



Public Comment No. 156-NFPA 70-2021 [Global Input]

The word "ground" with prefixes and suffixes is ambiguous and confusing. Ungrounded, grounded, grounding instead of phase conductor, return (neutral), bonded conductor is not helpful. There's no dirt (ground) in a submarine, car or space station.

Type your content here ...

Statement of Problem and Substantiation for Public Comment

Clearer language.

Related Item

- Definition

Submitter Information Verification

Submitter Full Name: Ralph Bliquez

Organization: Ewing-Foley

Street Address:

City:

State:

Zip:

Submittal Date: Wed Jul 07 16:26:43 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The base term "Ground" is well understood and requires the modifiers to adequately describe an installation or use requirement. The scope of the NEC is found at 90.2 and describes what is and is not covered by the NEC. The Public Comment does not meet the requirements of Section 4.4.4 of Regulations Governing the Development of NFPA Standards. Specifically, 4.4.4.3, in part, requires: (c) Proposed text of the Public Comment, including the wording to be added, revised (and how revised), or deleted. The changes shall be indicated through the use of underlines for new text and strikethrough for deleted text. (d) Statement of the problem and substantiation for the Public Comment. (e) Supporting data and scientific evidence, when available



Public Comment No. 1995-NFPA 70-2021 [Global Input]

The Correlating Committee directs the Chair of CMP-5 to assign a task group to review all the definitions under their purview for compliance with the NEC Style Manual and to review definitions identified by the Correlating Committee that may contain correlation issues. The attachment includes a list of those definitions identified that need to be reviewed.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
CN_449.pdf	70_CN449

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 449 appeared in the First Draft Report.

The Correlating Committee directs the Chair of CMP-5 to assign a task group to review all the definitions under their purview for compliance with the NEC Style Manual and to review definitions identified by the Correlating Committee that may contain correlation issues. The attachment includes a list of those definitions identified that need to be reviewed.

Related Item

- Correlating Note No. 449

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 18 21:45:34 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected
Resolution: No action needed, a task group was formed to correlate grounding and bonding terms

**Correlating Committee Note No. 449-NFPA 70-2021 [Part I.]****Supplemental Information**

<u>File Name</u>	<u>Description Approved</u>
NEC_P05_Definitions_TG_Attachment_CN449.docx	

Submitter Information Verification

Committee: NEC-AAC

Submittal Date: Mon May 10 13:29:48 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs the Chair of CMP-5 to assign a task group to review all the definitions under their purview for compliance with the NEC Style Manual and to review definitions identified by the Correlating Committee that may contain correlation issues. The attachment includes a list of those definitions identified that need to be reviewed.

Ballot Results

✓ **This item has passed ballot**

12 Eligible Voters

0 Not Returned

12 Affirmative All

0 Affirmative with Comments

0 Negative with Comments

0 Abstention

Affirmative All

Ayer, Lawrence S.

Gallo, Ernest J.

Hickman, Palmer L.

Holub, Richard A.

Hunter, Dean C.

Johnston, Michael J.

Kendall, David H.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Porter, Christine T.

Williams, David A.

