader insight into the expected temperatures of conductors for 10, 15 and 20-ampere circuits when running at rated ampacity. The conditions set by the test plan were designed to simulate the NEC-permitted limits of what a conductor might encounter in a real installation. The test plan was reviewed by Intertek, a Nationally Recognized Test

Laboratory (NRTL), before testing began. The execution of the test plan was physically witnessed by Intertek, and the resulting data and analysis validated by Intertek, see Appendix A for the Intertek letter report.

In addition to specifying an experimental approach to the evaluation of small circuit conductors, the FPRF report also recommended an analytical approach using systems such as Finite Element Analysis (FEA). It stated that the analytical approach serves to

> *"extend experimental results to a larger range of parameters (including more permutations among parameters) than are practical to test. A thermal model can be generated to represent the baseline cable conditions and applied to the impacted condition."*

Following that recommendation the team built a Finite Volume Method (FVM) program to calculate the heating of small circuit conductors using the parameters of the experimental test plan. The FVM process is more applicable to the type of installation being addressed rather than discrete elements. Physical test results of the conductors from the experimental plan were used to validate the accuracy of the model. The modeling team employed the Siemens STAR-CCM+ software for the simulation. Like the COMSOL mentioned in the FPRF report, the STAR-CCM+ is another (and widely preferred)

> *"multiphysics CFD software enabling simulation engineers to model the complexity and explore the possibilities of products operating under real-world conditions."*

Exponent, a leading U.S. multi-disciplinary scientific research firm with an active practice in thermal modeling and an expertise in STAR-CCM+, was contracted to lead the team in the modeling aspect of this project.

Table 1 below displays the maximum temperatures achieved by the copper and CCA conductors under like conditions. Table 2 shows the results simulated by the STAR-CCM+ model.

Table 1 – Summary Test Results

Conductor Size and Material (90°C rated)	Outside Ambient (°C)	Interlevel Ambient (°C)	Lowest recorded Temperature at Stability (°C)	Highest recorded Temperature at Stability (°C)
Free Air Results				
10-2 NM-B CCA	22.2	22.4	31.8	35.7
12-2 NM-B copper	22.7	22.8	34.9	37.8
R43 Thermal Insulation Results				
10-2 NM-B CCA	24.4	29.0	54.1	74.0
12-2 NM-B copper	24.1	25.6	54.1	74.2

Table 2 – Model Maximum Temperatures

Conductor Size (NM-B)	Conductor Material	Circuit Rating	Model Maximum Temperature – R43 Insulation (°C)
10-2 w/G	CCA	20	77.7
12-2 w/G	Copper	20	78.4
12-2 w/G	CCA	15	75.5
14-2 w/G	Copper	15	74.2
14-2 w/G	CCA	10	61.4

NM-B cable was utilized as the wiring method for the test data acquisition. The conductors used within NM-B cable are rated at 90°C, which is the acceptable temperature level suggested by the FPRF report for NM-B cable. All the conductors, both tested and modeled, have resulting temperatures well below 90°C, therefore, all test subjects in this experiment met the acceptance criteria.

Based upon this additional research, it is highly improbable that 14 AWG CCA conductors would overheat under full load at the proposed ampacities and considering the circuit conditions set by section 210.23(A). 14 AWG CCA had the lowest reported temperature of all the conductors in the study and was well below the rated temperature rating of 90°C.

1.0 Introduction and Purpose

1.1 Purpose

The purpose of this project is to provide empirical data using both an experimental and analytical approach to evaluate the heating profiles and safety of small branch circuit conductors. Both physical testing and thermal modeling were employed to evaluate the temperature performance under worst-case thermal insulation conditions of small branch circuits of copper and copper-clad aluminum (CCA). Small branch circuits encompass 10-, 15-, and 20-amperes. The branch circuits with the greatest application presently are 15- and 20-ampere. With the introduction of the 10-ampere branch circuit for energy efficient circuits, such as LED lighting, this application may see usage grow significantly in future construction.

Research and evaluation of small circuit conductors is on-going. This report is provided as substantiation for adding 14 AWG CCA to article 310 as a branch circuit conductor as well as to certain sections of Chapter 3 wiring methods such as Article 334, Nonmetallic-Sheathed Cable.

1.2 Project Personnel

This project was initiated by Mr. Peter Graser of Copperweld Bimetallics, LLC., as part of the ongoing evaluation of the suitability for 14 AWG CCA for use as general branch circuit wiring .

Mr. Justin Wilson and Mr. Sam Keefe with Construction Instruction assembled the test fixture framing and installed the foam board insulation. The blown in fiberglass insulation was installed by Koala Insulation under contract with Construction Instruction. The installation of the electrical wiring, thermocouples and connection to the test instruments was completed by Mr. Justin Brace, Mr. Brandon Allen (both with Copperweld Bimetallics, LLC.) and Mr. Chuck Mello with cdcmello Consulting.

Testing was conducted by Mr. Chuck Mello, Mr. Brandon Allen and Mr. Justin Brace. All testing was witnessed by Mr. Harry van der Meer of Intertek and Mr. John Kovacik of Trusted Safety Solutions. Please see the Intertek's test witnessing letter incorporated into section 1.0 of this report.

The modeling work was completed by Dr. May Yen, PhD, and Dr. Peter Lindahl, PhD with Exponent, a leading U.S. multi-disciplinary scientific research firm with an active practice in thermal modeling. The materials science and thermodynamics evaluations were completed by Dr. David Pope, PhD and Dr. Mark Licurse, PhD with Pope & Licurse Consulting.

1.3 Project Schedule

The construction of the test fixture and installation of all cables was completed at the Construction Instruction facility in Denver, Colorado between July 8 and 16, 2024.

Testing without thermal insulation inside the test fixture was completed on July 22 and 23, 2024. The blown in fiberglass thermal insulation was installed on July 24, 2024. Testing of the conductors in the thermal insulation was conducted July 24, and 25, 2024.

2.0 Test Assembly and Test Set Up Description

2.1 Overview

Following the guidance provided in the NFPA Fire Protection Research Foundation (FPRF) report, *Evaluation of Electrical Conductors in Thermal Insulation: Literature Review, Gap Analysis, & Development of a Research Plan, August 2023*, a single test fixture was constructed. The main parameters to be met were to provide 100 feet of cable to be tested and to have a thermal insulation rating of R43. Other parameters that had to be considered were spacing between the portions of the cables under test to minimize or eliminate any influences by mutual heating through the testing environment, air or thermal insulation.

The testing and cable selections were designed in consultation with the expert team and executed at the 20-ampere current level representing a worst-case small branch circuit condition. As shown in Table 3 below, the 20-ampere test level was chosen considering heat generation is a function of the current squared times the resistance of the conductors that are typically considered "small branch circuits".

Table 3

Circuit Rating	10		15		20	
Conductor Type	Copper	CCA	Copper	CCA	Copper	CCA
AWG Size	16	14	14	12	12	10
Resistance @ 20°C	0.004019	0.003987	0.002523	0.002509	0.001588	0.001579
Power Generated (I^2R) per conductor (watts/ft)	0.402	0.399	0.568	0.565	0.635	0.631

The 20-ampere circuit has the greatest energy generation per linear foot of conductor, therefore would exhibit the worst-case condition for any environment.

2.2 Text Fixture Construction to Achieve R43 Thermal Insulation

To achieve the parameters required in the FPRF report, 2 x 6 standard construction lumber was used to build a structure with overall dimensions of 20' 4" long by 10' high. See photo 1 below and Appendix B, figure no. 1 for the design layout.

Photo 1 – Test Fixture

The base was a single 2" x 6" board representing a standard bottom plate. The top had two 2" x 6" boards installed representing standard construction top plate. The vertical studs were installed on 16" centers. The outside wall was sheathed with 7/16" oriented strandboard (OSB). The entire structure was assembled on two end platforms approximately 3 feet by 6 feet with casters to permit moving of the test structure as needed.

The thermal insulation system to achieve an R43 value consisted of R10 rated foam panels mounted on the outside and the inside of the structure with no gaps and blown-in fiberglass thermal insulation with a R23 value. Plywood strips were installed on the outside edges of the foam panels to facilitate mounting with screws.

Initial "free air" testing was completed with only the sheathing and foam board on one side to establish temperature baseline data in "free air". To complete the testing in thermal insulation, the bays in the structure were filled with blown-in fiberglass thermal insulation to obtain a R23 value and then both sides of the test fixture were covered with R10 rated foam board without any gaps, achieving overall rating of R43. See Appendix B figure 2.

2.3. Cable Installation

The cables tested in the data acquisition phase in this project were:

- 10-2 w/G NM-B copper-clad aluminum cable
- 12-2 w/G NM-B copper cable

These cables have a temperature rating of 90°C. To meet the 100-foot requirement, the installation consisted of 5 levels of cables each 20+ feet in length. To minimize possible mutual heating influence each level of cable was spaced 20 inches apart from the top, bottom and each other. See Appendix B figure 3 for the hole pattern and photo 4 for spacing. The NM-B was routed outside the structure for approximately 30" in length and reentered at the next level following the guidance provided in the FPRF report.

At the end of the NM-B cables, the two insulated (black and white) conductors were connected to complete the circuit for testing. See Appendix B figure 5 for a photo showing this connection for both the 10-2 NM-B CCA and 12-2 NM-B copper.

A length of approximately 10 feet of cable was extended outside the test fixture at the supply end to facilitate connection to a constant current power supply.

2.4 Thermocouple Installation and Data Logger Connection

Prior to the installation the design layout and identification scheme for all the thermocouples was completed. The details and referenced figures below provide how the thermocouple installation was accomplished.

2.4.1 Ambient

Two thermocouples to monitor the ambient temperature were installed in the center on the front and rear of the structure. The location was approximately 2 feet from the face and 5 feet from the top of the structure. Ambient temperatures were continually recorded throughout all the testing sequences. See Appendix B, Figures 6 and 7 for the ambient thermocouple locations.

2.4.2 Monitoring for Mutual Heating:

To monitor possible mutual heating between levels of cables under test, six thermocouples were placed halfway between each cable level and between the bottom plate and top plate to the nearest cable level. These locations are shown in Appendix B, Figures 6 and 7. To mount these thermocouples, a length of non-thermally conductive paracord was attached and centered between the studs in the middle (eighth) stud bay. The thermocouple was then cemented to the paracord and reinforced with electrical tape to mitigate any stress on the thermocouple connection, particularly from the force from blown in thermal insulation. Additionally, electrical tape was used to secure the thermocouple wire to the paracord.

2.4.3 Thermocouple Locations on NM-B Cables

Thermocouple locations were selected where the team forecasted maximum temperatures and to monitor horizontal and vertical temperature gradients, see Appendix B figures 8 through 10. A thermocouple was installed in the first (top left) and last (bottom right) stud bays to monitor these locations with the expectation these would be the lowest readings. On levels 2, 3 and 4 thermocouples were installed in the second and fifteenth stud bays. For all the levels two thermocouples were installed in the middle, 8th and 9th stud bays. The two thermocouples in this middle area were to provide redundancy in data acquisition in the event there was any malfunction with a thermocouple.

2.4.4 Thermocouple Installation on NM-B Cables

For the NM-B cables at each thermocouple location, the jacket was opened to expose the applicable conductor. The thermocouple was attached to the indicated bare conductor using thermocouple cement. The jacket was then closed back with wraps of black insulating tap to restore the jacket integrity. See Appendix B Figure 11 for photos.

2.4.5 Data Logger Connections

The thermocouples wires were identified with the circuit and location for connection to the data logger cards in accordance with the design plan. The thermocouples for each test circuit were installed onto the cards for a data logger identified for the respective circuit(s). The data logger channel identification was confirmed as the thermocouples were being terminated onto the data logger card.

2.4.7 Power Supply

The power supply for the test circuit was a 1000-watt constant current unit. The Amp Line Corporation Model: AL-1000-CR-H/S-50A constant current power supply provided the required current to complete this testing. See Appendix B, Figure 16 for a photo of the power supply, calibrated multimeter used to confirm the current magnitude and data loggers.

2.4.8 Thermal Insulation Installation

Once the initial round of testing was completed, the blown in fiberglass thermal insulation was installed. The blown in insulation installed was Johns Manville B-7700 Climate Pro®. In order to hold the blown in thermal insulation in place, sheeting was installed and stapled to the studs, bottom plate and top plate. See Appendix B figures 12 to 15. Each stud space was filled with the blown in thermal insulation. The thermal insulation value for the 2 x 6 stud spaces with this material was R23.

To achieve the R43 rating as required by the FPRF report, R10 rated foam thermal insulation panels, DuPont™ Styrofoam™ Brand ST-100 Series XPS, were installed without any gaps on both sides of the structure.

3.0 Test Procedures

3.1 All testing was conducted based with 20 amperes applied to the 12-2 NM-B copper and 10-2 NM-B CCA cables using the 60°C ampacity rating of the wiring method (NM-B cable) and as used in typical construction. Only the two insulated conductors (black and white) within the cable were energized. The bare equipment grounding conductor was not energized, representing normal circuit operation.

3.2 One circuit was tested at a time so as not to introduce mutual heating into the data being collected. During testing, all thermocouples were monitored and recorded on the data loggers, including those measuring the ambient temperature, as well as the thermal insulation temperatures between the cable levels to monitor mutual heating

The testing sequence for both the free air testing and the testing within thermal insulation was:

- 10-2 w/G NM-B CCA cable
- 12-2 w/G NM-B copper cable

3.3 Testing Steps

3.3.1 The test circuit was verified as complete with the power supply connected to the conductor set to be tested.

3.3.2 The data loggers were programmed to scan:

- The two ambient temperature thermocouples
- The six interlevel thermocouples within the stud bay
- The channels for the applicable thermocouples installed on the conductors under test
- The thermocouples installed on conductors not under test

3.3.3 The power supply was initiated, and final adjustments made to the applicable output current of 20 amps for the NM-B cable.

3.3.4 The data loggers were initiated to start scanning and recording data at time zero and then an interval of 5 minutes.

3.3.5 The current was verified as being correct with the calibrated digital multimeter and current clamp probe.

3.3.6 The testing was monitored, and temperature data recorded by the data logger.

3.3.7 In addition to the data logger recordings manual monitoring of data was conducted:

- During the initial test, data was manually recorded every 5 minutes until temperature equilibrium was reached.
- Once the data logger recording was confirmed as performing satisfactorily, the current and temperatures were then manually recorded at approximately 30-minute intervals to determine when temperature equilibrium was achieved.
- For every test the start time and end time was manually recorded

3.3.8. For the purposes of this project, temperature equilibrium is defined as three temperature recordings at minimum of 10-minutes apart with no greater than 1°C change over the 30-minute time interval. This criterion was determined after reviewing temperature testing requirements in several UL standards.

3.3.9 When temperature equilibrium was achieved, the test was terminated.

3.3.10 Upon completion, the manual results were reviewed, and the data from the data logger downloaded to a separate storage device.

3.3.11 Once testing was completed and data confirmed, the foam panels were removed as needed and fans used to bring the test fixture down to a suitable ambient condition.

3.3.12 Once the test fixture was cooled, the next test in the sequence initiated.

3.3.13 The next test in the sequence was set up and the above procedure steps were repeated for the next set of cables.

4.0 Results

4.1 General

4.1.1 Ambient temperatures outside the test structure ranged from 22°C to 24°C. The ambient temperatures within stud bay 8 of the structure ranged from 22°C to 23°C for the free air testing and from 24°C to 29°C for testing in thermal insulation. For each test the ambient temperatures recorded remained very steady throughout the test period. No evidence of mutual heating was found within the stud bay from one level to the next.

4.1.2 For residential single phase branch circuits, there are only two current carrying conductors, therefore this data represents the heating effects from typical residential branch circuits that are loaded to the maximum ampacity allowed for the wiring method.

Even with multi-wire branch circuits in single phase installations, the third or neutral conductor will only have the unbalanced current present and not full rated ampacity load from the two ungrounded conductors.

In addition, the levels of thermal insulation used in this project represent a worst-case scenario -- the highest required for Climate Zones 6, 7 and 8 that apply to very few locations in the lower 48 states and to most of Alaska.

4.1.3 Temperature equilibrium is a state where the temperature of an object does not change over time. It happens when the object gains and loses heat at the same rate. In this case, electric current passes through the wire and the wire generates heat due to the resistance in the wire. When energized, the wire will increase in temperature until it reaches a point where it loses heat to the surrounding environment (free air, thermal insulation, studs, etc.) at the same rate as it generates heat at which point it has attained its steady state temperature.

4.2 Testing in Free Air

Each of the NM-B cable circuits was tested individually in free air with no thermal insulation installed in the test fixture.

The testing found both the 10-2 NM-B CCA, and the 12-2 NM-B copper to attain thermal equilibrium in approximately 1 hour. The temperatures recorded are shown below in Table 4:

Table 4

Conductor (90°C rated)	Outside Ambient (°C)	Interlevel Ambient (°C)	Lowest recorded Temperature at Stability (°C)	Highest recorded Temperature at Stability (°C)
10-2 NM-B CCA	22.2	22.4	31.8	35.7
12-2 NM-B copper	22.7	22.8	34.9	37.8

It is noted that all conductor temperatures are well below the 90°C conductor insulation rating or the insulated conductors in NM-B cable assemblies. See Appendix B figures 17 and 18 for the graphs of the test results.

4.3 Testing in R43 Thermal Insulation

4.3.1 10-2 w/G NM-B CCA In Thermal Insulation

The final recorded temperatures, at equilibrium, for the 10-2 NM-B CCA cable ranged from 54.08°C to 74.02°C. Figure 4.3.1 shows the graph of the 20 temperature recordings for the 10-2 NM-B CCA cables and the 8 temperature recordings for the ambient and stud bay 8 interlevel thermal insulation. Figure 4.3.2 shows the temperature distribution at temperature equilibrium and confirms the expectation that the highest temperatures, thermocouplesT106 and T107, would be in the middle of the test fixture and near the top of the test fixture as shown in the red circle.

It is noted that the maximum recorded temperature of the fully loaded cable of in the R43 thermal insulation did not reach the 90°C rating of the insulated conductors within the cable assembly.

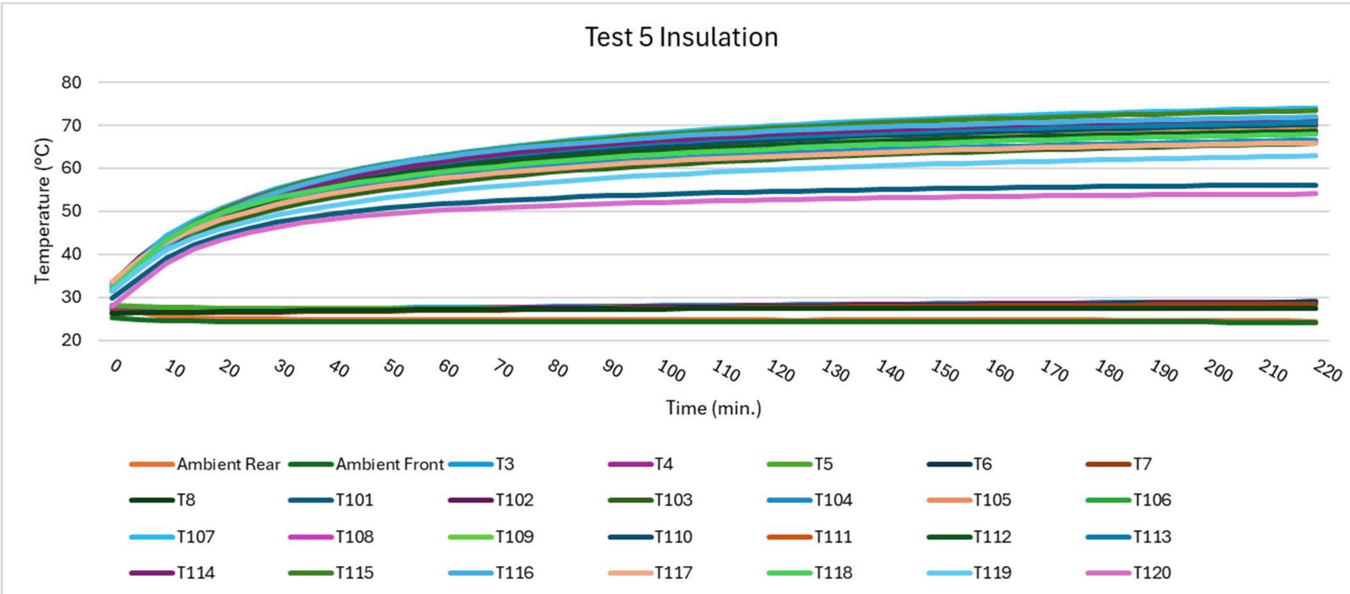

Figure 4.3.1 – 10-2 NM-B CCA In Thermal Insulation

Test #5: 100’ [135’] 20A 10-2 w/G NM-B CCA in insulation

Thermocouple	Temp (°C)
T120	54.08
T101	56.11
T119	62.86
T103	65.77
T117	65.94
T104	66.56
T118	67.94
T102	68.47
T112	68.62
T109	68.66
T105	69.55
T110	70.20
T113	70.62
T108	71.14
T111	71.32
T114	71.81
T116	71.95
T115	73.44
T106	73.85
T107	74.02

Figure 4.3.2 – 10-2 NM-B CCA: Temperature Distribution at Equilibrium In Thermal Insulation

4.3.2 12-2 w/G NM-B Copper in Thermal Insulation

The final recorded temperatures, at equilibrium, for the 12-2 NM-B copper cable ranged from 54.08°C to 73.87°C. Figure 4.4.1 shows the graph of the 20 temperature recordings for the 12-2 NM-B copper cables and the 8 temperature recordings for the ambient and stud bay 8 interlevel thermal insulation. Figure 4.4.2 shows the temperature distribution at temperature equilibrium and confirms the expectation that the highest temperatures, T206, T207 and T215 would be in the middle of the test fixture and near the top of the test fixture as shown in the red circles.

It is noted that the maximum recorded temperature of the fully loaded cable of in the R43 thermal insulation did not reach the 90°C rating of the conductor insulation within the cable assembly.

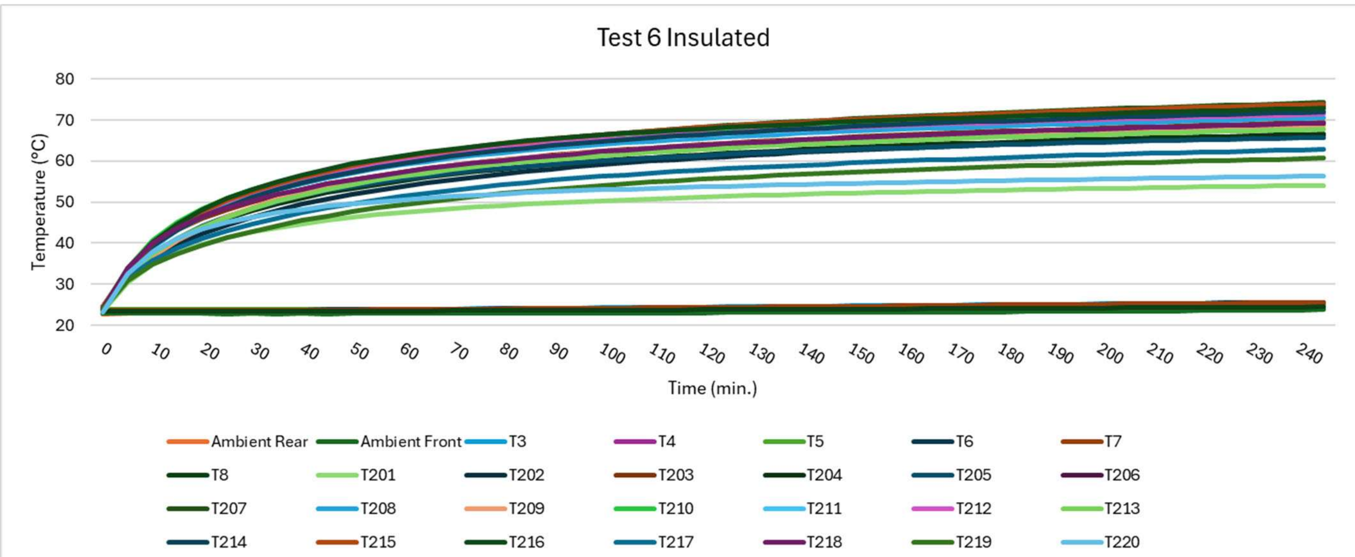

Figure 4.4.1 – 12-2 NM-B Copper In Thermal Insulation

Test #6: 100’ [135’] 20A 12-2 w/G NM-B Cu in insulation

Figure 4.4.2 – Copper 12/2 NM-B: Temperature Distribution at Equilibrium In Thermal Insulation

4.4 Summary Testing in Thermal Insulation

As detailed above, each of the NM-B cable circuits were tested individually within an R43 thermal insulation environment. The testing found the 10-2 NM-B CCA and the 12-2 NM-B copper conductors to reach thermal stability at 3 1/2 hours and 4 hours. The temperatures at equilibrium recorded are shown below in Table 3:

Table 5

Conductor (90°C rated)	Outside Ambient (°C)	Interlevel Ambient (°C)	Lowest recorded Temperature at Stability (°C)	Highest recorded Temperature at Stability (°C)
10-2 NM-B CCA	24.4	29.0	54.1	74.0
12-2 NM-B copper	24.1	25.6	54.1	74.2

It is noted that all conductor temperatures at equilibrium are well below the 90°C conductor insulation rating or the insulated conductors in NM-B cable assemblies.

4.5 Thermal Gradient and Influence

For each test the temperatures recorded for the thermocouples installed between the cable layers in stud bay 8 were reviewed. As shown in the graphs figures 5.3.1, and 5.4.1, the temperatures recorded were very steady and barely above the recorded ambient. Figure 5.7.1 below shows the temperature distribution of the interlevel thermocouples at the end of testing in thermal insulation. This demonstrates that there was no thermal heating influence from any level of cables under test to an adjacent level of cables.

Thermocouple	Temp (°C)
T1	24.07
T2	23.76
T3	25.59
T4	25.50
T5	25.31
T6	25.59
T7	25.56
T8	24.47

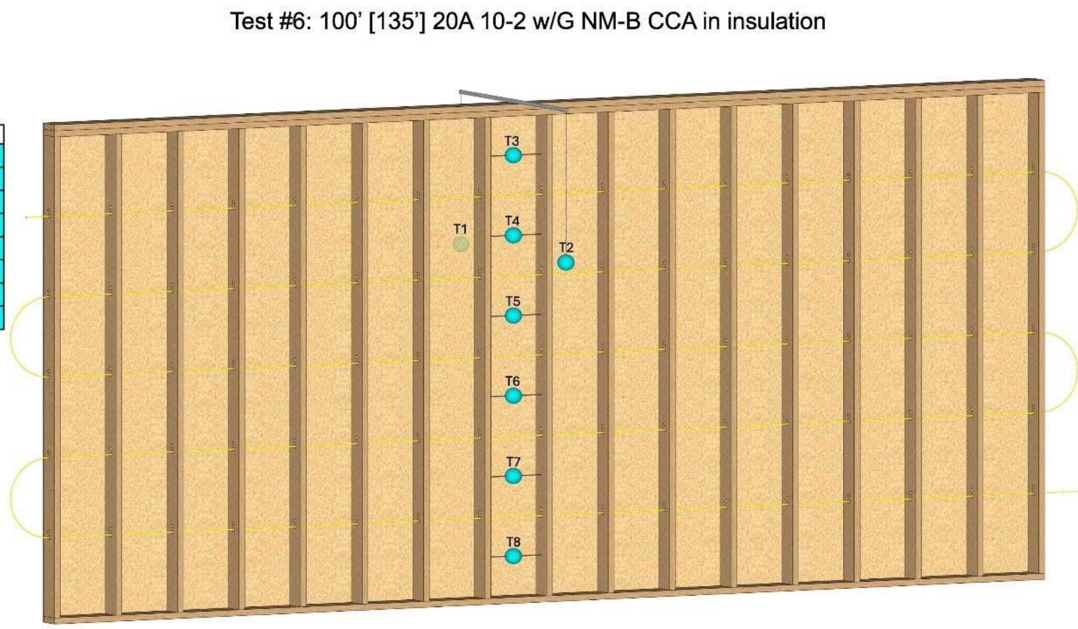

Figure 5.7.1 – Thermal Distribution of Ambient and Interlevel Thermocouples

4.6 Small Branch Circuit Modeling

The development of a model for the expected performance of small branch circuits, 10-, 15-, and 20-amp, installed in worst case thermal insulation was completed in parallel with the 20-amp cable circuit testing. The data acquired from the testing conducted in R43 insulation at the full rated current of 20-amps was then used to validate the model.

The results from the model are based on a perfect thermal insulation system, no gaps, holes or other thermal anomalies, and with the conductors operated at the rated current for an infinite distance and infinite time to establish temperature equilibrium. It was expected that under these conditions, the model results would indicate temperatures higher than the results from the testing.

As can be seen in Table 6 the maximum temperatures under these worst-case conditions were very close and slightly higher to what was found in the testing for the 10-2 w/G CCA and the 12-2 w/G copper cables. The results from the model also show the maximum temperatures for the 15- and 10- amp circuit cables to be less, as expected. In all these cases the maximum temperature was less than the 90°C rating of the conductors and well below that which could cause a fire.

See Appendix C, *Thermal Modeling of Insulated Branch Circuits* from Exponent, for a detailed report and explanation of the model creating and application.

Table 6 – Model Maximum Temperatures

Conductor Size (NM-B)	Conductor Material	Circuit Rating	Model Maximum Temperature – R43 Insulation (°C)
10-2 w/G	CCA	20	77.7
12-2 w/G	Copper	20	78.4
12-2 w/G	CCA	15	75.5
14-2 w/G	Copper	15	74.2
14-2 w/G	CCA	10	61.4

4.7 Materials Science and Thermodynamics Summary

An analysis by two recognized materials scientist was completed as part of witnessing the testing conducted and to provide their perspective of the results from the testing and the model discussed in section 4.8. The results of this analysis found the following:

- "The most essential conclusion from the testing is that the temperatures of conductors in 10, 15 and 20-ampere small branch circuits, running at their rated ampacities, did not exhibit any unsafe heating trends".
- Thermoplastic insulated conductors rated 90°C do not show any degradation even at temperatures as high as 120°C or 136°C which are standard test temperatures applied to thermoplastic insulation for listing.
- With a maximum temperature of 77°C established from the model, as a worst-case condition, NM-B cables and thermoplastic insulated conductors will not degrade.
- Combustible materials near the wire will not ignite at the temperatures found in the testing or determined in the model. Wood framing needs 200°C or more for ignition. The fiberglass insulation is non-combustible. Therefore, there is no risk of fire because cable heating at 74°C or 77°C.
- The 100-foot circuit length required for the testing was found not to be a factor when considering the actual thermodynamic heat transfer paths to dissipate heat being generated by current going through the conductors.

See Appendix D, for a detailed report and explanation of the materials science and thermodynamics for these installations.

4.8 Building Science Summary

As reported by Construction Instruction, a leading researcher in building insulation systems, the building industry is in transition from the traditional insulation system of filling the stud to joist spaces with thermal insulation. The trend now and into the future is to have no, or some insulation in the stud or joist cavity, and to have a solid sheeting of insulating material on the exterior and roof deck before applying the building finish. Some key results of this report include:

- There will be less insulation interfacing with the electric wiring and the concentration for thermal insulation efficiency will be with exterior thermal cladding.
- "R43 insulated wall assemblies are not common and present numerous challenges that make it difficult and expensive to achieve. Instead, the mix of cavity insulation and continuous exterior insulation will achieve greater energy conservation, as well as meet energy code".
- Fiberglass batt insulation, which is the most used in today's construction, must be correctly installed to be effective. "Gaps and voids create air pockets within insulation which increases the rate of thermal conduction, essentially decreasing insulations' effectiveness. Gaps, voids, and compressions also create areas for convection loops reducing the labeled R-value of fibrous insulation".

See Appendix E, for a detailed report and explanation of the buildings science and future of building thermal insulation systems.

5.0 Summary and Conclusions

5.1 As summarized in tables 7 and 8 below, the testing demonstrated that at full rated current, the conductor temperatures in free air or in the R43 thermal insulation did not reach the conductor rating of 90°C. The results of the model, shown in table 8, were validated from the testing conducted.

Table 7

Conductor Size and Material (90°C rated)	Outside Ambient (°C)	Interlevel Ambient (°C)	Lowest recorded Temperature at Stability (°C)	Highest recorded Temperature at Stability (°C)
Free Air Results				
10-2 NM-B CCA	22.2	22.4	31.8	35.7
12-2 NM-B copper	22.7	22.8	34.9	37.8
R43 Thermal Insulation Results				
10-2 NM-B CCA	24.4	29.0	54.1	74.0
12-2 NM-B copper	24.1	25.6	54.1	74.2

Table 8 – Model Maximum Temperatures

Conductor Size (NM-B)	Conductor Material	Circuit Rating	Model Maximum Temperature – R43 Insulation (°C)
10-2 w/G	CCA	20	77.7
12-2 w/G	Copper	20	78.4
12-2 w/G	CCA	15	75.5
14-2 w/G	Copper	15	74.2
14-2 w/G	CCA	10	61.4

5.2 Both the model and the testing determined the cable temperatures in thermal insulation at equilibrium are well below the cable rating of 90°C at 20-amps continuously load (10-2 NM-B CCA avg temp center bays 68.9C and 12-2 NM-B Cu avg temp center bays 70.3C).

5.3 A review of the final temperature gradients found that there was no additional information provided with a cable length of 100'. In fact, cable length had very little influence on the results.

5.4 Mutual influence of cables in the same bay is negligible given that thermocouples between the cables were only slightly higher than ambient temperature.

5.5 On average CCA conductors ran slightly cooler than copper conductors in the test fixture, however, the team considered the difference negligible. CCA runs slightly cooler (68.9C vs 70.3C), although this may be affected by the relative position of the thermocouples.

5.6 The issues that have been raised about small branch circuits, particularly 14 AWG CCA applied at 10-amps, installed in thermal insulation, are not valid. 14 AWG NM-B CCA rated for a temperature of 90°C, installed in a worst-case thermal insulation of R43 had a maximum conductor temperature of 60.4°C. This temperature is 19% less than 14 AWG NM-B copper at its rated current and 32% less than the wire temperature rating.

5.7 Continuous Loading

The National Electrical Code in Article 100 defines a continuous load as:

> *"A load where the maximum current is expected to continue for 3 hours or more."*

Where loads are continuous, the maximum current allowed by the code is required to be reduced to 80% or less. This reduction for the 20-amp circuit means the maximum continuous current is 16-amps. The resultant energy, I^2R, generated at 16-amps is 64% of the energy generated at 20-amps. At temperature equilibrium, the reduced thermal energy would result in lower temperatures in both the free air and thermal insulation environments.

6.0 Test and Measurement Equipment Calibration

The following test and measurement equipment was used for the testing. The certificates of calibration for each of the below items are provided in Appendix F.

Description	manufacturer	Asset/Serial #	Cal Date	Cal Due
Digital Multi-Meter Model TX-3	Tektronix	B029681	6/26/2024	6/26/2025
Current Clamp Probe 80-i600	Fluke	----	6/26/2024	6/26/2025
Current Clamp Probe Y8101A	Fluke	66463670	6/26/2024	6/26/2025
Thermocouples, UL 4047, Type J, 10 to 125 feet	Pacific Test and Measurement	995284A-014A	6/24/2024	N/A
Thermocouples, UL 4047, Type J, 5 to 30 feet	Pacific Test and Measurement	993036-009C	4/8/2024	N/A
Data Logger Model DAQ 970A	Keysight	MY58018798	1/4/2023	1/4/2025
Data Logger Model DAQ 970A	Keysight	MY58018811	1/4/2023	1/4/2025
Data Logger Model DAQ 970A	Keysight	MY58029603	1/4/2023	1/4/2025

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INTERTEK ASSURANCE
Copperweld Witness Test.
Witness and Certification

SCOPE OF WORK
WITNESS TESTING AT CONSTRUCTION INSTRUCTION LLC

REPORT NUMBER
105885650CSLT-001

ISSUE DATE
August 19, 2024

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Page 1 of 3

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Letter for witness testing at Construction Instruction LLC, 6850 Argonne St., Unit 100, Denver, CO 80249

Intertek Report No. 105885650CSLT-001
Intertek Project No. G105885650

Peter Graser
Vice President – Building Wire
Copperweld
5141 Virginia Way, Suite 410
Brentwood, TN 37027
404-550-9064
pgraser@copperweld.com

Subject: Witness testing at Construction Instruction LLC

To whom it may concern,

During July 22-25, 2024, Harry van der Meer, Contract Consultant for Intertek, witnessed testing at Construction Instruction LLC, 6850 Argonne St., Unit 100, Denver, CO 80249 as described in report 105885650CSLT-001.

CopperWeld (CW) in collaboration with Construction Instruction (CI) in Denver, CO, built a test fixture to determine the temperature behaviors of 12-2 NM-B copper (12-2 NM-B Cu) and 10-2 NM-B copper-clad-aluminum cable (10-2 NM-B CCA). The test fixture consists of a 10 ft high x 20 ft long wall constructed with 2x6 regular lumber and insulated to R43. 100 ft of both cables were installed in the wall using standard practice per the NEC. Using separate tests, both cables were energized with 20 A-ac until temperature equilibrium was achieved. The temperature of both cables was measured by several thermocouples mounted on the cables. Dataloggers and well as manual recording of the temperature of each of the thermocouples was performed.

The purpose of these tests was to show that NM-B CCA cable is an acceptable product to be installed as an alternative to NM-B copper cable. In addition to the above-mentioned cables, other cable types and wiring configurations were evaluated.

Intertek's scope was to assure that testing was performed in accordance with the applicable standards and assure that details of the test fixture, cables and test equipment is accurately represented in the final report which will be submitted to the NFPA-NEC code panel in August.

This is to certify that:

1. The test fixtures were constructed as described in report 105885650CSLT-001
2. The test equipment used were as described in report 105885650CSLT-001
3. The test equipment calibration reports were reviewed and deemed up to date
4. The testing procedures as outlined in report 105885650CSLT-001 were adhered to
5. The test results were verified for accuracy

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Letter for witness testing at Construction Instruction LLC,
6850 Argonne St., Unit 100, Denver, CO 80249