Correlating Committee Definitions Task Group

CMP-5 - Definitions

CMP-5 Definitions	Correlating Committee Comments
	The Correlating Committee directs the Chair of CMP-5 to assign a task group to review all the definitions under their purview for compliance with the NEC Style Manual and to review definitions identified by the Correlating Committee that may contain correlation issues. The attachment includes a list of those definitions identified that need to be reviewed.
Bonding Conductor or Jumper (BJ) Bonding Jumper, Equipment (EBJ) Bonding Jumper, Supply-Side (SSBJ) Bonding Jumper, Main (MBJ) Bonding Jumper, System (SBJ)	The Correlating Committee directs the panel to review the "Bonding Jumper" definitions to comply with the NEC Style Manual Section 2.2.2.3 concerning the use of the base term. The panel should consider the use of the term "bonding conductor" instead of the term "bonding conductor or jumper" for clarity and usability. The Panel should reconsider PI-3413 referencing changing the term "Supply-Side Bonding Jumper" to "Supply-Side Bonding Conductor". The term "conductor" is more appropriate, since we are referring to a conductor that performs an action, and not the action itself ("the connection"). The following definitions also need to be revised: Bonding Conductor or Jumper to Bonding Conductor (BC); Bonding Jumper, Equipment to Bonding Conductor, Equipment (EBC) (Equipment Bonding Conductor); Bonding Jumper, Supply-Side to Bonding Conductor, Supply Side (SSBC) (Supply-Side Bonding Conductor); Bonding Jumper, Main to Bonding Conductor, Main (MBC) (Main Bonding Conductor) Bonding Jumper, System to Bonding Conductor, System (SBC) (System Bonding Conductor) The Correlating Committee directs that these definitions comply with the NEC Style Manual Section 2.2.2.3.1 for Defined Terms. To assist in electronic searching, the defined term shall then appear in parentheses as it would be found in the document.

	References throughout the document will need to be revised to reflect the changes. 2.2.2.5 Synonyms, Similar Terns or Alternate Terms could be added under these terms.
Bonding Conductor or Jumper (BJ). A conductor that ensures the required electrical conductivity between metal parts that are required to be electrically connected. (CMP-5)	2.2.2.5 Alternate Term 2.2.2.3.1 Searchable Title 3.2.3 Acronym Use PI 3413 Reconsider
Ground-Fault Condition. An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non-current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth. (CMP-5)	Defining a term that we are not using in the document. This definition does not correlate with the usage of (Ground-Fault) throughout the code.
Bonding Jumper, Equipment (EBJ). The connection between two or more portions of the equipment grounding conductor. (CMP-5)	2.2.2.3.1 Searchable Title Suggest (Equipment Bonding Jumper)
Bonding Jumper, Supply-Side (SSBJ). The connection between the grounded circuit conductor and the equipment grounding conductor, or the supply-side bonding jumper, or both, at the service. (CMP-5)	2.2.2.3.1 Searchable Title Suggest (Supply-Side Bonding Jumper)
Bonding Jumper, Main (MBJ). A conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected. (CMP-5)	2.2.2.3.1 Searchable Title Suggest (Main Bonding Jumper)
Bonding Jumper, System (SBJ). The connection between the grounded circuit conductor and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system. (CMP-5)	2.2.2.3.1 Searchable Title Suggest (System Bonding Jumper)
Grounded, Solidly. Connected to ground without inserting any resistor or impedance device. (CMP-5)	2.2.2.3.1 Searchable Title Suggest (Solidly Grounded)
Grounding Conductor, Equipment (EGC). A conductive path(s) that is part of an effective ground-fault current path and connects normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. (CMP-5) Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.	2.2.2.3.1 Searchable Title Suggest (Equipment Grounnding Conductor)

Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

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Public Comment No. 2147-NFPA 70-2021 [Global Input]

Restore Section 250.22 with updates to section references

250.22 Circuits or Systems Not to Be Grounded.

The following circuits shall not be grounded:

- (1) **Circuits for electric cranes operating over combustible fibers in Class III locations, in accordance with 503.155(A)**
- (2) **Circuits in health care facilities in accordance with 517.160(A)(2)**
- (3) **Circuits for equipment within electrolytic cell line working zones in accordance with Article 668.3(C)(3), 668.11, and 668.30(A)**
- (4) **Secondary circuits of lighting systems in accordance with 411.6(A) and exception**
- (5) **Secondary circuits of lighting systems in accordance with 680.23(A)(2)**

Statement of Problem and Substantiation for Public Comment

This PC along with a correlating PC seeks to reverse the panel action and remove the new informational note and restore section 250.22 with any updated information.