Harry van der Meer
Contract Consultant
Intertek

Peter Graser
Copperweld

Date: August 19, 2024

Appendix B - Drawings and Photos

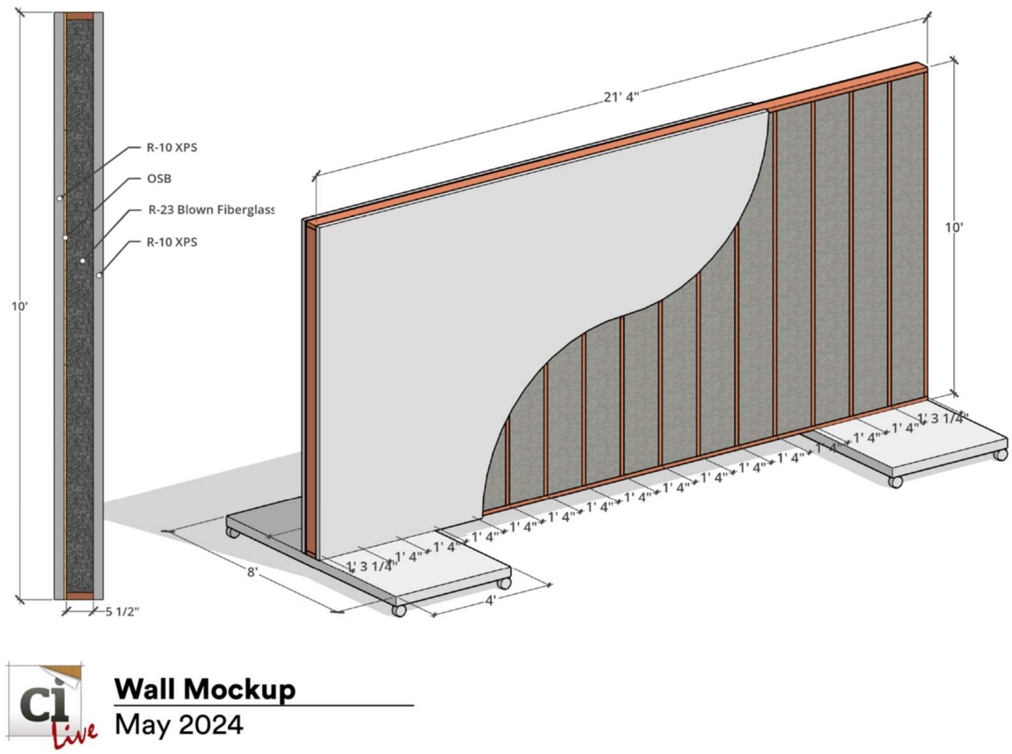

Figure 1 – Test Fixture Structure Design

Figure 2 – Test Fixture with Blown Insulation and 2 Panels of R-10 Foam

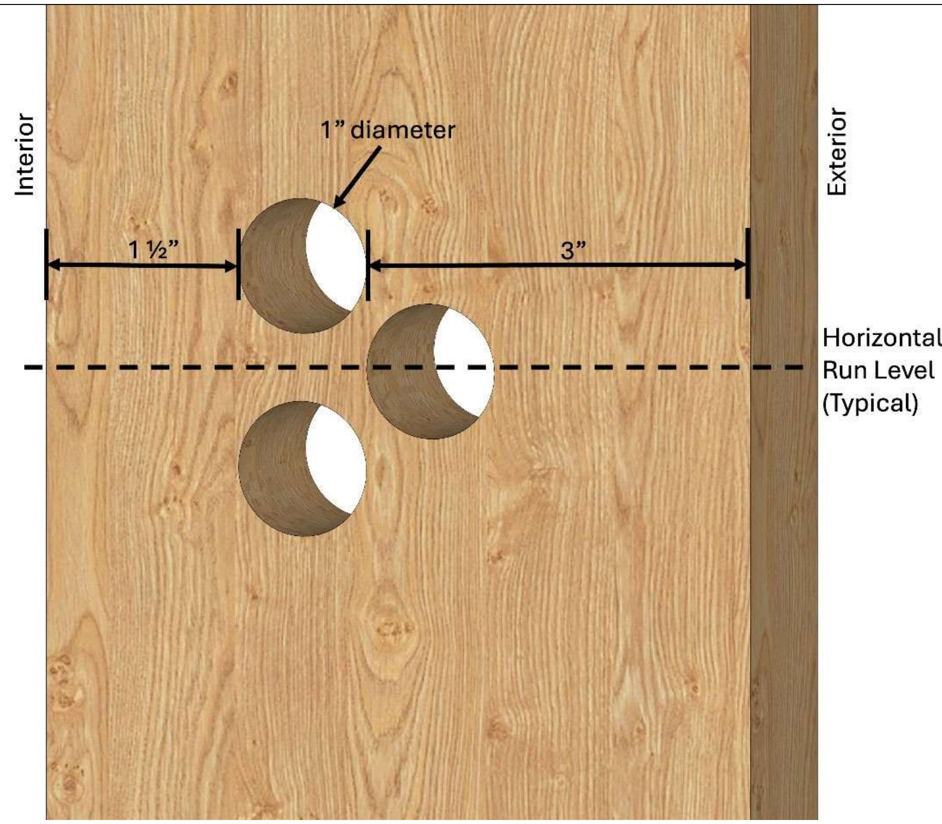

Figure 3 – Test Fixture Stud Section Hole Drill Pattern

Figure 4 – Test Fixture with Conductors Installed

Figure 5 – 10-2 and 12-2 NM-B Conductors Connection at End

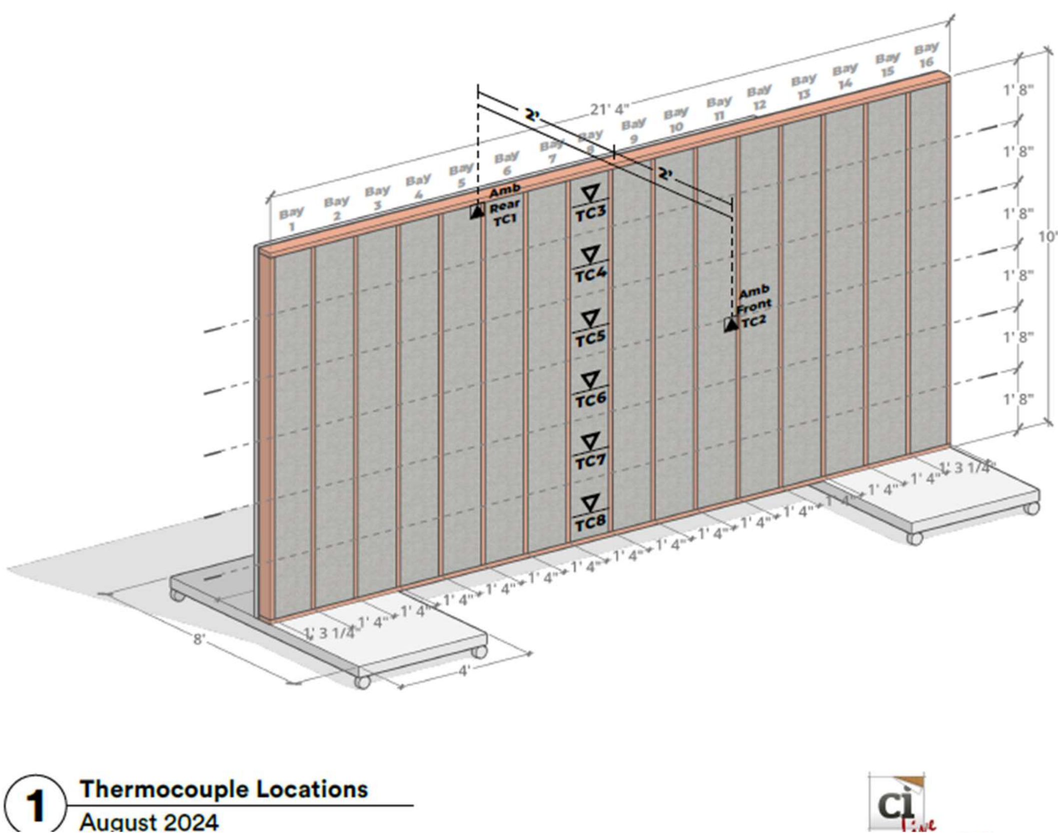

Figure 6 – Ambient and Inter Level Thermocouples

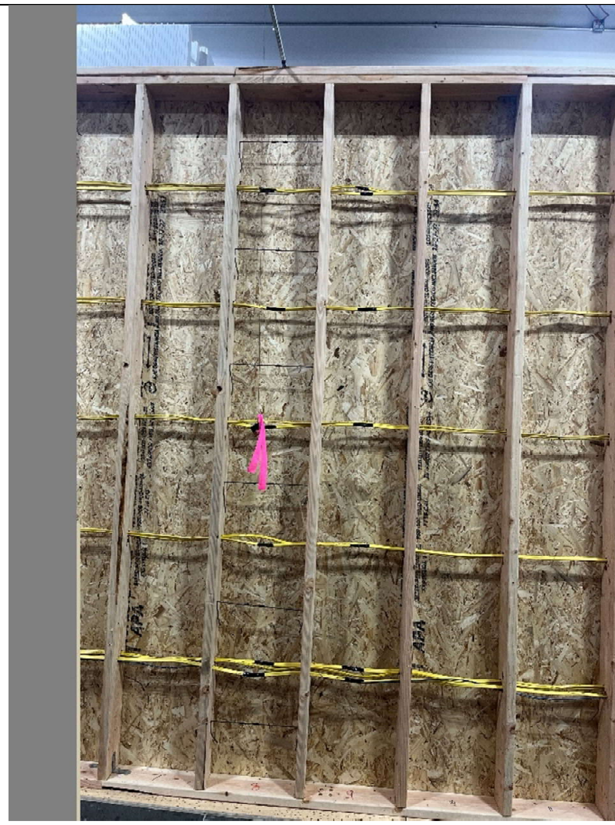

Figure 7 – Inter Level Thermocouples Between Conductor Levels on Paracord

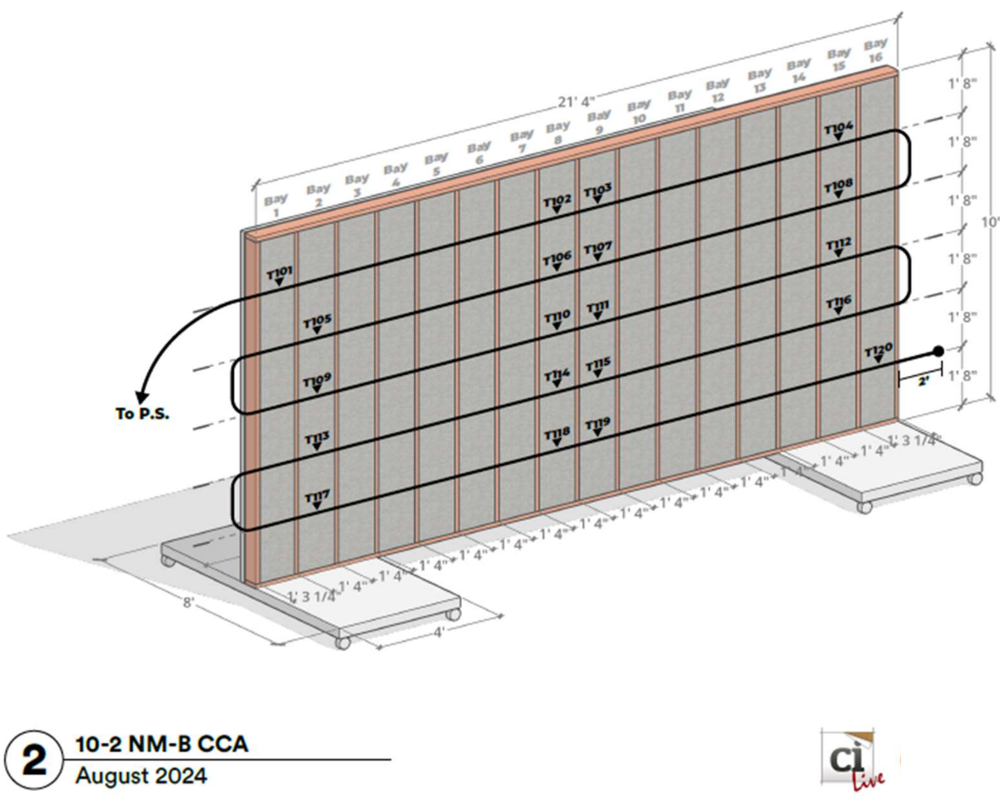

Figure 8 – Thermocouple Positions for 10-2 NM-B CCA Cable

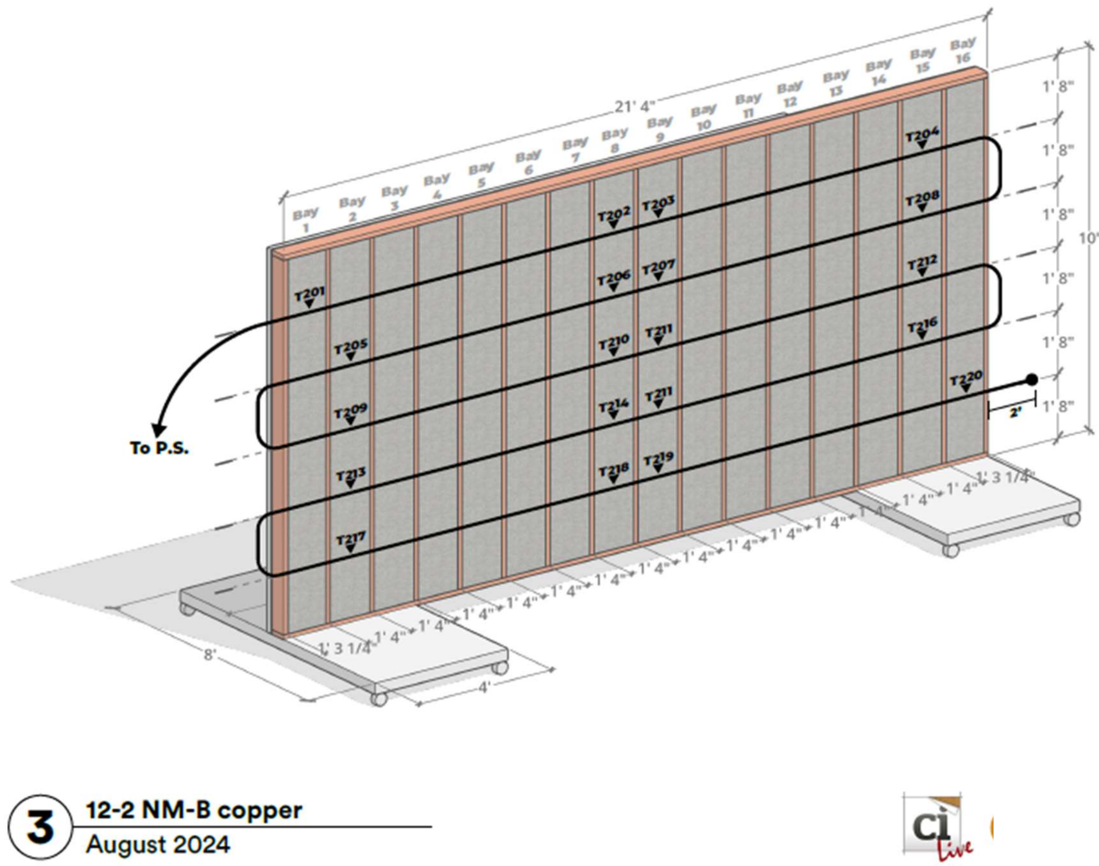

Figure 9 – Thermocouple Positions for 12-2 NM-B Copper Cable

Figure 10 – Thermocouple Location on NM-B Cables

Figure 11 – Thermocouple Attachment to Bare Conductor and Jacket Closed

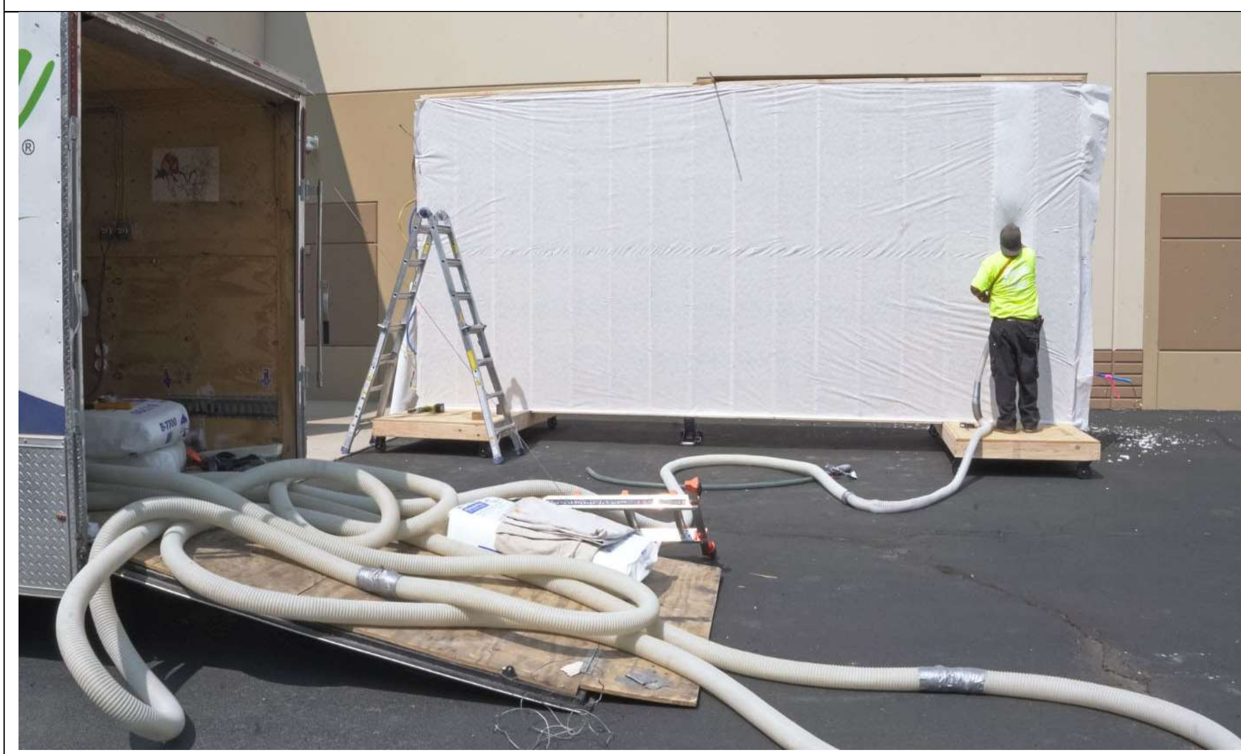

Figure 12 – Thermal Insulation Installation

Figure 13 – Thermal Insulation Installation

Figure 14 – Thermal Insulation Installation

Figure 15 – Thermal Insulation Installation

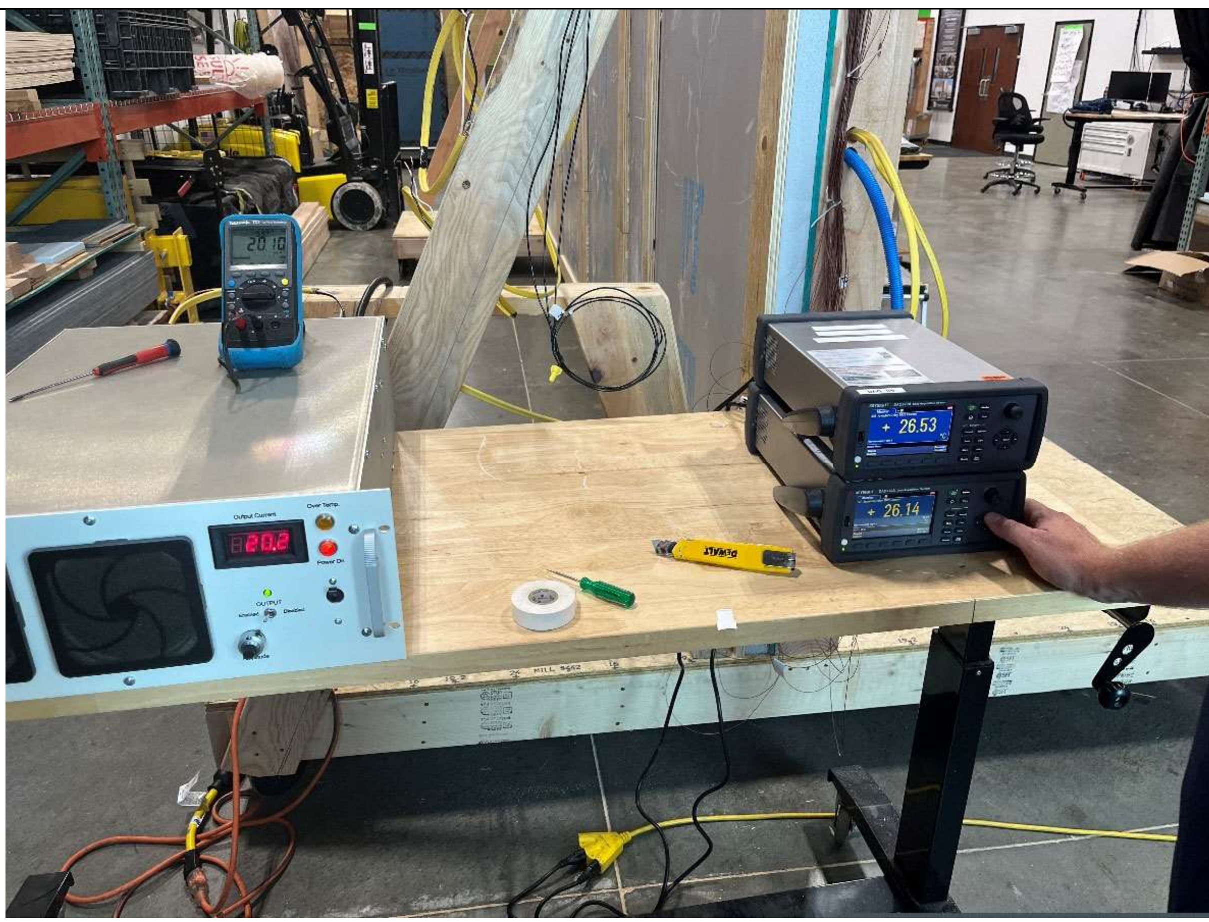

Figure 16 – Power Supply and Data Loggers

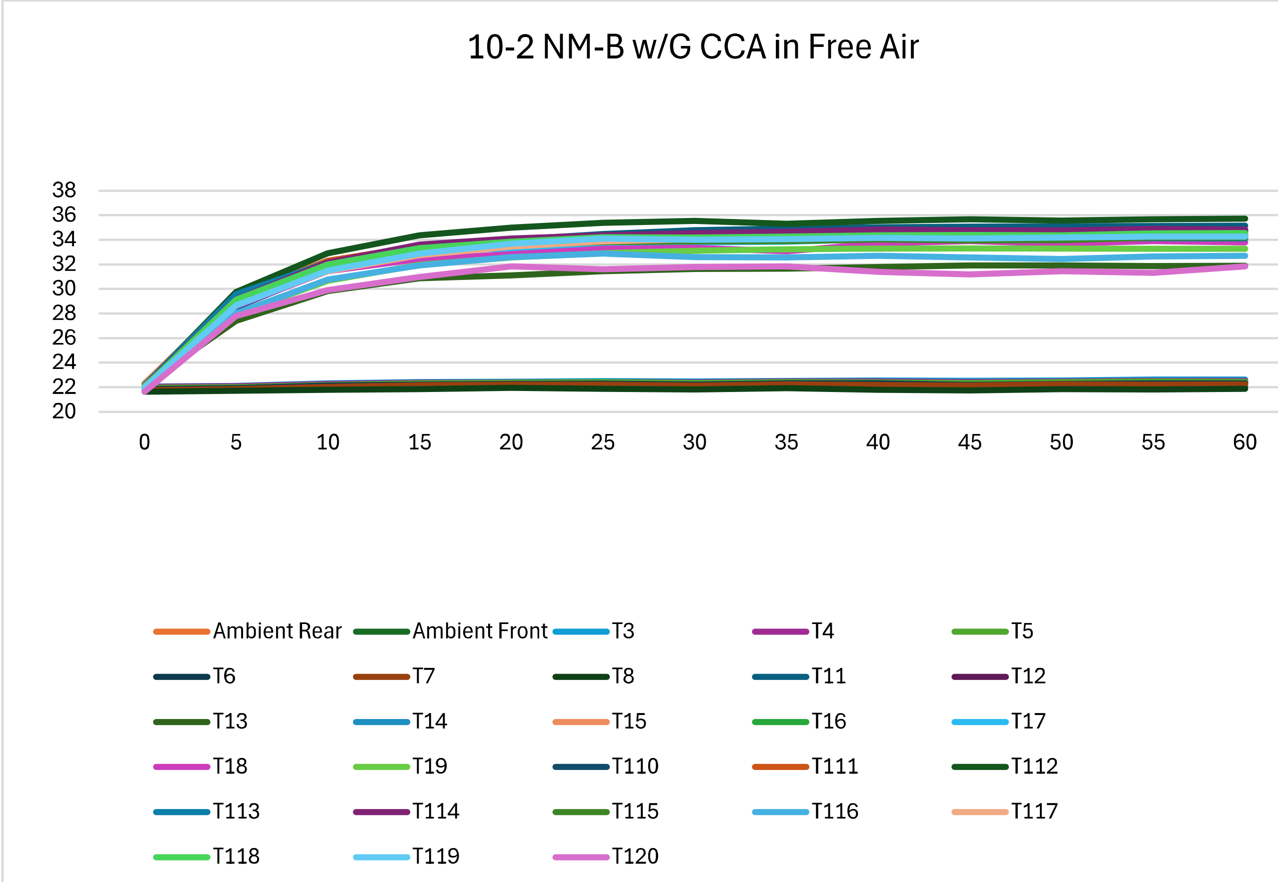

Figure 17 – 10-2 w/G NM-B CCA Testing in Free Air

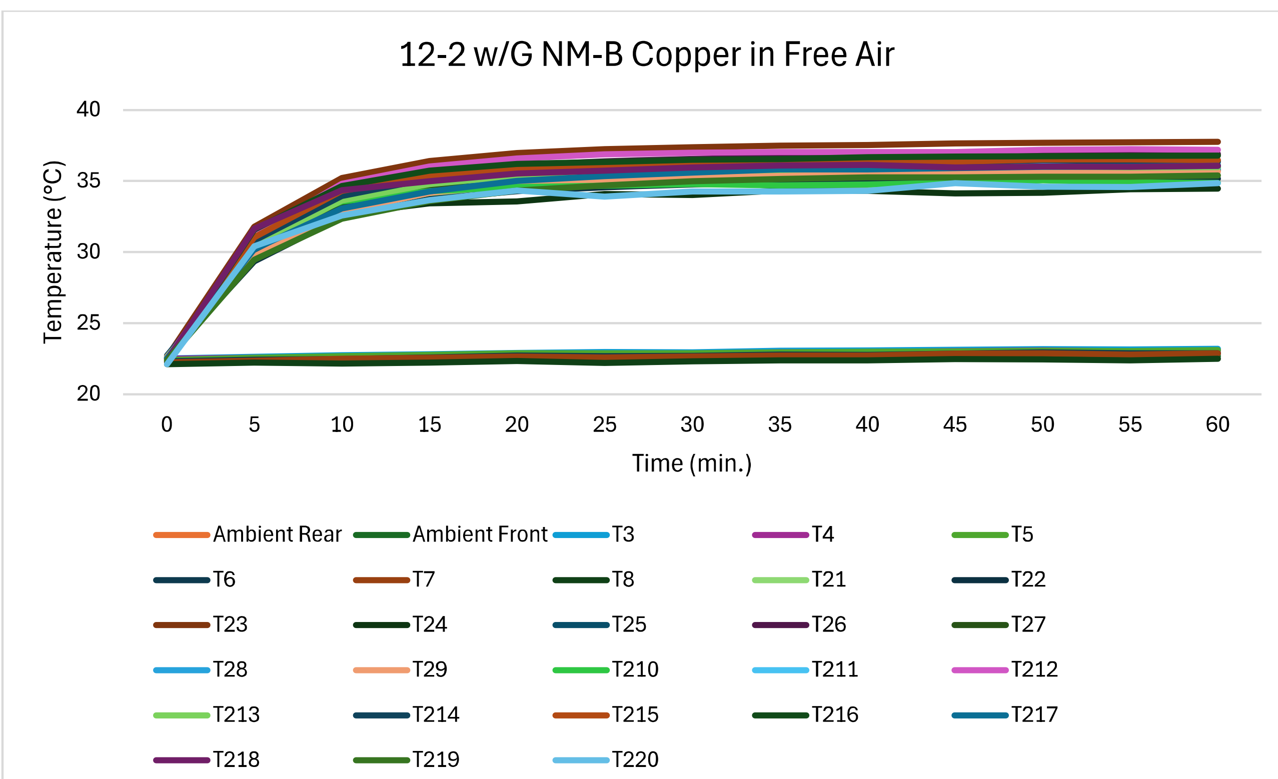

Figure 18 – 12-2 w/G NM-B Testing in Free Air

Exponent®

Thermal Modeling of Insulated Branch Circuits

Exponent®

Thermal Modeling of Insulated Branch Circuits

Prepared For:

Copperweld Bimetallics, LLC.
Brentwood, TN 37027
For Use and Publication in the NFPA Standards Setting Process

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Exponent, Inc.
1075 Worcester St.,
Natick, MA 01760

August 27, 2024

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Acronyms and Abbreviations

A	ampere or amp
AWG	American Wire Gauge
CCA	copper-clad aluminum
3D	three dimensional
Cu	copper
Al	aluminum
PVC	polyvinyl chloride
cmil	circular mils
NM-B	non-metallic sheathed cable
w/G	ground wire (with ground)
OSB	oriented strand board
CAD	computer aided design
kg	kilogram
m	meter
lb	pound
ft	foot/feet
NFPA	National Fire Protection Association
Ω	ohm
FPRF	Fire Protection Research Foundation
UL	Underwriters Laboratory
W	watt

1.0 Executive Summary

1. At the request of Copperweld Bimetallics LLC (Copperweld), Exponent, Inc. (Exponent) was retained to develop a computational heat transfer model to simulate the temperatures of copper-clad aluminum (CCA) and copper (Cu) non-metallic sheathed (NM-B) cables operating at temperature-rated currents (ampacity) and placed in structures constructed with modern building materials. The simulated layout was based on the experimental setup and tests performed at Construction Instruction in July 2024 and described in the report, *Small Branch Circuit Conductor Performance in Thermal Insulation for Copperweld Bimetallics, LLC.*[1] The model geometry was based on drawings and measurements obtained at the test facility and material thermal properties were obtained from the literature (see paragraphs 13, 14, 15).

2. The initial model evaluated the two insulated test scenarios[2]: a 10-2 CCA NM-B conductor with two wires carrying a 20-A current and a 12-2 Cu NM-B conductor with two wires carrying a 20-A current. The conductors were routed through a structure constructed with 2 x 6 standard lumber (actual dimensions 1.5" x 5.5"), internally insulated with fiber glass blown-in insulation, and further insulated by foam board insulation on both sides.

3. The maximum cable temperature rise above ambient from 3D computational models for Cu and CCA were 8.4% and 7.4%, respectively, above experimentally measured values.

4. The comparison to the experimental measurements confirmed the ability of the model to predict the maximum cable temperatures and provides a conservatively high value.

5. The model was then used to predict the steady-state heating in a wall caused by a 15-A current through a 14-2 Cu NM-B conductor and a 12-2 CCA NM-B conductor, and a 10-A current flowing through a 14-2 CCA NM-B conductor. The maximum steady-state NM-B temperature was predicted to be 75.5 °C, 74.2 °C, and 61.4 °C, respectively.

---

[1] C. Mello et al., Small Branch Circuit Conductor Performance in Thermal Insulation, Intertek Report No. 105885650CSLT-001.

[2] C. Mello et al., Small Branch Circuit Conductor Performance in Thermal Insulation, Intertek Report No. 105885650CSLT-001.

Notably, none of the maximum temperatures ever exceed the 90 °C temperature rating of the NM-B conductor insulation.

2.0 Computational Methods

6. Following the guidance provided by the NFPA Fire Protection Research Foundation (FPRF) report,[3] Copperweld constructed and performed testing on a test fixture where 100 feet of conductor carrying 20 A would be tested in a structure with a thermal insulation rating of R43.[4] The conductors were arranged on 5 different vertical levels. The structure, seen in Figure 1, was made from 2 x 6 standard lumber with vertical studs installed every 16”. One wall was sheathed with a $^{7}/_{16}$” oriented strand board (OSB). A thermal insulation rating of R43 was implemented through R23 blown-in fiberglass insulation in the stud space and R10 foam board insulation panels mounted on both sides of the structure.[5]

Figure 1. Test fixture, seen without fiberglass blown-in insulation and foam board insulators, used in Copperweld’s July 2024 tests.

[3] Vasilak, Lindsay, Dick, Peter, Azordegan, Ehsan, NFPA FPRF Report: *Evaluation of Electrical Conductors in Thermal Insulation: Literature Review, Gap Analysis, & Development of a Research Plan*, August 2023.

[4] C. Mello et al., Small Branch Circuit Conductor Performance in Thermal Insulation, Intertek Report No. 105885650CSLT-001.

[5] C. Mello et al., Small Branch Circuit Conductor Performance in Thermal Insulation, Intertek Report No. 105885650CSLT-001.