The overall usability of the NEC has been reduced by the panel action to remove 250.22 and relocate some of the valuable information in an informational note. For all users of the code, the general requirements of Chapters 1 through 4 are provided and sometimes for usability lists of other requirements or permissions found in other code sections related to a particular requirement are also provided. Changes should not be made the reduce usability for the general user in the field.

Sections 250.20, 250.21, 250.22 provided the users of the NEC a single location to find the general requirements of what systems are:

- required to be grounded,
- what systems are permitted to be grounded, and
- lastly what systems are prohibited from being grounded.

Section 250.22 had consolidated the 6 locations in the NEC where this prohibition existed along with the reference pointer so that users would not have to search for those locations or make the mistake of applying the general requirement not realizing there was another mandatory opposing requirement. Using the panel's logic for removing 250.22, then the panel should look at 250.118 where some of those equipment grounding conductor requirements are also found in the chapter 3 wiring methods Articles. Having 250.118 gives greater usability because all of these various applications from the wiring method Articles along with applicable conditions are provided in the single location for ease of use and reference.

In addition, the new informational note that was provided in 250.20 is incomplete, as 411.6(A)(1) still has a general prohibition for grounding low voltage lighting systems and other references to sections are not fully accurate to where the grounding prohibition is stated. CMP-18 added an exception for the class 2 systems where grounding would be optionally permitted, neither required or prohibited which addressed the need of the PI submitted. But they did not delete the existing prohibition for grounding of the secondary side of low voltage lighting systems such as for landscape lighting systems. Testing laboratories should be using the applicable product standard and not using the NEC for listing of products as was indicated in the PI substantiation.

The previous sixth system for 393.60 was deleted with the CMP-18 action in FR 7660 that changed the Class 2 secondary circuit grounded prohibition to one that is permitted making grounding the installer's choice. The listing of these remaining five systems where system grounding is prohibited with the pointer to the applicable code section alerts users to the prohibition as well as being able to immediately go to the section for any other requirements or as now exists for 411.6(A)(1) the exception. This text within a full code section improves overall usability to installers, inspectors and other in the industry.

All the identified code sections were verified against the first draft text and section references were updated for accuracy.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Comment No. 2142-NFPA 70-2021 [Section No. 250.20 [Excluding any Sub-Sections]]	
Public Comment No. 2142-NFPA 70-2021 [Section No. 250.20 [Excluding any Sub-Sections]]	

Related Item

- FR 8159

Submitter Information Verification

Submitter Full Name: Charles Mello

Organization: Cdcmello Consulting Llc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 19 13:59:10 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The proposed list of circuits not to be grounded will result in on-going difficulties correlating with other articles in the code and is not in compliance with sec. 4.1.1 of the NEC style manual.



Public Comment No. 892-NFPA 70-2021 [Global Input]

The Correlating Committee refers FR 7969 to CMP 5 noting that 490.55 is referenced in 250.188(F) and has been renumbered to 490.65.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
9_CN_12_Global.pdf	9 CN12

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 12 appeared in the First Draft Report on First Revision No. 7969.

The Correlating Committee refers FR 7969 to CMP 5 noting that 490.55 is referenced in 250.188(F) and has been renumbered to 490.65.

Related Item

- First Revision No. 7969

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 15:41:39 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The reference to 490.55 was changed to 490.65 by NFPA staff in response to an action taken in the First Draft by CMP 9.



Correlating Committee Note No. 12-NFPA 70-2021 [Global Input]

Submitter Information Verification

Committee: NEC-P09

Submittal Date: Mon May 03 11:32:55 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee refers FR 7969 to CMP 5 noting that 490.55 is referenced in 250.188(F) and has been renumbered to 490.65.

[First Revision No. 7969-NFPA 70-2020 \[Global Input\]](#)

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.



Public Comment No. 274-NFPA 70-2021 [Definition: Bonding Conductor or Jumper (BJ).]

Bonding Conductor or (Bonding Jumper- (BJ)).