7. A 3D heat transfer model of the NM-B cables installed in a representation of the test fixture with two conductors energized with 20 A was developed using commercial software package Siemens Simcenter StarCCM+ (version 2302). Two NM-B, 2-conductor cables with ground wires, one 10-2 w/G CCA and another 12-2 w/G Cu, were routed along the 2 x 6 stud space through 1" holes with centers placed $1^{5}/_{8}$" away from the stud wall surface and the edge of the hole $1^{1}/_{4}$" back from the stud wall surface. The $5^{1}/_{2}$" stud space was filled with R23 fiberglass blown-in insulation. A $^{7}/_{16}$-inch thick sheet of OSB was secured to the inside of the wall and 2" of R10 foam board insulation was placed on both the inside and outside of the wall.

8. The modeled test fixture[6] has many planes of symmetry that can be leveraged to reduce computational costs. The front view representation of the long, tall studded wall used in the experimental test fixture, shown in Figure 2, shows that the wall consists of repeating sections due to symmetry. Using this feature of the setup, only a small part of the domain, shown in red as the computational domain, is needed to understand the center portions of the wall, where end effects are minimal and highest temperatures will occur, through the use of symmetry boundary conditions.

[6] C. Mello et al., Small Branch Circuit Conductor Performance in Thermal Insulation, Intertek Report No. 105885650CSLT-001.

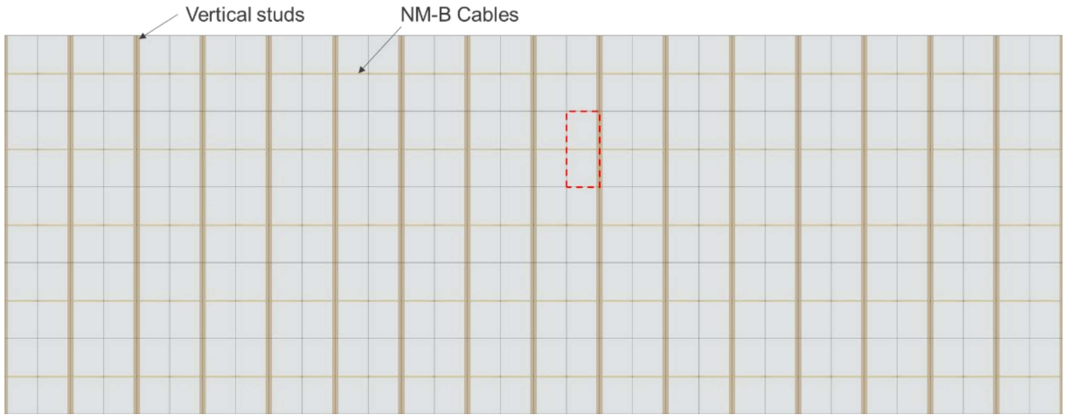

Figure 2. Front view of effective representation of a long, tall studded wall due to symmetry boundary conditions identified in Figure 4 and Figure 5 with computational domain in dotted red.

9. The geometry of a section of the wall was created using a computer-aided design (CAD) rendering of the conductors, insulation, and wall studs as seen in Figure 3.

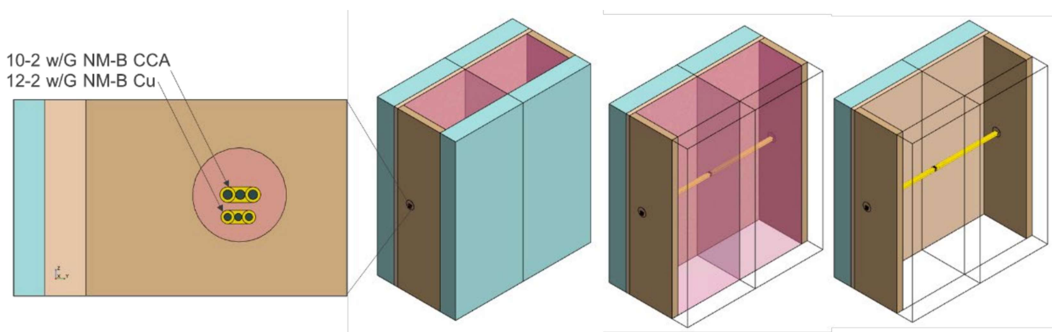

Figure 3. CAD geometry of conductors (black wire with yellow jacket) running through a stud space (brown) filled with R23 fiberglass blown-in insulation (pink) with OSB(brown) on the inside wall and further insulated with two R10 foam boards (blue).

10. The computational domain shown in Figure 4 and Figure 5 is discretized into polyhedral cells that are collectively referred to as the mesh (see Figure 6). The symmetry along the centerline of the stud space was leveraged and the computational domain was drawn from the center of the stud space along the wall until halfway into the vertical stud. The surfaces along the stud centerline and the plane halfway into the vertical stud were treated with symmetry boundary conditions to simulate a long, tall studded wall with a long conductor running throughout every 20” in height as seen in Figure 2.

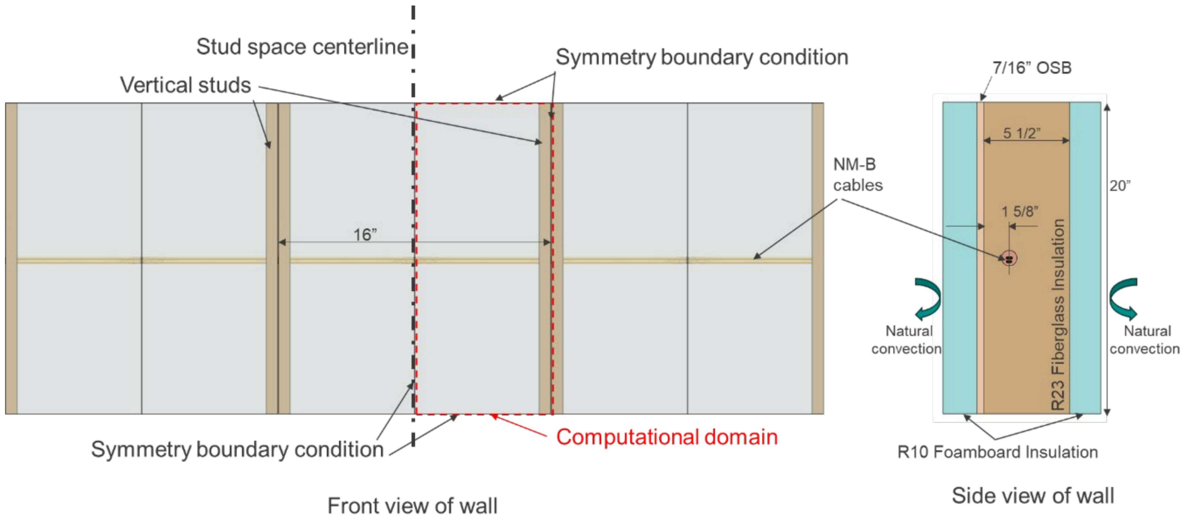

Figure 4. Computational domain comprised of half of the stud space, with symmetry boundary conditions that effectively model a long, tall wall of 16" stud compartments containing a conductor running through every height of 20".

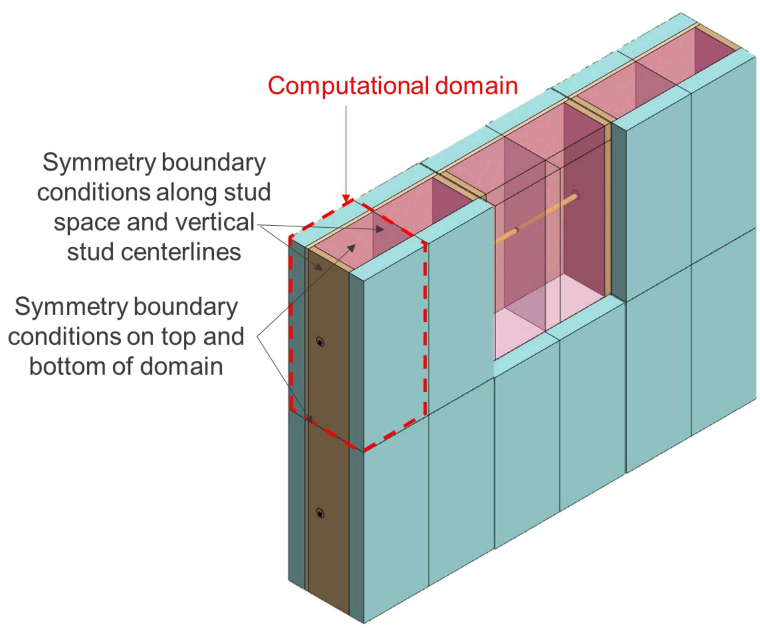

Figure 5. Computational domain (outlined in red) comprised of half of the stud space, with symmetry boundary conditions that effectively model a long, tall wall structure with the top center foam board panel removed for visual clarity.

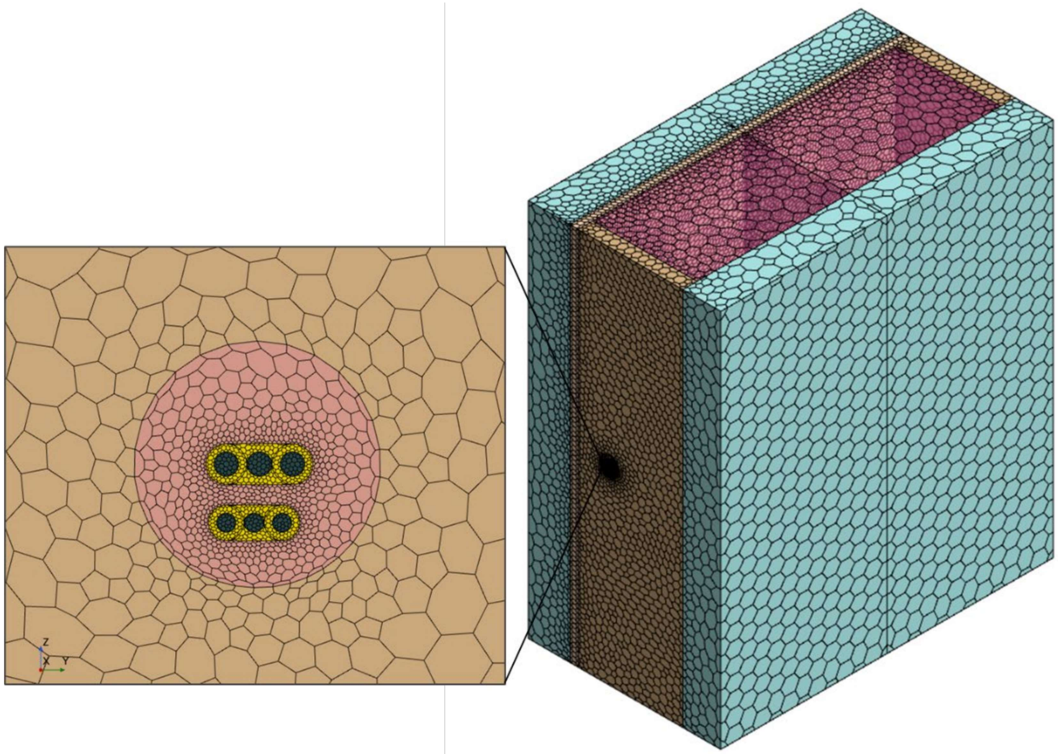

Figure 6. Computational mesh of the insulated wall domain with the vertical studs and oriented strand board (brown), fiber glass blown-in insulation (pink), foam board insulation (blue), and NM-B cables (black wires with yellow jackets).

11. A natural convection boundary condition was imposed on the external surfaces exposed to air with heat transfer coefficients from established empirical correlations.[7,8] An ambient temperature of 24 °C was used based on ambient temperatures during testing.[9]

12. The governing equation, the steady-state heat diffusion equation, below, is numerically solved for the temperature of each cell.

$$\nabla \cdot (k \nabla \mathrm{T}) = \dot{q_v}$$

---

7 Churchill, Stuart W., and Humbert HS Chu. "Correlating equations for laminar and turbulent free convection from a vertical plate." International journal of heat and mass transfer 18.11 (1975): 1323-1329.

8 Bergman, Theodore L., Frank P. Incropera, David P. DeWitt, and Adrienne S. Lavine. Fundamentals of heat and mass transfer. John Wiley & Sons, 2011.

9 Small Branch Circuit Conductor Performance in Thermal Insulation. Intertek Report No. 105885650CSLT-001. 2024.

where T is temperature, k is thermal conductivity, and $\dot{q_v}$ is the volumetric heat generation term. In the steady-state heat diffusion equation, the volumetric heat generation term, $\dot{q_v}$, is equal to the heat diffusion term, $\nabla \cdot (k\nabla T)$. In other words, the steady state temperature depends on the balance between the heat generated by electric heating and the dissipation of heat into the surrounding materials which depends on the material's thermal conductivity.

13. A temperature-dependent thermal conductivity of fiberglass[10] with a density of 24.0 kg/m^3 (1.5 lb/ft^3) was used to model the R23 fiberglass blown-in insulation.[11] This density and thermal conductivity corresponds to an R-value between R23 and R24.[12]

14. A temperature-dependent thermal conductivity of extruded polystyrene[13] with a density of 32.5 kg/m^3 (2 lb/ft^3) was used to model the 2-inch R10 foamboard insulation.[14]

15. Thermal conductivity of Cu[15], polymer wire insulation[16], studs[17], and OSB[18] were taken from literature values. Thermal conductivity of CCA was taken to be the volume average (10% Cu, 90% Al) of Cu[19] and Al[20] thermal properties.

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[10] Levinson, Ronnen, et al. "Impact of the Temperature Dependency of Fiberglass Insulation R-Value of Cooling Energy Use in Building." (1996).

[11] The thermal conductivity of fiberglass depends on density and temperature. A density of 24.0 kg/m^3 (1.5 lb/ft^3) was selected for modeling purposes.

[12] Johns Manville Climate Pro B-7700 Blow-In Fiberglass Data Sheet, Climate Pro Cavity Wall (Sidewall) Coverage Chart, 2023.

[13] Abdou, Adel A., and Ismail M. Budaiwi. "Comparison of thermal conductivity measurements of building insulation materials under various operating temperatures." *Journal of building physics* 29.2 (2005): 171-184.

[14] Owens Corning. FOAMULAR Extruded Polystyrene (XPS) Insulation, Technical Bulletin. 2011.

[15] Bergman, Theodore L., Frank P. Incropera, David P. DeWitt, and Adrienne S. Lavine. Fundamentals of heat and mass transfer. John Wiley & Sons, 2011, Appendix A.

[16] De Carvalho, G., Frollini, E. and Santos, W.N.D. (1996), Thermal conductivity of polymers by hot-wire method. J. Appl. Polym. Sci., 62: 2281-2285.

[17] Bergman, Theodore L., Frank P. Incropera, David P. DeWitt, and Adrienne S. Lavine. Fundamentals of heat and mass transfer. John Wiley & Sons, 2011, Appendix A.

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[19] Bergman, Theodore L., Frank P. Incropera, David P. DeWitt, and Adrienne S. Lavine. Fundamentals of heat and mass transfer. John Wiley & Sons, 2011, Appendix A.

[20] Bergman, Theodore L., Frank P. Incropera, David P. DeWitt, and Adrienne S. Lavine. Fundamentals of heat and mass transfer. John Wiley & Sons, 2011, Appendix A.

16. The flow of electrical current through a conductor generates heat through a process called Joule heating (also referred to as resistive heating). The heat generation can be calculated using Ohm's law.[21]

$$P = R_e I^2,$$

where P is the rate of heat generation, R_e is the electrical resistance of the wire, and I is the current flowing through the wire. Heat generation due to Joule heating has been incorporated in the model.

17. Electrical resistance of the CCA and Cu can be calculated as:

$$R_e = \frac{\rho_e L}{A}$$

where ρ_e is the resistivity of the conducting material, L is the length of the conductor, and A is the cross-sectional area of the conductor. In this simulation, a resistivity of 10.37 Ω-cmil/ft and 16.385 Ω-cmil/ft were used for Cu[22] and CCA,[23] respectively.

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[21] Bergman, Theodore L., Adrienne S. Lavine, Frank P. Incropera, and David P. DeWitt. Introduction to heat transfer. John Wiley & Sons, 2011, p. 143.

[22] National Bureau of Standards Circular 31, 4th edition issued January 27, 1956; Handbook 100 issued February 21, 1966 (supercedes Circular 31).

[23] ASTM project number WK67615.

3.0 Model Comparison to Experimental Measurements

18. Copperweld constructed and performed testing of Cu and CCA NM-B cables in insulated structures under 20-A current conditions.[24] The test conditions and conductor selection were chosen to represent a full ampacity scenario. The experimental procedure had a temperature stability criterion defined as a temperature change lower or equal to 1 °C over a 30-minute time interval as defined in multiple UL standards.[25,26,27] Thermocouples were placed on energized conductors in the middle of the two center-most stud spaces on all five vertical levels to track the maximum conductor temperatures. A maximum conductor temperature of 74.2 °C and 74.0 °C was measured for 12-2 w/G Cu NM-B and 10-2 w/G CCA NM-B, respectively (see

19. Table 1).

20. Both a 12-2 w/G Cu and a 10-2 w/G CCA NM-B cable passed the acceptance criteria provided by the FPRF report which is that the cable temperature did not exceed 90 °C.

21. As previously mentioned in this report, the steady-state temperature of conductors depends upon the rate of Joule heating of the wire and the rate at which energy dissipates from the wire, influenced by the thermal conductivity of the insulating materials. The Joule heating rate for wires operating under identical current conditions depends on their resistance. Given that the resistance of the 12-2 Cu NM-B conductor is slightly higher than the 10-2 CCA NM-B conductor both will exhibit similar total heating power per linear unit, as shown in

22. Table 1 with the 12-2 Cu NM-B conductor exhibiting marginally increased heating per unit length. This difference is evident in both experimental data and the model, where the

[24] C. Mello et al., Small Branch Circuit Conductor Performance in Thermal Insulation, Intertek Report No. 105885650CSLT-001.

[25] UL 486AB. Wire Connectors. 2023. (three temperature readings taken at not less than 10 min intervals show no more than a 2C variation between three consecutive readings)

[26] UL 498. Attachment Plugs and Receptacles. 2024. (three consecutive readings, taken at 5-minute intervals, in dictate no further rise above the ambient temperature)

[27] UL508. Industrial Control Equipment. 2021. (three successive readings, that are taken at intervals of not less than 15 minutes, indicate no change between any two of three consecutive readings of more than +/- 1 C in the temperature rise)

12-2 Cu NM-B conductor shows a slightly higher peak temperature than the 10-2 CCA NM-B conductor. The modeled peak temperatures shows the same trend, with the maximum computed temperature for the Cu conductor being 78.4 °C compared to 77.7 °C for the CCA conductor.

23. The calculated maximum cable temperature rise above ambient from 3D computational models for CU and CCA were 8.4% and 7.4%, respectively, above experimentally measured values, confirming the ability of the model to predict the maximum cable temperatures.

Table 1. Measured and computed max conductor temperature.

Material	NM-B Cable Size	Current (A)	Measured Max temp [°C]	Computed Max Temp [°C]	Resistance [Ohm/ft/wire]	Total Power [W/ft]
Cu	12-2 w/G	20	74.2	78.4	1.588E-03	1.270
CCA	10-2 w/G	20	74.0	77.7	1.579E-03	1.263

4.0 Modeling Results of Additional Scenarios

24. At the request of Copperweld, the model was used to evaluate additional scenarios characterized by various conductor materials, conductor sizes, and operating currents (see Table 2). Two scenarios under a 15-A load are modeled: 14-2 Cu NM-B and 12-2 CCA NM-B, with both cables having two active wires. The resistances of these two conductors are similar in value with the 14-2 Cu having a slightly higher resistance than 12-2 CCA resulting in a slightly higher total power per linear distance in the 14-2 Cu NM-B compared to the 12-2 CCA NM-B. Because 14-2 Cu NM-B has higher total power per linear distance, it would be expected that the max temperature would be higher than its CCA counterpart. The simulations reflect this with Cu and CCA having a maximum computed temperature of 75.5 °C and 74.2 °C, respectively.

25. In a scenario where a 14-2 CCA NM-B conductor carries a 10-A load through both wires, the predicted maximum temperature is 61.4 °C.

Table 2. Model temperatures of energized NM-B building wire in an insulated wall.

Material	NM-B Cable Size	Current [Amps]	Computed Max Temp [°C]	Power [W/m^3/wire]	Total Power [W/ft]
Cu	12-2 w/G	20	78.4	629,875	1.270
CCA	10-2 w/G	20	77.7	393,739	1.263
Cu	14-2 w/G	15	75.5	895,088	1.135
CCA	12-2 w/G	15	74.2	559,815	1.129
CCA	14-2 w/G	10	61.4	628,566	0.797

5.0 Limitations

26. This report includes the computational methodology and results of thermal modeling of energized Cu and CCA NM-B cables in insulated structures at the request of Copperweld Bimetallics LLC.

27. The material contained herein is presented to a reasonable degree of scientific and engineering certainty, and may not adequately address the needs of any or all users of this presentation. Any re-use of this report, or any of its contents, is made at the sole risk of the user. No guarantee or warranty as to future relevance is expressed or implied. Exponent reserves the right to supplement this report and to expand or modify its contents based on review of additional material as it becomes available and/or through any additional work or review of additional work performed by others.

28. In the presentation, we have relied on materials and information provided by Copperweld Bimetallics LLC. We cannot verify the correctness of this input and rely on Copperweld Bimetallics LLC for accuracy.

29. Although Exponent has exercised usual and customary care in preparing this report, the responsibility for the design, manufacture, and quality of their products remains fully with Copperweld Bimetallics LLC.

Appendix A
May Yen, Ph.D., CFEI
Curriculum Vitae

Exponent® Engineering & Scientific Consulting

May Yen, Ph.D., P.E., CFEI

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Professional Profile

Dr. Yen is a mechanical engineer in Exponent's Thermal Science Practice with a background in combustion, heat transfer, thermodynamics, and fluid dynamics. She specializes in multidimensional modeling and computational analysis of complex systems including industrial equipment, combustion system and fluid & heat transfer equipment with focus on failure analysis and fire and explosion investigations.

Dr. Yen has experience on consequence analysis associated with flammable releases and vapor cloud explosions in Oil & Gas facilities including performing facility evaluations for permitting and planning purposes. She specializes in computation modeling, using computational tools including FLACS, StarCCM+, and Ansys Fluent.

Dr. Yen has performed proactive burn injury hazard analysis for wearables and consumer electronics. She is also experienced in the analysis and investigation of scalds, burn injuries, and frostbite.

Dr. Yen regularly performs computational fluid dynamics(CFD) for biological flows such as heart pumps, specialized catheters, IV infusion devices, and blood oxygenators.

Dr. Yen has extensive experience in turbulent diffusion flames, soot formation for direct injection engine applications and performance and emission evaluations of diesel engines in test cells. She is proficient at coding in Fortran, C, Python, and MATLAB as well as parallelizing code with MPI (Message Passing Interface) and OpenMP. Dr. Yen regularly utilizes CAD software (Solidworks, Catia, ProE, Spaceclaim).

Prior to joining Exponent, Dr. Yen was a manager at a contract manufacturing company specializing in CNC machining of large engine components such as cylinder blocks, heads, main bearing caps, and connecting rods. Dr. Yen performed her PhD research at Purdue University where she conducted multidimensional modeling of turbulent diffusion flames for diesel engine applications. She assessed the effect of exhaust gas recirculation, combustion chamber temperature, and injection pressure on fuel-air mixing and soot formation under direct injection engine conditions. Dr. Yen's work focused on evaluating and developing soot models that were experimentally validated across several regimes and fuels types. Additionally, she has experience in evaluating performance and emissions of diesel engines in test cells.

Academic Credentials & Professional Honors

Ph.D., Mechanical Engineering, Purdue University, 2017

B.S., Mechanical Engineering, Purdue University, 2011

Pi Tau Sigma – National Mechanical Engineering Honorary

Tau Beta Pi Engineering Honor Society

Purdue University Presidential Scholarship

Licenses and Certifications

Professional Engineer Mechanical, California, #41289

Professional Affiliations

National Association of Fire Investigators—NAFI (Member)

National Fire Protection Association—NFPA (Member)

Combustion Institute

Society of Automotive Engineers (SAE)

American Society of Mechanical Engineers (ASME)

Publications

Colella F., Yen, M., “Contact Burn Injuries – Analytical Assessment of Thermal Damage in a Perfused Tissue”, IEEE International Symposium on Product Compliance Engineering, ISPCE 2021

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Appendix B
Peter Lindahl, Ph.D., CFEI
Curriculum Vitae

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Peter Lindahl, Ph.D., CFEI

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Professional Profile

Dr. Lindahl's education and training is in electrical engineering with expertise in power systems, sensors and instrumentation, electromechanical machinery (motors and generators), electrochemical systems (e.g. batteries, fuel cells, and their associated electronics), renewable and distributed energy systems, industrial controllers such as variable speed motor drives, and consumer appliances and electronics. His professional activities involve, amongst others, conducting complex investigations related to product safety, reliability, failures, and standards compliance; advising clients and providing engineering services on matters concerning intellectual property; and developing condition monitoring and fault detection and isolation techniques.

Prior to Exponent, Dr. Lindahl was a postdoctoral associate at the Massachusetts Institute of Technology. While there, he conducted research and oversaw graduate student projects related to smart grid power management and control, condition monitoring in electrical and mechanical systems, and smart building technology development including capacitive occupancy sensing and HVAC performance tracking via smart meter measurements. He received his PhD from Montana State University for his work devising sensing methods and power control management schemes for solid oxide fuel cell systems.

Throughout his career, Dr. Lindahl has provided technical and scientific services to clients in a variety of industries including aerospace, construction, electrical power, oil and gas, automotive and marine transportation, and defense including the U.S. Navy, Coast Guard, Army, and Air Force. He's co-authored over two dozen research articles in high-impact academic journals and conference proceedings. His research work has also been featured in news outlets and engineering society magazines including MIT News, the SNAME Marine Technology Magazine, and the IEEE Instrumentation & Measurement Magazine.

Academic Credentials & Professional Honors

Ph.D., Engineering, Montana State University, 2013

M.S., Electrical Engineering, Montana State University, 2009

B.S., Electrical Engineering, Penn State University, 2003

Research Affiliate, Research Laboratory of Electronics, Massachusetts Institute of Technology

Licenses and Certifications

Professional Engineer Electrical, California, #25012

Certified Fire and Explosion Investigator (CFEI)

Academic Appointments

MIT - Massachusetts Institute of Technology, Research Laboratory of Electronics (RLE), Research Affiliate/Research Scientist

Postdoctoral Associate, Research Laboratory of Electronics, Massachusetts Institute of Technology, 2014 - 2019

Communication Lab Advisor, Electrical Engineering & Computer Science Department, Massachusetts Institute of Technology, 2015 - 2018

Assistant Teaching Professor & Research Engineer, Electrical & Computer Engineering Department, Montana State University, 2013 - 2014

Ph.D. Research Assistant, Electrical & Computer Engineering Department, Montana State University, 2009 - 2013

M.S. Research Assistant, Electrical & Computer Engineering Department, Montana State University, 2006 - 2009

Undergraduate Summer Researcher, Department of Physics, University of Maryland, Baltimore County, 2000 - 2002

Prior Experience

Assistant Project Engineer, Cianbro Corporation, Baltimore, MD 2006

Field Engineer & Electrical Estimator, Cianbro Corporation, Baltimore, MD, 2005-2006

Professional Affiliations

Senior Member, Institute of Electrical and Electronics Engineers (IEEE)

Member, Tau Beta Pi Engineering Honors Society

Publications

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The following analysis is provided by Dr. David Pope PhD and Dr. Mark Licurse PhD. Drs. Pope & Licurse are both PhD materials scientists (Pope earned his degree from the California Institute of Technology & Licurse from the University of Pennsylvania). They teach at the University of Pennsylvania in the Materials Science & Engineering department, including a class on Failure Analysis of Engineering Materials. Together they have written hundreds of reports & peer reviewed journal articles on materials related issues.

Introduction:
In this section we consider the testing setup and results from our perspective as Materials Scientists. The most essential conclusion from the testing is that the temperatures of conductors in 10, 15 and 20-ampere small branch circuits, running at their rated ampacities, did not exhibit any unsafe heating trends. In addition, we clarify and/or elaborate on several specific points in the report.

Setup:
From a materials perspective, the setup is simple. Two different conductors were utilized for this testing: 10-2 w/G NM-B copper-clad aluminum cable and 12-2 w/G NM-B copper cable. The Cu & CCA NM-B cables differed in size (12 vs. 10 AWG, respectively) but each consisted of two THHN conductors and a bare equipment grounding conductor, held together in a flat row with a paper cover and an outer PVC jacket. The Cu & CCA wires in the THHN conductors are insulated with polyvinyl chloride (PVC) and covered with nylon (both of these materials are thermoplastics).

The conductors were installed through Douglas fir 2 x 6 studs. Tests were done in open air (without surrounding thermal insulation) and with thermal insulation approximating R43. To achieve this R-value, two types of insulation were used. First, Johns Manville B-7700 Climate Pro® blow-in fiberglass insulation surrounded the test cables providing an R-value of 23. Then, on one side, the studs were covered with oriented strand board (OSB), along with a sheet of 2” DuPont™ Styrofoam™ Brand ST-100 Series XPS Insulation providing an R-value of 10. On the opposite side of the studs, another 2” XPS insulation was also used. The total R-value of the insulation was 10 + 23 + 10 = 43, ignoring the additional small contribution from the OSB.

Question: could the heated cables damage the insulation and/or ignite nearby materials?
First and foremost, consider how 74°C (the maximum temperature observed in these tests) affects the insulation around the cable. This temperature is not at all dangerous for the Cu or CCA cables of any size. UL testing of NM-B cables has shown that significant insulation weight losses (by loss of plasticizer) are not observed even when cables are exposed to temperatures of as high as 120°C for 20 days, much higher than the maximum of 74°C observed in these tests. Only about 2% weight loss was observed in the UL tests after continuous exposure to 120°C for 20 days, and this exposure actually increased the breakdown voltage. Therefore, exposure to temperatures as high as 120°C for tens of days has little effect on cables insulated with plasticized, nylon-coated PVC. While temperatures did not surpass 74°C, it should be noted that exceeding 90°C by a few degrees for short times is not of major concern. Again, this is far below the cited 120°C test temperature. Note, test standard UL 83 (Standard for Thermoplastic-Insulated Wires and Cables) specifies subjecting the cables to higher temperatures of 136°C, yet even that does not cause degradation of the insulation.

Given that the insulation does not degrade at 74°C (or even 90°C), there is no concern about ignition of combustible materials surrounding the cable. The 74°C was measured on the bare conductor, and so the temperature on the outside of the cable is even lower (our tests showed an average of a 2°C drop). However, to simplify things we can ignore this drop in temperature and use 74°C, representing an even more conservative number. The materials in contact with the cable include the Douglas fir studs and the blow-in fiberglass insulation. As outlined in NFPA 921, materials can ignite by autoignition or with a pilot source (such as a flame or arc).[1] To simplify things, we will assume the worst-case scenario and simply take the lower temperature. In a review by Vytenis Babrauskas, over 30 studies were summarized and showed that 200°C is the lowest reported ignition temperature for wood (and many results are as high as 510°C).[2] Furthermore, the fiberglass insulation is noncombustible. In other words, these materials can resist far higher temperatures than the cable insulation and therefore the cables are very safe at 74°C.

Question: is 100 feet a relevant benchmark circuit length?

At each point along a conductor, the temperature is determined by a balance of heat generated by electrical resistance (I^2R) versus heat conducted away from the wire to the environment (*i.e.*, heat flow in vs. heat flow out). Near the ends of a conductor, heat is conducted away from the wire both radially (outward from the wire) and axially (along the wire out to the surrounding environment). Away from the ends of the wire, heat conduction is restricted to radial flow because the nearby conductor is at the same temperature. This creates a temperature profile where the wire is cooler near its ends and is uniform beyond a transition region near the ends. (Note, the temperature is uniform away from the ends because both the heat generation rate (from I^2R) and heat removal rate are uniform). The length of this transition region (where it goes from the cold ends to the constant temperature) is on the order of inches and not feet. This explains why the test thermocouples near the outer edges were relatively cooler, but all of the thermocouples farther in were consistently warmer. The length of the transition depends on the wire radius and the ratio of thermal conductivity of the insulation to the thermal conductivity of the wire. In other words, a higher R-value insulation will actually increase the length of the transition region. As a result of this analysis, wires longer than this transition length have a constant temperature in their middle section. This simple argument explains why no hot spots develop in long length wires and that even a 20-foot (or shorter) circuit would give the same results in the central region.

Question: How can one model the temperatures in the system?

The starting point for the proposed model is to consider the heat generated by electrical resistance (I^2R) per unit length of conductor. For a given current in the appropriate sizes (AWG) of copper and CCA, the resistance (in ohms/ft) can easily be calculated using standard resistivity

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[1] These are discussed throughout NFPA 921.

[2] Babrauskas, Vytenis, "Ignition of Wood: A Review of the State of the Art." Journal of Fire Protection Engineering. Vol. 12 (2002). 163-189. 10.1177/10423910260620482.

Note, Vytenis Babrauskas was awarded the 2024 Philip J. DiNenno Prize by the NFPA (and named a "DiNenno Prize Laureate").

values.[3] For example, for a 15A current, it would be appropriate to use 14 AWG Cu and 12 AWG CCA. This configuration leads to a resistance of 0.002523 ohms/ft for 14 AWG Cu and 0.002509 ohms/ft for 12 AWG CCA, very similar values. Then returning to heat generated by electrical resistance (I^2R), we find similar values for 14 AWG Cu and 12 AWG CCA (0.5677 and 0.5646 watts/ft, respectively). If anything, the heating rate in CCA is slightly lower, but only slightly, so test results for this comparison should be very similar, and the testing showed this to be the case. Likewise, a similar comparison of 12 AWG Cu vs. 10 AWG CCA, each energized with 20A, leads to very similar values of heat generation (0.6352 vs. 0.6314 watts/ft, respectively).

From here, one must consider the heat conducted away from the wire to the outside environment. From a given point along a conductor, heat flows radially outward, except in the cooler transition region. Closest to the conductor are layers of cable insulation; for NM-B cables, these consist of nylon and PVC (see detailed description above). Each of these slows the flow of heat from the conductor. For open air testing, one must then only consider the contributions of the other building materials, such as the studs, to slowing heat flow. For the other tests shown in this report, thermal insulation (blow-in fiberglass plus rigid XPS boards equaling R-43) was added and is designed to reduce the transfer of heat through the wall. The model considers the contributions of all of these components to find an energy balance, which gives the steady-state (no longer changing with time) temperature.

The proposed model was then validated by comparing results from it to the test data. As expected, the model provided temperatures that are slightly higher than the test data – for two main reasons: First, the physical tests were terminated once the temperature change slowed to 1°C/30 min (or less). However, the model predicts what happens if you let the test run for many (many) more hours beyond that point, allowing the temperature to slightly increase. Second, the model considers a perfect system in which there are no gaps, holes, etc. in the thermal insulation. This is good news, though, because the model predicts conservative (slightly higher) temperatures. Furthermore, the model showed that that the temperature of neither the CCA nor the Cu conductors approach 90°C. Again, this value is in itself very conservative, which we have argued to be the case based on both the stability of the insulation at much higher temperatures and the lack of fires caused by the degradation of the conductors when used in accordance with NEC recommendations.

With the validated model, one can then repeat the model simulations for other wire sizes and current loadings, as was done in this report for the 15A or 10A circuits. In each case though, the heat generation is necessarily lower, because the currents utilized are lower (15A or 10A vs. 20A for the tests in which the temperatures were monitored with thermocouples), and so the maximum (steady-state) temperatures are lower.

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[3] Cu = 10.37 Ω-cm/ft: National Bureau of Standards Circular 31, 4th edition issued January 27, 1956; Handbook 100 issued February 21, 1966 (supersedes Circular 31).
CCA = 16.385 Ω-cm/ft: value will appear in ASTM 67615 (https://www.astm.org/workitem-wk67615). This is an updated value compared to 16.5 Ω-cm/ft from ASTM B566. This difference does not alter the calculation substantially.

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Summary:

1. Construction Instruction (Ci) is a research firm dedicated to building science, industry education, and advancing construction best-practices. The Ci research facility is in Denver, Colorado where the test fixtures for this study were built, and the testing was conducted. Visit the Ci website for more information.
2. Since the early 2000s, Ci has been working with insulation manufacturers and major residential builders on advancing air sealing and thermal products for residential and light commercial new construction in route to a net zero future.
3. A major economic trend in construction points to less insulation (lower R-value) interfacing with electrical wiring methods inside of walls, and more insulation (higher R-value) on the exterior of walls and the roof deck. This trend should reduce the amount of insulation in contact with electrical wires, thus reducing the retained heat inside of walls and attics resulting from the operation of electrical wires. To be clear, we at CI do not consider the overheating of electrical wire within thermal insulation to be an inherent threat to public safety given the amperage limitations placed upon branch circuits by the National Electrical Code.
4. Future net zero energy goals for buildings will require the use of an exterior insulation product or system to boost wall thermal values in every climate zone.
5. R43 insulated wall assemblies are not common and present numerous challenges that make it difficult and expensive to achieve. Instead, the mix of cavity insulation and continuous exterior insulation will achieve greater energy conservation, as well as meet energy code.
6. Insulation was installed into test fixtures by a professional insulation contractor to meet or exceed industry standards for proper insulation installation. Insulation used meets ASTM C687-18, the Standard Practice for Determination of Thermal Resistance of Loose-Fill Building Insulation.

Construction Instruction (Ci) is a training and consulting company with four of the most-respected building scientists in the country, Justin Wilson, Gord Cooke, Mark LaLiberte, and Andrew Oding. We help North America's biggest (and smaller) builders, architects, and developers improve and refine their construction details, processes, and product selection to build higher performing homes that exceed energy codes towards a net zero and low carbon future. With this critical information, we also help major building product manufacturers develop new products that will promote more durable, healthier, better performing buildings.

Ci also teaches high performance building best-practices to thousands of building professionals each year at trade shows, industry conferences, and our Ci live experience center located in Denver, CO. Ci Productions is the media wing of the company. Ci Productions manages the Ci HD app, the website (https://constructioninstruction.com/), and Ci's VIP Newsletter. The Ci app began as a leave-behind for big builders after we consulted on their job sites — an information safety-net that could help them continue to make sense of what we teach. The app has since grown in popularity into the most-downloaded construction mobile application in Apple's app store with more than 300,000 downloads and over 60,000 active users. Ci's key customers are product manufacturers, builders, remodelers, engineers, and designers.

Ci has been working with both manufacturers and builders on advanced air sealing, water management, thermal products and applications since the early 2000's. We have reviewed numerous building and insulation materials with a focus on application in the field, durability measures, occupant comfort, and decreases in mechanical heating and cooling loads. Our recent focus in the Ci lab has been a 2-year study regarding the durability, water retention, and impact resistance of various continuous exterior insulation applications. The rationale behind this is that our client base has accepted the notion above grade walls in light frame residential construction will require thermal improvements to meet energy and carbon goals of the future.

The main types of building cavity insulation used in today's homes include fiberglass estimated usage 50-60% of residential insulation installations, blown cellulose estimated usage 15-20% of residential insulation installations, spray foam estimated usage 10-20% of residential insulation installations, and mineral wool estimated usage 5-10% of residential insulation installations. The R value of each material varies per inch with most fiberglass insulation being around 3-4 per inch and up to 6-7 per inch for closed cell spray foam. R value is a measure of a material's thermal resistance which indicates how effective the insulation material can resist the flow of heat. The higher the R value the greater the performance and resistance to heat transfer.

It is important to note that fiberglass batt insulation must be installed to a RESNET grade 1 installation. A grade 1 Installation requires that insulation material should uniformly fill wall cavities, filling each cavity from side to side and top to bottom, without substantial gaps or voids around obstructions and with an air barrier on all 6 sides. Gaps and voids create air pockets within insulation which increases the rate of thermal conduction, essentially decreasing insulations' effectiveness. Gaps, voids, and compressions also create areas for convection loops reducing the labeled R-value of fibrous insulation. Batt insulation should be cut to fit around any wiring or piping installed in the wall cavities. A grade 1 installation ensures the best performance for fiberglass batt insulation. Follow the links for more reading on insulation and how heat flows.

Since the 1950's buildings have transitioned to insulating, starting in the colder climates first, and then making its way to warmer climates to help reduce the energy costs associated with cooling. Walls were typically 2 x 4 light frame wood constructed with insulation in the wall cavities. In the 2000's energy conscious codes were implemented and a transition to 2 x 6 walls began to allow for more wall cavity insulation. In the 80's North American walls saw the first uses of continuous exterior insulation due to the energy crisis.

Since the early 2000's, code developments have increased insulation levels with objectives of new construction to meet net zero energy goals in the coming decades. Building science has been a driving factor to advance the enclosures performance through the understanding of heat, air, and moisture flows. A key to improving thermal performance of enclosure assemblies is to install insulation outboard the structure keeping structural components closer to the conditioned space. Installing insulation to the outside is advantageous because there are limitations to the amount of insulation that can be placed in wall cavities to achieve total wall R values for example the framing creates these limitations. In addition to excellent thermal control, continuous exterior insulation contributes to increased durability measures by further controlling air leakage and moisture loading of the wall assemblies. Manufacturers have seen the need for developing products to meet the construction industry's ever-increasing demands to increase thermal performance of the enclosure with new continuous exterior insulation systems that combine reasonable cavity R-values with exterior thermal insulation to create walls and roof systems that are cost effective and readily constructable.

The increase in code adoption of continuous exterior insulation can be seen in the exhibit below of the 2021 IECC prescriptive insulation values. In this table we see the wood framed walls listed with the plus… which is indicative of exterior insulation. This table is adapted from Table R402.1.2 in the 2015 and 2018 IECC, and Table R402.1.3 in the 2021 IECC. Yellow lined boxes indicate changes from previous codes.

Climate Zone	Ceilings		Wood Frame Walls		Basement Walls	
	2015/2018	2021	2015/2018	2021	2015/2018	2021
1	30	30	13	13 or **0+10**	0	0
2	38	**49**	13	13 or **0+10**	0	0
3	38	**49**	20 or 13+5	**20 or 13+5 or 0+15**	5/13	5/13
4	49	**60**	20 or 13+5	**20+5 or 13+10 or 0+15**	10/13	10/13
5	49	**60**	20 or 13+5	**20+5 or 13+10 or 0+15**	10/13	**15/19 or 13+5**
6	49	**60**	20+5 or 13+10	20+5 or 13+10 or **0+20**	15/19	**15/19 or 13+5**
7	49	**60**	20+5 or 13+10	20+5 or 13+10 or **0+20**	15/19	**15/19 or 13+5**
8	49	**60**	20+5 or 13+10	20+5 or 13+10 or **0+20**	15/19	**15/19 or 13+5**

2015-2021 IECC Minimum Insulation Requirements for New Homes

In residential construction, achieving R-43 wall cavity insulation would be considered extreme and not of a standard practice. As discussed above, while higher R-values are often associated with better thermal performance, pursuing an R-43 value within wall cavities presents several challenges. The increased thickness required to achieve this level of insulation can result in impractical wall depths, complicating both the design and construction processes. Additionally, the diminishing returns on energy savings relative to the costs involved make R-43 cavity insulation an impractical choice for most residential applications. For typical residential projects, cavity wall insulation values in the range of R-19 to R-24 are more common and provide a balanced approach between performance and feasibility. This combined with continuous exterior insulation will achieve higher total/effective wall R values in a more cost effective manner and provide increased energy efficiency.

The insulation used in the test rig was installed per the manufacturer's guidelines to ensure that the results reflect real-world applications. The installation was performed by a professional contractor, Koala Insulation, who has extensive experience in applying blown fiberglass insulation products. The installation followed typical procedures common in residential construction, ensuring that the results are relevant and applicable to standard building practices. The insulation was uniformly applied to fill the entire wall cavity, minimizing gaps, voids, and a uniform density between 1.5 and 2 lbs/ft^3. As mentioned above, air gaps within thermal insulation increase thermal conduction, allowing heat from an electrical wire to escape at a faster rate. To achieve the objectives of the insulation for the building, however, proper installation is paramount, as even the highest quality insulation materials can underperform if not correctly installed.

The insulation materials used in the test fixture conform to several industry standards that ensure their performance, safety, and durability. These materials comply with ASTM (American Society for Testing and Materials) standards, which provide guidelines for thermal performance, fire resistance, and environmental impact. For example, the blown fiberglass insulation adheres to ASTM C687-18, is the *Standard Practice for Determination of Thermal Resistance of Loose-Fill Building Insulation* and ASTM C518-21 the *Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*. Additionally, the insulation materials are tested to meet building code requirements (IRC, IECC, IBC), which establish minimum insulation standards for different climate zones. These standards help ensure that the materials used not only provide the required thermal resistance but also contribute to the overall safety and health of the building's occupants.

Construction Instruction is not an electrical engineering company, and we do not have any electrical engineers on staff. Over the past 2 years Ci has been a part of an in-depth literature review of CCA for a large national builder where we found no causes for concern when using CCA in residential building applications. Ci has been the enclosure designer, builder, and building science consultant for two Copperweld thermal conductor testing projects at our facility in Denver, CO. Ci advised and facilitated the installation of the insulation systems to meet or exceed industry standards. Ci witnessed the testing at all phases and was onsite to insure the thermal properties of the test fixtures were not altered or tampered with. We work with builders of all sizes throughout all of North America and are continuously soliciting feedback from our clients on field applications and we support forensic field investigations. Ci has not been asked to look into any issues around the application of copper-clad aluminum conductors.