A conductor that ensures the required electrical conductivity between metal parts that are required to be electrically connected. (CMP-5)

Statement of Problem and Substantiation for Public Comment

Added (Bonding Jumper) as a synonym for Bonding Conductor to comply with the Manual of Style 2.2.2.5 Synonyms, Similar Terms, or Alternate Terms. If the defined term has synonyms, similar terms, or alternate terms associated with the main term that all are to be understood as having the same definition, the base term being defined shall be followed by the alternate term in parentheses. The panel removed acronym to cause less confusion by using BC or BJ as an acronym when it could refer to other electrical terms such as Branch Circuit. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Related Item

- First Revision No. 8242-NFPA 70-2020 [Definition: Bonding Conductor or Jumper.]

Submitter Information Verification

Submitter Full Name: Christine Porter

Organization: Intertek Testing Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 12:40:59 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-8013-NFPA 70-2021](#)

Statement: Bonding was added to be more descriptive of the term. The acronym is removed as it is not used.



Public Comment No. 763-NFPA 70-2021 [Definition: Bonding Conductor or Jumper (BJ).]

Bonding Conductor or Jumper (BJ).

A conductor that ensures the required electrical conductivity between metal parts that are required to be electrically connected. (CMP-5)

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_413.pdf	5 CN413

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 413 appeared in the First Draft Report on First Revision No. 8242.

The Correlating Committee directs the panel to review the "Bonding Jumper" definitions to comply with the NEC Style Manual Section 2.2.2.3 concerning the use of the base term. The panel should consider the use of the term "bonding conductor" instead of the term "bonding conductor or jumper" for clarity and usability. The Panel should reconsider PI-3413 referencing changing the term "Supply-Side Bonding Jumper" to "Supply-Side Bonding Conductor". The term "conductor" is more appropriate, since we are referring to a conductor that performs an action, and not the action itself ("the connection").

The following definitions also need to be revised:

Bonding Conductor or Jumper to Bonding Conductor (BC);

Bonding Jumper, Equipment to Bonding Conductor, Equipment (EBC) (Equipment Bonding Conductor);

Bonding Jumper, Supply-Side to Bonding Conductor, Supply Side (SSBC) (Supply-Side Bonding Conductor);

Bonding Jumper, Main to Bonding Conductor, Main (MBC) (Main Bonding Conductor)

Bonding Jumper, System to Bonding Conductor, System (SBC) (System Bonding Conductor)

The Correlating Committee directs that these definitions comply with the NEC Style Manual Section 2.2.2.3.1 for Defined Terms. To assist in electronic searching, the defined term shall then appear in parentheses as it would be found in the document.

References throughout the document will need to be revised to reflect the changes.

2.2.2.5 Synonyms, Similar Terms or Alternate Terms could be added under these terms.

Related Item

- First Revision No. 8242

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 04 09:31:43 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected but held

Resolution: The impact of the changes proposed in the Comment is extensive and the panel sees that a more holistic review of article 250 and throughout the NEC regarding the use of the terms bonding jumper and its derivatives is warranted. Based on the amount of time involved in such a review, this comment is held in accordance with 4.4.8.3.1(c) of the regulations governing the development of NFPA standards. The acronym is addressed in a separate action on PC 274.

**Correlating Committee Note No. 413-NFPA 70-2021 [Definition: Bonding Conductor or Jumper.]****Submitter Information Verification****Committee:** NEC-P05**Submittal Date:** Sun May 09 21:49:28 EDT 2021**Committee Statement**

Committee Statement: The Correlating Committee directs the panel to review the "Bonding Jumper" definitions to comply with the NEC Style Manual Section 2.2.2.3 concerning the use of the base term. The panel should consider the use of the term "bonding conductor" instead of the term "bonding conductor or jumper" for clarity and usability. The Panel should reconsider PI-3413 referencing changing the term "Supply-Side Bonding Jumper" to "Supply-Side Bonding Conductor". The term "conductor" is more appropriate, since we are referring to a conductor that performs an action, and not the action itself ("the connection").