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Report #:	35564-212051-3646	**Customer PO#:**	Verbal - Chuck
Customer Name:	CDC Mello		
Customer Address:	PO BOX 872317		
City:	Vancouver	**State:** WA	**Zip:** 98687
Contact:	Chuck Mello		
Service Address:	5777 SE International Way	Milwaukie, OR 97222	

Calibration Standards

23-01199 I Thermo-Hygrometer I Comark I SN: 06210350026 I Cal: 06/21/2023 I Due: 06/30/2024 I Vendor: Cal-Cert I Range: 122 °F 95 %RH I Report #: 29877-51920-4201
LP-00050 I Electrical Meter I Fluke I SN: 6725008 I Cal: 03/27/2024 I Due: 02/28/2025 I Vendor: Tektronix - Irving I Report #: C004064871

Instrument Data

Calibration Date:	June 26, 2024	**Reference:**		Manufactures Tolerances
Recommended Due Date:	June 26, 2025	**Cal-Cert Procedure:**		CP-033
Calibration Frequency:	12 Months	**Indicating System:**		Digital
Manufacturer:	Tektronix	**Temperature:**	74	°F
Type:	Multi-meter	**Humidity:**	42%	RH
Model Number:	TX3	**Asset #:**		None
Serial #:	B029681	**Service Location:**		Cal-Cert Lab
		As Found:		PASS
		As Left:		PASS

Meter Function Tested	AC Voltage	Meter Range: 1,000					Meter Setting: Measure	
Test Point	**Calibrator Setting**	**Meter Resolution**	**Tolerance ±**	**As Found**	**As Left**	**As Found Condition**	**As Left Condition**	**Expanded Uncertainty**
mV AC 60Hz	330.00	0.100	2.70	329.800	329.800	PASS	PASS	0.14
mV AC 13KHz	600.00	0.100	14.00	600.000	600.000	PASS	PASS	0.19
VAC 60Hz	3.30	0.001	0.025	3.298	3.298	PASS	PASS	0.00081
VAC 20Khz	3.30	0.001	0.086	3.297	3.297	PASS	PASS	0.0016
VAC 60Hz	33.00	0.010	0.250	32.980	32.980	PASS	PASS	0.066
VAC 20Khz	33.00	0.010	0.860	33.180	33.180	PASS	PASS	0.016
VAC 60Hz	330.00	0.100	2.500	329.700	329.700	PASS	PASS	0.13
VAC 2.5Khz	330.00	0.100	7.000	329.000	329.000	PASS	PASS	0.84
VAC 60Hz	500.00	1.000	6.000	499.700	499.700	PASS	PASS	0.61
VAC 1Khz	1000.00	1.000	14.00	1,000.000	1,000.000	PASS	PASS	0.66
Notes:								

Meter Function Tested	Frequency	Meter Range: 199,500					Meter Setting: Measure	
Test Point	**Calibrator Setting**	**Meter Resolution**	**Tolerance ±**	**As Found**	**As Left**	**As Found Condition**	**As Left Condition**	**Expanded Uncertainty**
Khz 150mV	99.95	0.010	0.0200	99.950	99.950	PASS	PASS	0.0058
Khz 150mV	199.50	0.010	0.0200	199.500	199.500	PASS	PASS	0.0059
Khz 700mV	99.95	0.010	0.0200	99.950	99.950	PASS	PASS	0.0058
Khz .7V	99.95	0.010	0.0200	99.950	99.950	PASS	PASS	0.0058
Khz 7V	99.95	0.010	0.0200	99.950	99.950	PASS	PASS	0.0058
3.4V 1Khz Sq. Wave	1000.00	0.100	0.2000	1,000.000	1,000.000	PASS	PASS	0.058
Notes:								

Meter Function Tested	DC Voltage	Meter Range: 1,000					Meter Setting: Measure	
Test Point	**Calibrator Setting**	**Meter Resolution**	**Tolerance ±**	**As Found**	**As Left**	**As Found Condition**	**As Left Condition**	**Expanded Uncertainty**
DCV	3.30	0.001	0.030	3.2990	3.2990	PASS	PASS	0.0006
DCV	33	0.01	0.030	32.9900	32.9900	PASS	PASS	0.0059
DCV	330	0.10	0.300	329.9000	329.9000	PASS	PASS	0.059
DCV	1000	1.00	2.000	1,000.0000	1,000.0000	PASS	PASS	0.58
mV	33	0.10	0.100	33.0000	33.0000	PASS	PASS	0.058
mV	330	0.10	0.400	329.9000	329.9000	PASS	PASS	0.059
Notes:								

Manufacturer: Tektronix **Type:** Multi-meter **Serial #:** B029681

Meter Function Tested	Ohms	Meter Range: 30 Mohm					Meter Setting: Measure	
Test Point	Calibrator Setting	Meter Resolution	Tolerance ±	As Found	As Left	As Found Condition	As Left Condition	Expanded Uncertainty
Ohms	330	0.10	0.9000	330.4000	330.4000	PASS	PASS	0.059
Kohms	3.30	0.001	0.0080	3.3000	3.3000	PASS	PASS	0.00065
Kohms	33	0.01	0.0800	32.9900	32.9900	PASS	PASS	0.0059
Kohms	330	0.10	2.1000	329.9000	329.9000	PASS	PASS	0.06
Mohms	3.30	0.001	0.0210	3.3110	3.3110	PASS	PASS	0.00076
Mohms	30	0.01	0.3300	30.2000	30.2000	PASS	PASS	0.093
Notes:								

Meter Function Tested	Current	Meter Range: 10A					Meter Setting: Measure	
Test Point	Calibrator Setting	Meter Resolution	Tolerance ±	As Found	As Left	As Found Condition	As Left Condition	Expanded Uncertainty
DC µA	330	0.100	1.10	329.800	329.800	PASS	PASS	0.11
DC µA	3300	1.000	9.00	3,299.000	3,299.000	PASS	PASS	0.79
AC µA 60Hz	330	0.100	3.50	329.800	329.800	PASS	PASS	0.52
AC µA 60Hz	3300	1.000	35.00	3,298.000	3,298.000	PASS	PASS	20
DC mA	33	0.010	0.11	32.980	32.980	PASS	PASS	0.0089
DC mA	330	0.100	0.90	329.900	329.900	PASS	PASS	0.17
AC mA 60Hz	33	0.010	0.35	32.980	32.980	PASS	PASS	0.035
AC mA 60Hz	330	0.100	3.5000	329.800	329.800	PASS	PASS	0.37
DC A	3	0.001	0.0100	2.998	2.998	PASS	PASS	0.0021
DC A	10	0.010	0.0400	10.000	10.000	PASS	PASS	0.008
AC A 60Hz	3	0.001	0.0320	2.999	2.999	PASS	PASS	0.004
Notes:								

Meter Function Tested	MISC	Meter Range: Various					Meter Setting: Measure	
Test Point	Calibrator Setting	Meter Resolution	Tolerance ±	As Found	As Left	As Found Condition	As Left Condition	Expanded Uncertainty
Diode 3VDC	3	0.001	0.032	2.9980	2.9980	PASS	PASS	0.00058
Cap open	0	0.01	0.310	0.0000	0.0000	PASS	PASS	0.0058
Cap uf	5	0.01	0.300	5.0030	5.0030	PASS	PASS	0.013
Cap nf	10	0.01	0.300	10.0300	10.0300	PASS	PASS	0.0058
Temp °C Type K	0	0.1	1.000	1.0000	1.0000	PASS	PASS	0.18
Temp °C Type K	10	0.1	1.000	11.0000	11.0000	PASS	PASS	0.18
Temp °C Type K	100	1.0	2.000	101.0000	101.0000	PASS	PASS	0.61
Notes:								

Remarks:

We sincerely thank you for your business. Please call us at 503-654-9620 for all your sales and calibration needs.
Cleaning and preventative maintenance were performed as part of this service.

Cal-Cert is accredited by A2LA under Calibration Laboratory Code #4986.01.
A2LA is recognized under the ILAC mutual recognition agreement (MRA).

This certificate is hereby issued that the above instrument was tested for accuracy with calibrated standards traceable to the National Institute of Standards and Technology (NIST). The information provided on this form complies with the data gathering and reporting requirements of ISO/IEC 17025 and ANSI/NCSL Z540.1, and meets the requirements of all applicable references and Cal-Cert procedures listed above.
Any stated measurement uncertainty includes the uncertainty of the Calibration standards used, combined with the uncertainty of the measurement process using the RSS method with a k=2 for an approximate 95% level of confidence. The calibration process meets or exceeds a ratio of 4:1 unless otherwise stated.
All tolerances were derived from the applicable standards and pass/fail determination is based on those tolerances. The customer determined any recommended due dates indicated on the certificate.

This report shall not be reproduced except in full, without written approval from Cal-Cert.

Service Engineer: Brent Enbysk **Date:** June 26, 2024

Quality Manager: Jason Wimmer **Signature:**

Report #: 35564-212051-36

Electrical Multi Meter Fluke 87V CF-033-16 Revision 5 7/14/2023

Report and Certificate of Calibration

CAL-CERT
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www.Cal-Cert.com

Toll Free
800-356-4662

Address
5777 SE International Way
Milwaukie, OR 97222

Local
503-654-9620

ACCREDITED
CERT #4986.01

Report #: 35564-212135-3646 **Customer PO#:** Verbal - Chuck
Customer Name: CDC Mello
Customer Address: PO BOX 872317
City: Vancouver **State:** WA **Zip:** 98687
Contact: Chuck Mello
Service Address: 5777 SE International Way Milwaukie, OR 97222

Calibration Standards

23-01199 I Thermo-Hygrometer I Comark I SN: 06210350026 I Cal: 06/21/2023 I Due: 06/30/2024 I Vendor: Cal-Cert I Range: 122 °F 95 %RH I Report #: 29877-51920-4201
LP-00050 I Electrical Meter I Fluke I SN: 6725008 I Cal: 03/27/2024 I Due: 02/28/2025 I Vendor: Tektronix - Irving I Report #: C004064871
LP-00568 I Electrical Meter I Fluke I SN: 20080819 I Cal: 06/25/2021 I Due: 06/30/2026 I Vendor: Fluke I Report #: 1500310742

Instrument Data

Calibration Date:	June 26, 2024	**Reference:**	Euramet cg-15
Recommended Due Date:	June 26, 2025	**Cal-Cert Procedure:**	CP-033
Calibration Frequency:	12 Months	**Indicating System:**	Gauge
Manufacturer:	Fluke	**Temperature:**	75 °F
Type:	Current Clamp Probe	**Humidity:**	42% RH
Model Number:	80I-600	**Cal Factor:**	None
Serial #:	Unknown	**Asset #:**	None
Range Resolution:	0.1 AC Amperes	**Service Location:**	Cal-Cert Lab
Capacity:	600.0 AC Amperes	**As Found:**	Pass
Tolerance:	6.00 AC Amperes 1.00% of full scale	**As Left:**	Pass

Instrument Range: 600 **Range Resolution:** 0.1 **Mode Verified:** AC Amperes

Instrument Reading	As Found	Verification Reading #1	Error	Verification Reading #2	Error
0.00	0.00	0.00	0.00	0.00	0.00
10.00	9.98	9.98	-0.02	9.98	-0.02
30.00	29.95	29.95	-0.05	29.95	-0.05
60.00	60.00	60.00	0.00	60.00	0.00
125.00	125.00	125.00	0.00	125.00	0.00
250.00	250.10	250.10	0.10	250.10	0.10
550.00	549.00	549.00	-1.00	549.00	-1.00
0.00	0.00	0.00	0.00	0.00	0.00

Expanded Uncertainty ± 0.1154792 AC Amperes

Remarks:

Calibrated with meter sn B029681

We sincerely thank you for your business. Please call us at 503-654-9620 for all your sales and calibration needs.
Cleaning and preventative maintenance were performed as part of this service.

Cal-Cert is accredited by A2LA under Calibration Laboratory Code #4986.01.
A2LA is recognized under the ILAC mutual recognition agreement (MRA).

This certificate is hereby issued that the above instrument was tested for accuracy with calibrated standards traceable to the National Institute of Standards and Technology (NIST). The information provided on this form complies with the data gathering and reporting requirements of ISO/IEC 17025 and ANSI/NCSL Z540.1, and meets the requirements of all applicable references and Cal-Cert procedures listed above.
Any stated measurement uncertainty includes the uncertainty of the Calibration standards used, combined with the uncertainty of the measurement process using the RSS method with a k=2 for an approximate 95% level of confidence. The calibration process meets or exceeds a ratio of 4:1 unless otherwise stated.
All tolerances were derived from the applicable standards and pass/fail determination is based on those tolerances. The customer determined any recommended due dates indicated on the certificate.
This report shall not be reproduced except in full, without written approval from Cal-Cert.

Service Engineer: Brent Enbysk **Date:** June 26, 2024

Quality Manager: Jason Wimmer **Signature:**

Report and Certificate of Calibration

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Local
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ACCREDITED
CERT #4986.01

Report #:	35564-212134-3646	**Customer PO#:** Verbal - Chuck	
Customer Name:	CDC Mello		
Customer Address:	PO BOX 872317		
City:	Vancouver	**State:** WA	**Zip:** 98687
Contact:	Chuck Mello		
Service Address:	5777 SE International Way	Milwaukie, OR 97222	

Calibration Standards

23-01199 I Thermo-Hygrometer I Comark I SN: 06210350026 I Cal: 06/21/2023 I Due: 06/30/2024 I Vendor: Cal-Cert I Range: 122 °F 95 %RH I Report #: 29877-51920-4201
LP-00050 I Electrical Meter I Fluke I SN: 6725008 I Cal: 03/27/2024 I Due: 02/28/2025 I Vendor: Tektronix - Irving I Report #: C004064871
LP-00568 I Electrical Meter I Fluke I SN: 20080819 I Cal: 06/25/2021 I Due: 06/30/2026 I Vendor: Fluke I Report #: 1500310742

Instrument Data

Calibration Date:	June 26, 2024	**Reference:**	Euramet cg-15
Recommended Due Date:	June 26, 2025	**Cal-Cert Procedure:**	CP-033
Calibration Frequency:	12 Months	**Indicating System:**	Gauge
Manufacturer:	Fluke	**Temperature:**	75 °F
Type:	Current Clamp Probe	**Humidity:**	41% RH
Model Number:	Y8101A	**Cal Factor:**	None
Serial #:	66463670	**Asset #:**	None
Range Resolution:	0.1 AC Amperes	**Service Location:**	Cal-Cert Lab
Capacity:	150.0 AC Amperes	**As Found:**	Pass
Tolerance:	3.00 AC Amperes 2.00% of full scale	**As Left:**	Pass

Instrument Range: 150 **Range Resolution:** 0.1 **Mode Verified:** AC Amperes

Instrument Reading	As Found	Verification Reading #1	Error	Verification Reading #2	Error
0.00	0.00	0.00	0.00	0.00	0.00
1.00	0.912	0.912	-0.09	0.912	-0.09
10.00	9.960	9.960	-0.04	9.960	-0.04
20.00	19.970	19.970	-0.03	19.970	-0.03
40.00	40.080	40.080	0.08	40.080	0.08
70.00	70.400	70.400	0.40	70.400	0.40
140.00	139.900	139.900	-0.10	139.900	-0.10
0.00	0.00	0.00	0.00	0.00	0.00

Expanded Uncertainty ± 0.1154792 AC Amperes

Remarks:

Tolerance is ±2.5% +0.15A from 48Hz to 440Hz and ±3%+0.15A from 440Hz to 1200Hz
Calibrated with meter sn B029681

We sincerely thank you for your business. Please call us at 503-654-9620 for all your sales and calibration needs.
Cleaning and preventative maintenance were performed as part of this service.

Cal-Cert is accredited by A2LA under Calibration Laboratory Code #4986.01.
A2LA is recognized under the ILAC mutual recognition agreement (MRA).

This certificate is hereby issued that the above instrument was tested for accuracy with calibrated standards traceable to the National Institute of Standards and Technology (NIST). The information provided on this form complies with the data gathering and reporting requirements of ISO/IEC 17025 and ANSI/NCSL Z540.1, and meets the requirements of all applicable references and Cal-Cert procedures listed above.
Any stated measurement uncertainty includes the uncertainty of the Calibration standards used, combined with the uncertainty of the measurement process using the RSS method with a k=2 for an approximate 95% level of confidence. The calibration process meets or exceeds a ratio of 4:1 unless otherwise stated.
All tolerances were derived from the applicable standards and pass/fail determination is based on those tolerances. The customer determined any recommended due dates indicated on the certificate.
This report shall not be reproduced except in full, without written approval from Cal-Cert.

Service Engineer:	Brent Enbysk	**Date:**	June 26, 2024
Quality Manager:	Jason Wimmer	**Signature:**	

ACCREDITED
CERT #2496.01

Report of Calibration

Eustis Co., Inc./Pyrocom Calibration Lab
12407-B Mukilteo Speedway #200
Lynnwood, WA 98087

Report No: KJ202406473-003

Model: UL4047 Serial: 995284A-014A Description: TYPE J, 30AWG, FEP/FEP	Customer: .
Calibration Range: Limited Received Condition: New Current: N/A Procedure: ECP 336/301	CDC Mello Consulting Chuck Mello PO Box 872317 Vancouver, WA 98687

The unit under test (UUT) on this certificate has been calibrated by comparison method as covered by ASTM E220, and calibrated against standards traceable to the International System of Units (SI) through recognized national metrology institutes such as NIST, or ratiometric techniques, or natural physical constants. 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	20.80	20.78	-0.02	+/-0.31	COMP
40.00	40.22	40.16	-0.06	+/-0.37	COMP
95.00	94.20	94.02	-0.18	+/-0.37	COMP
150.00	149.03	148.98	-0.05	+/-0.37	COMP
200.00	198.88	198.85	-0.03	+/-0.37	COMP

Test Equipment

Manufacturer	Model	Description	Serial Number	Recall Date
Hart Scientific	1560	"Black Stack" Base Unit	6C135	NCR
Hart Scientific	2560	SPRT Module	A61877	12/1/2024
Fluke	5628	Sec Ref Probe	2789	12/10/2024
Fluke	2566	Thermocouple Scanner	B63321	12/2/2024
Hart Scientific	9127	Dry-well, High-Temperature	A26057	NCR
Hart Scientific	7103	Bath, Portable Micro	A95309	NCR

Calibration Date: 6/24/2024
Temperature: 23.0 C
Humidity: 41%
Customer Order: 311445-S

Technician: Kulin Julia

Approved By: Ariel Beringer, QA Manager

Report of Calibration

Notes: The thermocouple wire meets or exceeds the criteria established for type "J" SPECIAL LIMITS OF ERROR per ASTM E230/E230M-23A 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-23A 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 2 5 2024

Report of Calibration

ACCREDITED
CERT #2496.01

Eustis Co., Inc./Pyrocom Calibration Lab
12407-B Mukilteo Speedway #200
Lynnwood, WA 98087

Report No: JK202404383-004

Model: UL4047 Serial: 993036-009C Description: TYPE J, 30AWG, FEP/FEP	Customer: . . CDC Mello Consulting Chuck Mello 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, and calibrated against standards traceable to the International System of Units (SI) through recognized national metrology institutes such as NIST, or ratiometric techniques, or natural physical constants. 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	21.40	21.43	0.03	+/- 0.31	COMP
40.00	40.06	40.03	-0.03	+/- 0.40	COMP
95.00	95.03	94.89	-0.14	+/- 0.40	COMP
150.00	149.98	149.92	-0.06	+/- 0.50	COMP
200.00	199.96	200.06	0.10	+/- 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	10/20/2024
Fluke	5628	4 Wire SPRT	4303	5/2/2024
Fluke	2566	Thermocouple Scanner	B7A380	10/21/2024
Fluke	7380	Bath, Ultra Low-Temperature	B2A527	NCR
Fluke	9173	Metrology Well, 700 C	B47975	NCR

Calibration Date: 4/8/2024
Temperature: 24.0 C
Humidity: 33%
Customer Order: 2119-PTM REL#3 OF 3

Technician: Julia Kulin

Approved By: Ariel Beringer
QA Manager

Report of Calibration

Notes: The thermocouple wire meets or exceeds the criteria established for type "J" SPECIAL LIMITS OF ERROR per ASTM E230/E230M-23A 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-23A 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: APR 0 8 2024

ACCREDITED
CERT #2496.01

Report of Calibration

Eustis Co., Inc./Pyrocom Calibration Lab
12407-B Mukilteo Speedway #200
Lynnwood, WA 98087

Report No: KJ202406473-003

Model: UL4047 Serial: 995284A-014A Description: TYPE J, 30AWG, FEP/FEP	Customer: . . CDC Mello Consulting PO Box 872317 Vancouver, WA 98687
Calibration Range: Limited Received Condition: New Current: N/A Procedure: ECP 336/301	

The unit under test (UUT) on this certificate has been calibrated by comparison method as covered by ASTM E220, and calibrated against standards traceable to the International System of Units (SI) through recognized national metrology institutes such as NIST, or ratiometric techniques, or natural physical constants. 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	20.80	20.78	-0.02	+/-0.31	COMP
40.00	40.22	40.16	-0.06	+/-0.37	COMP
95.00	94.20	94.02	-0.18	+/-0.37	COMP
150.00	149.03	148.98	-0.05	+/-0.37	COMP
200.00	198.88	198.85	-0.03	+/-0.37	COMP

Test Equipment

Manufacturer	Model	Description	Serial Number	Recall Date
Hart Scientific	1560	"Black Stack" Base Unit	6C135	NCR
Hart Scientific	2560	SPRT Module	A61877	12/1/2024
Fluke	5628	Sec Ref Probe	2789	12/10/2024
Fluke	2566	Thermocouple Scanner	B63321	12/2/2024
Hart Scientific	9127	Dry-well, High-Temperature	A26057	NCR
Hart Scientific	7103	Bath, Portable Micro	A95309	NCR

Calibration Date: 6/24/2024
Temperature: 23.0 C
Humidity: 41%
Customer Order: 311445-S

Technician: Kulin Julia

Approved By: Ariel Beringer
QA Manager

Report of Calibration

Notes: The thermocouple wire meets or exceeds the criteria established for type "J" SPECIAL LIMITS OF ERROR per ASTM E230/E230M-23A 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-23A 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 2 5 2024

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	EL-146
Description	Data Acquisition System
Calibrated	9/21/2023
Performed At	PCS Lab

Manufacturer	Keysight	**Location**	Main	**Frequency**	Annual
Model Number	DAQ970A	**Building**	2550 Huntsville Highway • Fayetteville, TN 37334	**Certificate #**	CO092123JM-04
Serial Number	MY58018811	**Department**	Electrical Lab	**Temp**	68°F
Cal Procedure	QS0011JB2010	**Status**	In Service	**Humidity**	55%

This is a cover sheet. Please see subsequent pages for calibration results and details.

Test Instruments Used During the Calibration

Test Instrument ID					(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-EL-008 FLUKE 5522A CALIBRATOR	Fluke 5522A Multi-Product Electrical Calibrator	FLUKE	5522A	3364904	1/4/2023	1/4/2025

Notes about this calibration

DC Volts Uncertainty = ± 6.1 mVDC
DC Current Uncertainty = ± 0.22 mA
AC Volts Uncertainty = ± 0.34 VAC
AC Current Uncertainty = ± 0.0024 A
Resistance Uncertainty = ± 17 MOhms
Capacitance Uncertainty = ± 0.02 mF
Frequency Uncertainty = ± 0.6 kHz
Temperature Uncertainty = ± 0.42 °C
(95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By Administrator

Revision Date: 05/08/2020
Rev: 04

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

PJLA Calibration Accreditation# 73403

Copperweld

Instrument ID EL-146

Description Data Acquisition System

Calibrated 9/21/2023

Performed At PCS Lab

Date Finalized 9/21/2023 3:59:25PM

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.

Laboratory Authorized Signature Rayburn Flatt

Keysight 970A

ID: EL-146

DC VOLTS

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	mV	89.999	89.999	TRUE	TRUE	100	0.005%	0.006%	0	0.0105	89.9895	90.0105	± 22 µV
0.9	V	0.89997	0.89997	TRUE	TRUE	1	0.0035%	0.0006%	0	0.0000375	0.8999625	0.9000375	± 39 µV
9	V	8.99998	8.99998	TRUE	TRUE	10	0.003%	0.0004%	0	0.00031	8.99969	9.00031	± 0.4 mV
90	V	89.9997	89.9997	TRUE	TRUE	100	0.004%	0.0006%	0	0.0042	89.9958	90.0042	± 6.1 mV
270	V	269.999	269.999	TRUE	TRUE	300	0.004%	0.002%	0	0.0168	269.9832	270.0168	± 6.1 mV

AC VOLTS

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	mV	89.954	89.954	TRUE	TRUE	100	0.06%	0.02%	0	0.074	89.926	90.074	± 0.66 mV
0.9	V	0.900009	0.900009	TRUE	TRUE	1	0.06%	0.02%	0	0.00074	0.89926	0.90074	± 7.9 mV
9	V	9.000019	9.000019	TRUE	TRUE	10	0.06%	0.02%	0	0.0074	8.9926	9.0074	± 32 mV
90	V	89.9929	89.9929	TRUE	TRUE	100	0.06%	0.02%	0	0.074	89.926	90.074	± 0.34 V
270	V	269.972	269.972	TRUE	TRUE	300	0.06%	0.06%	0	0.342	269.658	270.342	± 0.34 V

RESISTANCE

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	Ω	89.9986	89.9986	TRUE	TRUE	100	0.007%	0.006%	0	0.0123	89.9877	90.0123	± 2 mOhm
0.9	kΩ	0.9000006	0.9000006	TRUE	TRUE	1	0.005%	0.001%	0	0.000052	0.899948	0.900052	± 0.04 Ohm
9	kΩ	8.999964	8.999964	TRUE	TRUE	10	0.005%	0.001%	0	0.0005	8.9995	9.0005	± 0.3 Ohm
90	kΩ	90.00013	90.00013	TRUE	TRUE	100	0.005%	0.001%	0	0.005	89.995	90.005	± 3.4 Ohm
0.9	MΩ	0.8999971	0.8999971	TRUE	TRUE	1	0.008%	0.001%	0	0.000077	0.899923	0.900077	± 0.1 kOhm
9	MΩ	8.999431	8.999431	TRUE	TRUE	10	0.03%	0.001%	0	0.0028	8.9972	9.0028	± 1.4 kOhm
90	MΩ	89.91536	89.91536	TRUE	TRUE	100	0.4%	0.001%	0	0.361	89.639	90.361	± 56 kOhm
900	MΩ	893.6025	893.6025	TRUE	TRUE	1000	4%	0.001%	0	36.01	863.99	936.01	± 17 MOhm

DC CURRENT

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
0.9	uA	0.89946	0.89946	TRUE	TRUE	1	0.06%	0.005%	0	0.00059	0.8994100	0.9005900	± 0.05 µA
9	uA	8.999945	8.999945	TRUE	TRUE	10	0.06%	0.002%	0	0.0056	8.9944000	9.0056000	± 0.05 µA
90	uA	89.9997	89.9997	TRUE	TRUE	100	0.06%	0.001%	0	0.055	89.9450000	90.0550000	± 0.05 µA
0.9	mA	0.900021	0.900021	TRUE	TRUE	1	0.06%	0.01%	0	0.00059	0.89941	0.90059	± 0.33 µA
9	mA	9.00062	9.00062	TRUE	TRUE	10	0.06%	0.02%	0	0.0074	8.9926	9.0074	± 3.3 µA
90	mA	90.0051	90.0051	TRUE	TRUE	100	0.06%	0.005%	0	0.059	89.941	90.059	± 36 µA
0.9	A	0.900134	0.900134	TRUE	TRUE	1	0.1%	0.01%	0	0.00064	0.89936	0.90064	± 0.22 mA

AC CURRENT

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	uA	90.0147	90.0147	TRUE	TRUE	100	0.1%	0.04%	0	0.13	89.8700000	90.1300000	± 1.7 µA
0.9	mA	0.900002	0.900002	TRUE	TRUE	1	0.1%	0.04%	0	0.0013	0.89870	0.90130	± 9.6 µA
9	mA	9.00155	9.00155	TRUE	TRUE	10	0.1%	0.04%	0	0.013	8.9870	9.0130	± 16 µA
90	mA	90.0115	90.0115	TRUE	TRUE	100	0.1%	0.04%	0	0.13	89.870	90.130	± 0.57 mA
0.9	A	0.90014	0.90014	TRUE	TRUE	1	0.1%	0.04%	0	0.0013	0.89870	0.90130	± 0.51 mA

FREQUENCY

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
9	Hz	9.00014	9.00014	TRUE	TRUE	10	0.07%	0	0	0.0063	8.9937	9.0063	± 0.6 mHz
90	Hz	90.0006	90.0006	TRUE	TRUE	100	0.03%	0	0	0.027	89.9730	90.0270	± 0.6 mHz
900	Hz	900.005	900.005	TRUE	TRUE	1000	0.01%	0	0	0.09	899.910	900.090	± 0.01 Hz
9	kHz	9.00004	9.00004	TRUE	TRUE	10	0.009%	0	0	0.00081	8.9992	9.0008	± 0.06 kHz
90	kHz	90.00004	90.00004	TRUE	TRUE	100	0.008%	0	0	0.0072	89.993	90.007	± 0.6 kHz

CAPACITANCE

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
9	nF	9.046	9.046	TRUE	TRUE	10	0.4%	0.1%	0	0.046	8.95	9.05	± 0.07 nF
90	nF	89.9	89.9	TRUE	TRUE	100	0.4%	0.1%	0	0.46	89.5	90.5	± 0.01 µF
0.9	uF	0.9001	0.9001	TRUE	TRUE	1	0.4%	0.1%	0	0.0046	0.895	0.905	± 0.29 µF
9	uF	8.998	8.998	TRUE	TRUE	10	0.4%	0.1%	0	0.046	8.954	9.046	± 0.29 µF
90	uF	89.96	89.96	TRUE	TRUE	100	0.4%	0.1%	0	0.46	89.54	90.46	± 0.02 mF

TEMPERATURE Type-K

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
-100	°C	-100.39	-100.39	TRUE	TRUE	-100	0.0%	0%	0.9	0.9	-100.9	-99.1	± 0.35°C
500	°C	499.71	499.71	TRUE	TRUE	500	0.0%	0%	0.9	0.9	499.100	500.900	± 0.42°C
1000	°C	999.69	999.69	TRUE	TRUE	1000	0.0%	0%	0.9	0.9	999.100	1000.900	± 0.42°C

END OF REPORT

PRECISION CALIBRATION SYSTEMS
107 N Porter St
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Website: www.pcsllctn.com

INSTRUMENT CALIBRATION REPORT

PJLA Calibration Accreditation# 73403

Copperweld

Instrument ID EL-148
Description Data Acquisition System
Calibrated 9/21/2023
Performed At PCS Lab

Manufacturer	Keysight	**Location**	Main	**Frequency**	Annual
Model Number	DAQ970A	**Building**	2550 Huntsville Highway • Fayetteville, TN 37334	**Certificate #**	CO092123JM-03
Serial Number	MY58018798	**Department**	Electrical Lab	**Temp**	68°F
Cal Procedure	QS0011JB2010	**Status**	In Service	**Humidity**	55%

This is a cover sheet. Please see subsequent pages for calibration results and details.

Test Instruments Used During the Calibration

Test Instrument ID					(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-EL-008 FLUKE 5522A CALIBRATOR	Fluke 5522A Multi-Product Electrical Calibrator	FLUKE	5522A	3364904	1/4/2023	1/4/2025

Notes about this calibration

DC Volts Uncertainty = ± 6.1 mVDC
DC Current Uncertainty = ± 0.22 mA
AC Volts Uncertainty = ± 0.34 VAC
AC Current Uncertainty = ± 0.0024 A
Resistance Uncertainty = ± 17 MOhms
Capacitance Uncertainty = ± 0.02 mF
Frequency Uncertainty = ± 0.6 kHz
Temperature Uncertainty = ± 0.42 °C
(95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By Administrator

Revision Date: 05/08/2020
Rev: 04

QF0016

PRECISION CALIBRATION SYSTEMS
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INSTRUMENT CALIBRATION REPORT

PJLA Calibration Accreditation# 73403

Copperweld

Instrument ID EL-148

Description Data Acquisition System

Calibrated 9/21/2023

Performed At PCS Lab

Date Finalized 9/21/2023 4:00:00PM

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.

Laboratory Authorized Signature

Keysight 970A

ID: EL-148

DC VOLTS

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	mV	89.996	89.996	TRUE	TRUE	100	0.005%	0.006%	0	0.0105	89.9895	90.0105	± 22 µV
0.9	V	0.900002	0.900002	TRUE	TRUE	1	0.0035%	0.0006%	0	0.0000375	0.8999625	0.9000375	± 39 µV
9	V	9.00005	9.00005	TRUE	TRUE	10	0.003%	0.0004%	0	0.00031	8.99969	9.00031	± 0.4 mV
90	V	90.0007	90.0007	TRUE	TRUE	100	0.004%	0.0006%	0	0.0042	89.9958	90.0042	± 6.1 mV
270	V	270.003	270.003	TRUE	TRUE	300	0.004%	0.002%	0	0.0168	269.9832	270.0168	± 6.1 mV

AC VOLTS

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	mV	89.969	89.969	TRUE	TRUE	100	0.06%	0.02%	0	0.074	89.926	90.074	± 0.66 mV
0.9	V	0.900022	0.900022	TRUE	TRUE	1	0.06%	0.02%	0	0.00074	0.89926	0.90074	± 7.9 mV
9	V	9.00032	9.00032	TRUE	TRUE	10	0.06%	0.02%	0	0.0074	8.9926	9.0074	± 32 mV
90	V	90.0003	90.0003	TRUE	TRUE	100	0.06%	0.02%	0	0.074	89.926	90.074	± 0.34 V
270	V	269.993	269.993	TRUE	TRUE	300	0.06%	0.06%	0	0.342	269.658	270.342	± 0.34 V

RESISTANCE

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	Ω	90.0027	90.0027	TRUE	TRUE	100	0.007%	0.006%	0	0.0123	89.9877	90.0123	± 2 mOhm
0.9	kΩ	0.9000121	0.9000121	TRUE	TRUE	1	0.005%	0.001%	0	0.000052	0.899948	0.900052	± 0.04 Ohm
9	kΩ	8.999963	8.999963	TRUE	TRUE	10	0.005%	0.001%	0	0.0005	8.9995	9.0005	± 0.3 Ohm
90	kΩ	89.99984	89.99984	TRUE	TRUE	100	0.005%	0.001%	0	0.005	89.995	90.005	± 3.4 Ohm
0.9	MΩ	0.8999972	0.8999972	TRUE	TRUE	1	0.008%	0.001%	0	0.000077	0.899923	0.900077	± 0.1 kOhm
9	MΩ	8.999215	8.999215	TRUE	TRUE	10	0.03%	0.001%	0	0.0028	8.9972	9.0028	± 1.4 kOhm
90	MΩ	89.91572	89.91572	TRUE	TRUE	100	0.4%	0.001%	0	0.361	89.639	90.361	± 56 kOhm
900	MΩ	888.6374	888.6374	TRUE	TRUE	1000	4%	0.001%	0	36.01	863.99	936.01	± 17 MOhm

DC CURRENT

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
0.9	uA	0.89956	0.89956	TRUE	TRUE	1	0.06%	0.005%	0	0.00059	0.8994100	0.9005900	± 0.05 µA
9	uA	8.99945	8.99945	TRUE	TRUE	10	0.06%	0.002%	0	0.0056	8.9944000	9.0056000	± 0.05 µA
90	uA	89.9995	89.9995	TRUE	TRUE	100	0.06%	0.001%	0	0.055	89.9450000	90.0550000	± 0.05 µA
0.9	mA	0.900002	0.900002	TRUE	TRUE	1	0.06%	0.01%	0	0.00059	0.89941	0.90059	± 0.33 µA
9	mA	9.00057	9.00057	TRUE	TRUE	10	0.06%	0.02%	0	0.0074	8.9926	9.0074	± 3.3 µA
90	mA	90.0047	90.0047	TRUE	TRUE	100	0.06%	0.005%	0	0.059	89.941	90.059	± 36 µA
0.9	A	0.900066	0.900066	TRUE	TRUE	1	0.1%	0.01%	0	0.00064	0.89936	0.90064	± 0.22 mA

AC CURRENT

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	uA	90.0068	90.0068	TRUE	TRUE	100	0.1%	0.04%	0	0.13	89.8700000	90.1300000	± 1.7 µA
0.9	mA	0.899977	0.899977	TRUE	TRUE	1	0.1%	0.04%	0	0.0013	0.89870	0.90130	± 9.6 µA
9	mA	9.00145	9.00145	TRUE	TRUE	10	0.1%	0.04%	0	0.013	8.9870	9.0130	± 16 µA
90	mA	90.0131	90.0131	TRUE	TRUE	100	0.1%	0.04%	0	0.13	89.870	90.130	± 0.57 mA
0.9	A	0.900075	0.900075	TRUE	TRUE	1	0.1%	0.04%	0	0.0013	0.89870	0.90130	± 0.51 mA

FREQUENCY

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
9	Hz	9.00012	9.00012	TRUE	TRUE	10	0.07%	0	0	0.0063	8.9937	9.0063	± 0.6 mHz
90	Hz	90.0004	90.0004	TRUE	TRUE	100	0.03%	0	0	0.027	89.9730	90.0270	± 0.6 mHz
900	Hz	900.006	900.006	TRUE	TRUE	1000	0.01%	0	0	0.09	899.910	900.090	± 0.01 Hz
9	kHz	9.00005	9.00005	TRUE	TRUE	10	0.009%	0	0	0.00081	8.9992	9.0008	± 0.06 kHz
90	kHz	90.0006	90.0006	TRUE	TRUE	100	0.008%	0	0	0.0072	89.993	90.007	± 0.6 kHz

CAPACITANCE

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
9	nF	9.037	9.037	TRUE	TRUE	10	0.4%	0.1%	0	0.046	8.95	9.05	± 0.07 nF
90	nF	90.1	90.1	TRUE	TRUE	100	0.4%	0.1%	0	0.46	89.5	90.5	± 0.01 µF
0.9	uF	0.903	0.903	TRUE	TRUE	1	0.4%	0.1%	0	0.0046	0.895	0.905	± 0.29 µF
9	uF	8.972	8.972	TRUE	TRUE	10	0.4%	0.1%	0	0.046	8.954	9.046	± 0.29 µF
90	uF	89.93	89.93	TRUE	TRUE	100	0.4%	0.1%	0	0.46	89.54	90.46	± 0.02 mF

TEMPERATURE Type-K

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
-100	°C	-100.3	-100.3	TRUE	TRUE	-100	0.0%	0%	0.9	0.9	-100.9	-99.1	± 0.35°C
500	°C	499.75	499.75	TRUE	TRUE	500	0.0%	0%	0.9	0.9	499.100	500.900	± 0.42°C
1000	°C	999.73	999.73	TRUE	TRUE	1000	0.0%	0%	0.9	0.9	999.100	1000.900	± 0.42°C

END OF REPORT

PRECISION CALIBRATION SYSTEMS
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INSTRUMENT CALIBRATION REPORT

ilac-MRA — PJLA Calibration Accreditation# 73403

Copperweld

Instrument ID EL-154
Description Data Acquisition System
Calibrated 9/21/2023
Performed At PCS Lab

Manufacturer	Keysight	**Location**	Main	**Frequency**	Annual
Model Number	DAQ970A	**Building**	2550 Huntsville Highway • Fayetteville, TN 37334	**Certificate #**	CO092123JM-06
Serial Number	MY58029603	**Department**	Electrical Lab	**Temp**	68°F
Cal Procedure	QS0011JB2010	**Status**	In Service	**Humidity**	55%

This is a cover sheet. Please see subsequent pages for calibration results and details.

Test Instruments Used During the Calibration

Test Instrument ID					(As Of Cal Entry Date) Last Cal Date	Next Cal Date
Z-EL-008 FLUKE 5522A CALIBRATOR	Fluke 5522A Multi-Product Electrical Calibrator	FLUKE	5522A	3364904	1/4/2023	1/4/2025

Notes about this calibration

DC Volts Uncertainty = ± 6.1 mVDC
DC Current Uncertainty = ± 0.22 mA
AC Volts Uncertainty = ± 0.34 VAC
AC Current Uncertainty = ± 0.0024 A
Resistance Uncertainty = ± 17 MOhms
Capacitance Uncertainty = ± 0.02 mF
Frequency Uncertainty = ± 0.6 kHz
Temperature Uncertainty = ± 0.42 °C
(95%CL; K=2)

Calibration Result Calibration Successful
Who Calibrated James Meadows
Finalized By Administrator

Revision Date: 05/08/2020
Rev: 04

QF0016

PCS | PRECISION CALIBRATION SYSTEMS

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INSTRUMENT CALIBRATION REPORT

PJLA Calibration Accreditation# 73403

Copperweld

Instrument ID EL-154

Description Data Acquisition System

Calibrated 9/21/2023 **Performed At** PCS Lab

Date Finalized 9/21/2023 4:03:25PM

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.

Laboratory Authorized Signature Rayburn Flatt

Keysight 970A

ID: EL-154

DC VOLTS

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	mV	89.998	89.998	TRUE	TRUE	100	0.005%	0.006%	0	0.0105	89.9895	90.0105	± 22 µV
0.9	V	0.899992	0.899992	TRUE	TRUE	1	0.0035%	0.0006%	0	0.0000375	0.8999625	0.9000375	± 39 µV
9	V	8.99996	8.99996	TRUE	TRUE	10	0.003%	0.0004%	0	0.00031	8.99969	9.00031	± 0.4 mV
90	V	89.9991	89.9991	TRUE	TRUE	100	0.004%	0.0006%	0	0.0042	89.9958	90.0042	± 6.1 mV
270	V	269.997	269.997	TRUE	TRUE	300	0.004%	0.002%	0	0.0168	269.9832	270.0168	± 6.1 mV

AC VOLTS

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	mV	89.991	89.991	TRUE	TRUE	100	0.06%	0.02%	0	0.074	89.926	90.074	± 0.66 mV
0.9	V	0.900041	0.900041	TRUE	TRUE	1	0.06%	0.02%	0	0.00074	0.89926	0.90074	± 7.9 mV
9	V	9.00045	9.00045	TRUE	TRUE	10	0.06%	0.02%	0	0.0074	8.9926	9.0074	± 32 mV
90	V	89.9974	89.9974	TRUE	TRUE	100	0.06%	0.02%	0	0.074	89.926	90.074	± 0.34 V
270	V	269.981	269.981	TRUE	TRUE	300	0.06%	0.06%	0	0.342	269.658	270.342	± 0.34 V

RESISTANCE

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	Ω	90.0015	90.0015	TRUE	TRUE	100	0.007%	0.006%	0	0.0123	89.9877	90.0123	± 2 mOhm
0.9	kΩ	0.9000081	0.9000081	TRUE	TRUE	1	0.005%	0.001%	0	0.000052	0.899948	0.900052	± 0.04 Ohm
9	kΩ	9.000016	9.000016	TRUE	TRUE	10	0.005%	0.001%	0	0.0005	8.9995	9.0005	± 0.3 Ohm
90	kΩ	90.00044	90.00044	TRUE	TRUE	100	0.005%	0.001%	0	0.005	89.995	90.005	± 3.4 Ohm
0.9	MΩ	0.8999775	0.8999775	TRUE	TRUE	1	0.008%	0.001%	0	0.000077	0.899923	0.900077	± 0.1 kOhm
9	MΩ	8.997451	8.997451	TRUE	TRUE	10	0.03%	0.001%	0	0.0028	8.9972	9.0028	± 1.4 kOhm
90	MΩ	89.98672	89.98672	TRUE	TRUE	100	0.4%	0.001%	0	0.361	89.639	90.361	± 56 kOhm
900	MΩ	888.5133	888.5133	TRUE	TRUE	1000	4%	0.001%	0	36.01	863.99	936.01	± 17 MOhm

DC CURRENT

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
0.9	uA	0.89952	0.89952	TRUE	TRUE	1	0.06%	0.005%	0	0.00059	0.8994100	0.9005900	± 0.05 µA
9	uA	8.99968	8.99968	TRUE	TRUE	10	0.06%	0.002%	0	0.0056	8.9944000	9.0056000	± 0.05 µA
90	uA	89.9997	89.9997	TRUE	TRUE	100	0.06%	0.001%	0	0.055	89.9450000	90.0550000	± 0.05 µA
0.9	mA	0.899996	0.899996	TRUE	TRUE	1	0.06%	0.01%	0	0.00059	0.89941	0.90059	± 0.33 µA
9	mA	9.0012	9.0012	TRUE	TRUE	10	0.06%	0.02%	0	0.0074	8.9926	9.0074	± 3.3 µA
90	mA	90.0091	90.0091	TRUE	TRUE	100	0.06%	0.005%	0	0.059	89.941	90.059	± 36 µA
0.9	A	0.90011	0.90011	TRUE	TRUE	1	0.1%	0.01%	0	0.00064	0.89936	0.90064	± 0.22 mA

AC CURRENT

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
90	uA	89.9979	89.9979	TRUE	TRUE	100	0.1%	0.04%	0	0.13	89.8700000	90.1300000	± 1.7 µA
0.9	mA	0.899997	0.899997	TRUE	TRUE	1	0.1%	0.04%	0	0.0013	0.89870	0.90130	± 9.6 µA
9	mA	9.00164	9.00164	TRUE	TRUE	10	0.1%	0.04%	0	0.013	8.9870	9.0130	± 16 µA
90	mA	90.0155	90.0155	TRUE	TRUE	100	0.1%	0.04%	0	0.13	89.870	90.130	± 0.57 mA
0.9	A	0.900151	0.900151	TRUE	TRUE	1	0.1%	0.04%	0	0.0013	0.89870	0.90130	± 0.51 mA

FREQUENCY

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
9	Hz	9.00002	9.00002	TRUE	TRUE	10	0.07%	0	0	0.0063	8.9937	9.0063	± 0.6 mHz
90	Hz	90.0004	90.0004	TRUE	TRUE	100	0.03%	0	0	0.027	89.9730	90.0270	± 0.6 mHz
900	Hz	900.002	900.002	TRUE	TRUE	1000	0.01%	0	0	0.09	899.910	900.090	± 0.01 Hz
9	kHz	9.00002	9.00002	TRUE	TRUE	10	0.009%	0	0	0.00081	8.9992	9.0008	± 0.06 kHz
90	kHz	90	90	TRUE	TRUE	100	0.008%	0	0	0.0072	89.993	90.007	± 0.6 kHz

CAPACITANCE

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
9	nF	9.038	9.038	TRUE	TRUE	10	0.4%	0.1%	0	0.046	8.95	9.05	± 0.07 nF
90	nF	89.8	89.8	TRUE	TRUE	100	0.4%	0.1%	0	0.46	89.5	90.5	± 0.01 µF
0.9	uF	0.8996	0.8996	TRUE	TRUE	1	0.4%	0.1%	0	0.0046	0.895	0.905	± 0.29 µF
9	uF	8.983	8.983	TRUE	TRUE	10	0.4%	0.1%	0	0.046	8.954	9.046	± 0.29 µF
90	uF	89.98	89.98	TRUE	TRUE	100	0.4%	0.1%	0	0.46	89.54	90.46	± 0.02 mF

TEMPERATURE Type-K

Nominal	Unit	Found As	Left As	Found As Result	Left As Result	Range	% of Nominal	% of Range	Count	+ / -	Low	High	Uncertainty
-100	°C	-100.36	-100.36	TRUE	TRUE	-100	0.0%	0%	0.9	0.9	-100.9	-99.1	± 0.35°C
500	°C	499.69	499.69	TRUE	TRUE	500	0.0%	0%	0.9	0.9	499.100	500.900	± 0.42°C
1000	°C	999.65	999.65	TRUE	TRUE	1000	0.0%	0%	0.9	0.9	999.100	1000.900	± 0.42°C

END OF REPORT

Public Comment No. 1170-NFPA 70-2024 [Section No. 336.2]

336.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type TC cables

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type TC cable to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an "approved" method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4's has been used for decades without incident. It would be very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

Related Item

- FR8220

Submitter Information Verification

Submitter Full Name: Megan Hayes

Organization: NEMA

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 16 11:29:15 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8477-NFPA 70-2024

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago.

Public Comment No. 1846-NFPA 70-2024 [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 installed in accordance with 300.28.

(6) For non-power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray, raceway, or enclosure and the utilization equipment or device(s), provided all of the following apply:

  (8) The cable is Type TC-ER and is surface marked "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 is secured at intervals not exceeding 1.8 m (6 ft).

  (12) 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 .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays

~~and~~

a.

, raceways, or enclosures, and between cable trays

~~and~~

a.

, raceways, or enclosures and utilization 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.

(13) Type TC cable shall be resistant to moisture and corrosive agents where installed in wet locations.

(14) For one- and two-family dwelling units, Type TC-ER-JP cable containing conductors for both power and control circuits shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Article 334, Part II and where installed as exterior wiring shall be installed per the requirements of Article 340, Part II.

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 No. 1: 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.

(15) Direct buried, where identified for such use.

(16) In hazardous (classified) locations where specifically permitted by other articles in this code.

(17) For service-entrance conductors where identified for such use and marked Type TC-ER.

Informational Note No. 2: See 310.14(A)(3) for temperature limitation of conductors.

Statement of Problem and Substantiation for Public Comment

FR8221 updated 336.10(7) to reference "cable trays, raceways, or enclosures". The proposed text updates the Exception to (7) text to align with this language for consistency with list item (7) text.

Note that Terra incorrectly underlined the proposed changes. The only changes are as indicated between << >> as follows:

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays<<, raceways, or enclosures,>> and between cable trays<<, raceways, or enclosures>> and <<utilization>> 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.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 1851-NFPA 70-2024 [Section No. 722.121(A)]	

Related Item

- FR8221

Submitter Information Verification

Submitter Full Name: Jay Tamblingson
Organization: Rockwell Automation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 27 17:05:52 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-8559-NFPA 70-2024
Statement: Updated to align with the charging text in section 336.10(7). The revision clarifies where Type TC-ER cable can be run unsupported. Updated cross reference in (9) per CC requests.

Public Comment No. 2022-NFPA 70-2024 [Section No. 336.104 [Excluding any Sub-Sections]]

For ungrounded, grounded, and equipment grounding conductors, the conductor sizes shall be ~~16 AWG~~ 14 AWG through 1000 kcmil copper, nickel, or nickel-coated copper ~~, 14 AWG~~ and 12 AWG through 1000 kcmil aluminum or copper-clad aluminum~~, and 12 AWG through 1000 kcmil aluminum~~ . Insulation types shall be one of the types listed in Table 310.4(1) or Table 310.4(2) 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, ~~16 AWG~~ 14 AWG copper-clad aluminum, and 12 AWG aluminum.

Statement of Problem and Substantiation for Public Comment

This proposal seeks to restore this section to the language of the 2023 National Electrical Code. When this section was modified during the 2026 NEC First Draft process, the discussions in favor of the modification were based upon whether the maximum temperature encountered during testing exceeded 90°C. The underlying assumption is that the maximum allowable temperature for Type NM-B Cable is 90°C (likely based upon the requirements in NEC 334.112 and UL 719 Section 1.1 which refers to the use of conductors with 90°C insulation). Nowhere in the NEC or in UL 719 is the maximum temperature for the complete Type NM-B Cable (not just the conductors) directly stated. Given this, the temperature rating for the overall cable jacket (sheath) should be considered in the determination of the maximum temperature for the complete cable assembly.

Section 5.2.1 of UL 719 (Nonmetallic-Sheathed Cable) requires compliance with the requirements in the “Physical properties of NM Cable PVC jacket” table in UL 1581 (Table 50.179). This testing involves aging the jacket material at 100°C for 240 hours before performing tensile and elongation tests. It is the aging of the test specimens at a specified time and temperature that determines the temperature rating of the material. The aging parameters in Table 50.179 (100°C for 240 hours) do not match those required for material rated 90°C.

Table 50.182 in UL 1581 includes the correlation of the temperature rating of the material with the specified oven time and temperature. In this table, aging at 100°C for 240 hours corresponds to a temperature rating of 75°C, not 90°C.

Given this, it is reasonable to conclude the maximum allowable temperature for Type NM-B Cable is not 90°C. It is also reasonable to conclude the maximum allowable temperature is 75°C or less.

Related Item

- FR 8232

Submitter Information Verification

Submitter Full Name: Dave Watson

Organization: Southwire

Affiliation: Southwire

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 28 16:03:26 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: The CMP 6 action on 336.104 at their first draft meeting was supported by data submitted in public inputs and the discussion on the reports provided during the first draft meeting. Review of the substantiation in the public comments on this section did not provide sufficient new data or test reports that supports changing the panel's first draft action.

Public Comment No. 1411-NFPA 70-2024 [Section No. 336.126]

336.126 Hazardous (Classified) Location Cable.

Cable listed and marked Type TC-ER-HL shall comply with the following:

(1) The overall nonmetallic jacket shall be suitable for the environment.

(2) The overall cable construction shall be essentially circular in cross-section.

(3) The overall nonmetallic jacket shall be continuous and gas/vapor tight.

(4) For ~~construction greater than 25.4 mm (1 in.) in diameter, the~~ cables having an ampacity of 350 amps or greater, the following shall apply:

(5) The equipment grounding conductor shall be bare.

(6) A metallic shield shall be included over all conductors under the outer jacket.

Informational Note: See ANSI/UL 2225-2022, *Cables and Cable Fittings for Use in Hazardous (Classified) Locations*, for information on construction, testing, and marking of cables.

Statement of Problem and Substantiation for Public Comment

Based on the panel's response to my previous public input to eliminate the 1.0" OD limitation, I determined the ampacity of a 3 conductor cable that would be of 1.0 inch in diameter to be 3C, 350 kcmil Type TC built in accordance with UL 1277. This cable has an ampacity of 350 amps. Therefore, since the concern is based on the power utilization of the cable, the diameter restriction should be replaced with a current threshold.

Related Item

• Public Input Number 1350

Submitter Information Verification

Submitter Full Name: Philip Laudicina

Organization: Marmon Industrial Energy & Infrastructure

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 22 14:37:19 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8587-NFPA 70-2024

Statement: List item (4) was removed to address the concerns of the submitter. The product standard contains many different constructions with power and control conductors, and a size or ampacity threshold is more appropriately covered in the product standard.

Public Comment No. 1171-NFPA 70-2024 [Section No. 337.2]

337.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type P cables

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type P cable to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an "approved" method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4's has been used for decades without incident. It would be very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

Related Item

- FR8222

Submitter Information Verification

Submitter Full Name: Megan Hayes

Organization: NEMA

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 16 11:31:42 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8478-NFPA 70-2024

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items already specified in .30. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago. Other approved means are permitted by the AHJ in the .30 section for securing and supporting.

Public Comment No. 582-NFPA 70-2024 [Section No. 337.108]

337.108 Equipment Grounding Conductor.

~~An equipment~~ <u>A tinned copper equipment</u> grounding conductor ~~complying with~~ ~~250.122~~ ~~shall~~ <u>sized in accordance with the Type P cable product standard shall</u> be provided within multiconductor Type P cable.

Statement of Problem and Substantiation for Public Comment

This proposed change eliminates ambiguity and clarifies original intent by explicitly stating the equipment grounding conductor shall be made from tinned copper and that it shall be sized in accordance with the Type P cable product standard.

Related Item

- 1023-NFPA 70-2023

Submitter Information Verification

Submitter Full Name: Mark Fillip

Organization: National Oilwell Varco

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 01 14:28:11 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: The NEC has specific rules for equipment grounding conductors that product standards should comply with. Product standards can additionally limit the materials or construction.

Public Comment No. 1172-NFPA 70-2024 [Section No. 338.2]

338.2 Listing Requirements.

The following items shall be listed and identified for such use:

(1) Type SE and Type USE cables

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type SE and Type USE cable to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an "approved" method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4's has been used for decades without incident. It would be very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

Related Item

- FR8223

Submitter Information Verification

Submitter Full Name: Megan Hayes

Organization: NEMA

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 16 11:47:08 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8479-NFPA 70-2024

Statement: To address the submitter's concerns, the panel replaced the general terminology with the specific items. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago.

Public Comment No. 1174-NFPA 70-2024 [Section No. 340.2]

340.2 Listing Requirements.

The following items shall be listedand identified for such use:

(1) Type UF cable

(2) ~~Support and securement hardware~~

(3) Fittings used for connecting Type UF cable to boxes, cabinets, or other equipment

Statement of Problem and Substantiation for Public Comment

This public comment seeks to remove the Listing requirement for support and securement hardware.

Securement and supporting hardware such as strut has been used for decades without a safety issue. The Public Input did not declare a safety issue nor an incident for an unsafe installation. Securement and support for cables have been an “approved” method to allow designers, installers, and the AHJs flexibility for the uniqueness of an installation.

In addition, building materials such as trusses or bored 2 by 4’s has been used for decades without incident. It would be
very difficult for these building materials to be listed.

CMP-8 Resolved the same Public Inputs for Conduits and Tubes with a similar substantiation.

Related Item

- FR8224

Submitter Information Verification

Submitter Full Name:	Megan Hayes
Organization:	NEMA
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Fri Aug 16 11:51:11 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8480-NFPA 70-2024
Statement:	To address the submitter's concerns, the panel replaced the general terminology with the specific. To avoid damage to cable and undue stress on electrical connections, the use of listed hardware for support and securement of cable is necessary. UL 2239, the Standard for Safety for Hardware for the Support of Conduit, Tubing, and Cable, was first published nearly 20 years ago.

Public Comment No. 1391-NFPA 70-2024 [Section No. 340.104]

340.104 Conductors.

The conductors shall be sizes ~~14 AWG~~ 16 AWG through 4/0 AWG copper ~~or~~ , 14 AWG through 4/0 AWG copper-clad aluminum, or 12 AWG through 4/0 AWG aluminum.

Statement of Problem and Substantiation for Public Comment

The minimum copper size should be adjusted to correlate with the changes in Article 310.

Related Item

- FR 8233

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:

Submittal Date: Wed Aug 21 21:35:52 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-8563-NFPA 70-2024
Statement: The minimum copper size was adjusted to correlate with the changes in Article 310.

Public Comment No. 2025-NFPA 70-2024 [Section No. 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 ~~, or 12 AWG through~~ through 4/~~0 AWG aluminum~~ 0 AWG .

Statement of Problem and Substantiation for Public Comment

This proposal seeks to restore this section to the language of the 2023 National Electrical Code. When this section was modified during the 2026 NEC First Draft process, the discussions in favor of the modification were based upon whether the maximum temperature encountered during testing exceeded 90°C. The underlying assumption is that the maximum allowable temperature for Type NM-B Cable is 90°C (likely based upon the requirements in NEC 334.112 and UL 719 Section 1.1 which refers to the use of conductors with 90°C insulation). Nowhere in the NEC or in UL 719 is the maximum temperature for the complete Type NM-B Cable (not just the conductors) directly stated. Given this, the temperature rating for the overall cable jacket (sheath) should be considered in the determination of the maximum temperature for the complete cable assembly.

Section 5.2.1 of UL 719 (Nonmetallic-Sheathed Cable) requires compliance with the requirements in the “Physical properties of NM Cable PVC jacket” table in UL 1581 (Table 50.179). This testing involves aging the jacket material at 100°C for 240 hours before performing tensile and elongation tests. It is the aging of the test specimens at a specified time and temperature that determines the temperature rating of the material. The aging parameters in Table 50.179 (100°C for 240 hours) do not match those required for material rated 90°C.

Table 50.182 in UL 1581 includes the correlation of the temperature rating of the material with the specified oven time and temperature. In this table, aging at 100°C for 240 hours corresponds to a temperature rating of 75°C, not 90°C.

Given this, it is reasonable to conclude the maximum allowable temperature for Type NM-B Cable is not 90°C. It is also reasonable to conclude the maximum allowable temperature is 75°C or less.

Related Item

- FR 8233

Submitter Information Verification

Submitter Full Name: Dave Watson

Organization: Southwire

Affiliation: Southwire

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 28 16:07:57 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action:	Rejected
Resolution:	The CMP 6 action on 340.104 at their first draft meeting was supported by data submitted in public inputs and the discussion on the reports provided during the first draft meeting. Review of the substantiation in the public comments on this section did not provide sufficient new data or test reports that supports changing the panel’s first draft action

Public Comment No. 594-NFPA 70-2024 [Section No. 394.10]

394.10 Uses Permitted.

Concealed knob-and-tube wiring shall be permitted to be installed in the hollow spaces of walls and ceilings, or in unfinished attics and roof spaces as provided by 394.23, only as follows:

(1) For extensions of existing installations

(2) Elsewhere by special permission

Informational Note: See 210.12(E) for further information on branch-circuit wiring extensions, modifications, or replacements.

Additional Proposed Changes

File Name	Description	Approved
CN_291.pdf		

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 291 appeared in the First Draft Report on First Revision No. 7861.

The Correlating Committee directs CMP-8 to review the addition of the informational note. This is repetitive of a chapter that applies generally throughout the Code and is not compliant with Section 4.1.1 of the NEC Style Manual.

Related Item

- First Revision No. 7861

Submitter Information Verification

Submitter Full Name: CC Notes
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 01 20:28:52 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-8564-NFPA 70-2024
Statement: The informational note was deleted to comply with the style manual.

Correlating Committee Note No. 291-NFPA 70-2024 [Section No. 394.10]

Submitter Information Verification

Committee: NEC-AAC
Submittal Date: Thu May 09 22:54:06 EDT 2024

Committee Statement

Committee Statement: The Correlating Committee directs CMP-8 to review the addition of the informational note. This is repetitive of a chapter that applies generally throughout the Code and is not compliant with Section 4.1.1 of the NEC Style Manual.

First Revision No. 7861-NFPA 70-2024 [Section No. 394.10]

Ballot Results

✔ **This item has passed ballot**

12 Eligible Voters
1 Not Returned
11 Affirmative All
0 Affirmative with Comments
0 Negative with Comments
0 Abstention

Not Returned

McDaniel, Roger D.

Affirmative All

Ayer, Lawrence S.
Bowmer, Trevor N.
Hickman, Palmer L.
Holub, Richard A.
Jackson, Peter D.
Kendall, David H.
Manche, Alan
Osborne, Robert D.
Porter, Christine T.
Schultheis, Timothy James
Williams, David A.

Public Comment No. 558-NFPA 70-2024 [Sections 400.2, 400.3]

Sections 400.2, 400.3

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.

Additional Proposed Changes

File Name	Description	Approved
CN_273.pdf		

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 273 appeared in the First Draft Report.

The Correlating Committee directs CMP 6 to relocate the requirements in 400.2 and 400.3. to comply with the NEC Style Manual for parallel numbering, Section 2.2.1. If the article does not contain listing or reconditioning requirements, the subdivisions shall not be included in the article.

Related Item

- Correlating Committee Note No. 273

Submitter Information Verification

Submitter Full Name: CC Notes

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jul 31 17:04:08 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8607-NFPA 70-2024

Statement: Section 400.2 was deleted since the use of this code requires the user to comply with the entire NEC.

Correlating Committee Note No. 273-NFPA 70-2024 [Sections 400.2, 400.3]

Submitter Information Verification

Committee: NEC-AAC
Submittal Date: Thu May 09 21:20:23 EDT 2024

Committee Statement

Committee Statement: The Correlating Committee directs CMP 6 to relocate the requirements in 400.2 and 400.3. to comply with the NEC Style Manual for parallel numbering, Section 2.2.1. If the article does not contain listing or reconditioning requirements, the subdivisions shall not be included in the article.

Ballot Results

✔ **This item has passed ballot**

12 Eligible Voters
1 Not Returned
11 Affirmative All
0 Affirmative with Comments
0 Negative with Comments
0 Abstention

Not Returned

McDaniel, Roger D.

Affirmative All

Ayer, Lawrence S.

Bowmer, Trevor N.

Hickman, Palmer L.

Holub, Richard A.

Jackson, Peter D.

Kendall, David H.

Manche, Alan

Osborne, Robert D.

Porter, Christine T.

Schultheis, Timothy James

Williams, David A.

Public Comment No. 1042-NFPA 70-2024 [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 Exception: cords for dishwashers and compactors shall be permitted to pass through cabinet dividers to comply with Article 422.16(B)(2) items 4 & 5

(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 590.6.

(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 300.25(C)(3).

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: See UL 817, *Cord Sets and Power-Supply Cords*, and UL 62, *Flexible Cords and Cables*, for proper application.

Statement of Problem and Substantiation for Public Comment

Article 422.16 allows the cords for dishwashers and compactors to pass through the walls of cabinetry. The exception would align the 2 articles with each other.

Related Item

- PI-4130

Submitter Information Verification

Submitter Full Name: Dennis Querry

Organization: Trinity River Authority

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 12 17:18:33 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected

Resolution: Cords for dishwashers and compactors are not prohibited by 400.12 to pass through cabinet dividers and Article 422.16(B)(2) items 4 & 5 allow for this option, therefore an exception in 400.12 is not needed.

Public Comment No. 769-NFPA 70-2024 [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.

Exception to (2): Openings in raised floors designed and intended for such purpose.

(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 590.6 .

(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 300.25(C)(3) .

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: See UL 817, *Cord Sets and Power-Supply Cords*, and UL 62, *Flexible Cords and Cables*, for proper application.

Statement of Problem and Substantiation for Public Comment

The exception to item (2) adds more clarity to this application. The committee resolved PI-4130 and stated that cables run through floors were already covered in (5) which is concealment of cables. This exception to (2) will allow a cable to pass through a floor designed and intended for the purpose.

Related Item

- PI- 4130

Submitter Information Verification

Submitter Full Name:	David Hittinger
Organization:	Independent Electrical Contractors
Affiliation:	IEC
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Mon Aug 05 08:19:35 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected
Resolution:	Article 645 contains permission for this installation and provides specific requirements that must be met for this application. Flexible cords and cables are not always permitted to be run through raised floors.

Public Comment No. 538-NFPA 70-2024 [Sections 402.2, 402.3]

Sections 402.2, 402.3

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: See Article 410, Part VI for application in luminaires.

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	- Type Letter	- Insulation	- AWG	Thickness of Insulation		- Outer Covering	- Maximum Operating Temperature	App Pro
				mm	mils			
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						90°C (194°F)	
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
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 nicke 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	PFF	Fluorinated ethylene	18–14	0.51	20	None	150°C	Fixtu wirin

Name	Type Letter	Insulation	AWG	Thickness of Insulation mm	Thickness of Insulation mils	Outer Covering	Maximum Operating Temperature	App Pro
— flexible stranding		propylene					(302°F)	
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 nicke coat copp
Extruded polytetrafluoroethylene — flexible stranding 26-36 (AWG silver or nickel-coated copper)	PTFF	Extruded polytetrafluo-roethylene	18–14	0.51	20	None	150°C (302°F)	Fixtu wirin (silve nicke coat copp
Heat-resistant rubber-covered fixture wire — solid or 7-strand	RFH-1	Heat-resistant rubber	18	0.38	15	Nonmetallic covering	75°C (167°F)	Fixtu wirin — lin 300
	RFH-2	Heat-resistant rubber Cross-linked synthetic polymer	18–16	0.76	30	None or non-metallic covering	75°C (167°F)	Fixtu wirin
Heat-resistant cross-linked synthetic polymer-insulated fixture wire — solid or 7-strand	RFHH-2* RFHH-3*	Cross-linked synthetic polymer	18–16 18–16	0.76 1.14	30 45	None or non-metallic covering	90°C (194°F)	Fixtu wirin
Silicone insulated fixture wire — solid or 7-strand	SF-1	Silicone rubber	18	0.38	15	Nonmetallic covering	200°C (392°F)	Fixtu wirin — lin 300
	SF-2	Silicone rubber	18–12 10	0.76 1.14	30 45	Nonmetallic covering	200°C (392°F)	Fixtu wirin
Silicone insulated fixture wire — flexible stranding	SFF-1	Silicone rubber	18	0.38	15	Nonmetallic covering	150°C (302°F)	Fixtu wirin — lin 300

Name	- Type Letter	- Insulation	- AWG	Thickness of Insulation mm	mils	- Outer Covering	- Maximum Operating Temperature	App Pro
	SFF-2	Silicone rubber	18–12 10	0.76 1.14	30 45	Nonmetallic covering	150°C (302°F)	Fixtu wirin
Thermoplastic covered fixture wire — solid or 7-strand	TF*	Thermoplastic	18–16	0.76	30	None	60°C (140°F)	Fixtu wirin
Thermoplastic covered fixture wire — flexible stranding	TFF*	Thermoplastic	18–16	0.76	30	None	60°C (140°F)	Fixtu wirin
Heat-resistant thermoplastic covered fixture wire — solid or 7-strand	TFN*	Thermoplastic	18–16	0.38	15	Nylon-jacket-ed or equivalent	90°C (194°F)	Fixtu wirin
Heat-resistant thermoplastic covered fixture wire — flexible stranded	TFFN*	Thermoplastic	18–16	0.38	15	Nylon-jacket-ed or equivalent	90°C (194°F)	Fixtu wirin
Cross-linked polyolefin insulated fixture wire — solid or 7-strand	XF*	Cross-linked polyolefin	18–14 12-10	0.76 1.14	30 45	None	150°C (302°F)	Fixtu wirin — li 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 — li 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 tetrafluoro-ethylene	18–14	0.38	15	None	150°C (302°F)	Fixtu wirin
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.

Additional Proposed Changes

File Name	Description	Approved

CN_270.pdf

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 270 appeared in the First Draft Report on First Revision No. 8157.

The Correlating Committee directs the CMP 6 to review FR 8157 with respect to relocating the requirements in 402.2 and 402.3. to comply with the NEC Style Manual for parallel numbering 2.2.1. If the article does not contain listing or reconditioning requirements, the subdivisions shall not be included in the article.

Related Item

- First Revision No. 8157

Submitter Information Verification

Submitter Full Name:	CC Notes
Organization:	NEC Correlating Committee
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Jul 30 23:30:22 EDT 2024
Committee:	NEC-P06

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	SR-8567-NFPA 70-2024
Statement:	Section 402.2 was deleted since the use of this code requires the user to comply with the entire NEC.

Correlating Committee Note No. 270-NFPA 70-2024 [Sections 402.2, 402.3]

Submitter Information Verification

Committee: NEC-AAC

Submittal Date: Thu May 09 21:13:46 EDT 2024

Committee Statement

Committee Statement: The Correlating Committee directs the CMP 6 to review FR 8157 with respect to relocating the requirements in 402.2 and 402.3. to comply with the NEC Style Manual for parallel numbering 2.2.1. If the article does not contain listing or reconditioning requirements, the subdivisions shall not be included in the article.

First Revision No. 8157-NFPA 70-2024 [Section No. 402.2]

Ballot Results

✔ **This item has passed ballot**

12 Eligible Voters
1 Not Returned
11 Affirmative All
0 Affirmative with Comments
0 Negative with Comments
0 Abstention

Not Returned

McDaniel, Roger D.

Affirmative All

Ayer, Lawrence S.

Bowmer, Trevor N.

Hickman, Palmer L.

Holub, Richard A.

Jackson, Peter D.

Kendall, David H.

Manche, Alan

Osborne, Robert D.

Porter, Christine T.

Schultheis, Timothy James

Williams, David A.

Public Comment No. 2029-NFPA 70-2024 [Section No. 402.5]

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- ~~copper or 16 copper-clad aluminum~~	6
16- ~~copper or 14 copper-clad aluminum~~	8
14- ~~copper~~	17
12- ~~copper~~	23
10- ~~copper~~	28

Statement of Problem and Substantiation for Public Comment

This proposal seeks to restore this section to the language of the 2023 National Electrical Code. When this section was modified during the 2026 NEC First Draft process, the discussions in favor of the modification were based upon whether the maximum temperature encountered during testing exceeded 90°C. The underlying assumption is that the maximum allowable temperature for Type NM-B Cable is 90°C (likely based upon the requirements in NEC 334.112 and UL 719 Section 1.1 which refers to the use of conductors with 90°C insulation). Nowhere in the NEC or in UL 719 is the maximum temperature for the complete Type NM-B Cable (not just the conductors) directly stated. Given this, the temperature rating for the overall cable jacket (sheath) should be considered in the determination of the maximum temperature for the complete cable assembly.

Section 5.2.1 of UL 719 (Nonmetallic-Sheathed Cable) requires compliance with the requirements in the "Physical properties of NM Cable PVC jacket" table in UL 1581 (Table 50.179). This testing involves aging the jacket material at 100°C for 240 hours before performing tensile and elongation tests. It is the aging of the test specimens at a specified time and temperature that determines the temperature rating of the material. The aging parameters in Table 50.179 (100°C for 240 hours) do not match those required for material rated 90°C.

Table 50.182 in UL 1581 includes the correlation of the temperature rating of the material with the specified oven time and temperature. In this table, aging at 100°C for 240 hours corresponds to a temperature rating of 75°C, not 90°C.

Given this, it is reasonable to conclude the maximum allowable temperature for Type NM-B Cable is not 90°C. It is also reasonable to conclude the maximum allowable temperature is 75°C or less.

Related Item

- FR 8234

Submitter Information Verification

Submitter Full Name: Dave Watson

Organization: Southwire

Affiliation: Southwire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 28 16:14:22 EDT 2024
Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8592-NFPA 70-2024

Statement: Based on test data on copper-clad aluminum conductors provided during this revision cycle copper-clad aluminum was limited to solid conductors as testing was on solid conductors only.

Public Comment No. 1744-NFPA 70-2024 [Section No. 402.6]

402.6 Minimum Size.

Fixture wires shall not be smaller than 18 AWG copper or 16 AWG copper-clad aluminum .

Statement of Problem and Substantiation for Public Comment

This revision will clarify minimum conductor sizes and correlate with the proposed changes in Table 402.5.

Related Item

- FR 8234

Submitter Information Verification

Submitter Full Name: Christel Hunter

Organization: Cerro Wire

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 26 22:31:55 EDT 2024

Committee: NEC-P06

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8592-NFPA 70-2024

Statement: Based on test data on copper-clad aluminum conductors provided during this revision cycle copper-clad aluminum was limited to solid conductors as testing was on solid conductors only.