The following definitions also need to be revised:

Bonding Conductor or Jumper to Bonding Conductor (BC);

Bonding Jumper, Equipment to Bonding Conductor, Equipment (EBC) (Equipment Bonding Conductor);

Bonding Jumper, Supply-Side to Bonding Conductor, Supply Side (SSBC) (Supply-Side Bonding Conductor);

Bonding Jumper, Main to Bonding Conductor, Main (MBC) (Main Bonding Conductor)

Bonding Jumper, System to Bonding Conductor, System (SBC) (System Bonding Conductor)

The Correlating Committee directs that these definitions comply with the NEC Style Manual Section 2.2.2.3.1 for Defined Terms. To assist in electronic searching, the defined term shall then appear in parentheses as it would be found in the document.

References throughout the document will need to be revised to reflect the changes.

2.2.2.5 Synonyms, Similar Terms or Alternate Terms could be added under these terms.

First Revision No. 8242-NFPA 70-2020 [Definition: Bonding Conductor or Jumper.]

Ballot Results

✓ **This item has passed ballot**

12 Eligible Voters

0 Not Returned

12 Affirmative All

0 Affirmative with Comments

0 Negative with Comments

0 Abstention

Affirmative All

Ayer, Lawrence S.

Gallo, Ernest J.

Hickman, Palmer L.

Holub, Richard A.

Hunter, Dean C.

Johnston, Michael J.

Kendall, David H.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Porter, Christine T.

Williams, David A.



Public Comment No. 275-NFPA 70-2021 [Definition: Bonding Jumper, Equipment (EBJ).]

Bonding Jumper Conductor , Equipment (EBJ). Equipment Bonding Jumper) **(Equipment Bonding Conductor)**

The connection between two or more portions of the equipment grounding conductor. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel added Equipment Bonding Jumper as a synonym to comply with the Manual of Style 2.2.2.5 Synonyms, Similar Terms, or Alternate Terms. If the defined term has synonyms, similar terms, or alternate terms associated with the main term that all are to be understood as having the same definition, the base term being defined shall be followed by the alternate term in parentheses. The panel added the searchable term to comply with the Manual of Style 2.2.2.3.1 Defined Term. To assist in electronic searching, the defined term shall then appear in parentheses as it would be found in the document. The panel removed the acronym as it did not add clarity. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Related Item

- Correlating Committee Note No. 413-NFPA 70-2021 [Definition: Bonding Conductor or Jumper.]

Submitter Information Verification

Submitter Full Name: Christine Porter

Organization: Intertek Testing Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 13:06:35 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but held

Resolution: The impact of the changes proposed in the comment is extensive and the panel sees that a more holistic review of Article 250 and throughout the NEC regarding the use of the term bonding jumper and its derivatives is warranted. Based on the amount of time involved in such a review this comment is held in accordance with 4.4.8.3.1(C) of the regulations.



Public Comment No. 63-NFPA 70-2021 [Definition: Bonding Jumper, Equipment (EBJ).]

Bonding Jumper, Equipment (EBJ) (Equipment Bonding Jumper) .

The connection between two or more portions of the equipment grounding conductor. (CMP-5)

Statement of Problem and Substantiation for Public Comment

Adding the parenthetical will comply with the NEC Style Manual and facilitate searching for the term digitally.

Related Item

- PI-3013, PI-3327

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jul 01 13:31:31 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-8055-NFPA 70-2021](#)

Statement: The searchable term was added in to comply with 2.2.2.3.1 of the NEC Style Manual and the acronym was removed as it is not needed.



Public Comment No. 276-NFPA 70-2021 [Definition: Bonding Jumper, Main (MBJ).]

Bonding Conductor, Main (Main Bonding Jumper,) (Main Bonding Conductor) (MBC) (MBJ).

The connection between the grounded circuit conductor and the equipment grounding conductor, or the supply-side bonding jumper, or both, at the service. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel added the synonym for Main Bonding Conductor to comply with the Manual of Style 2.2.2.5 Synonyms, Similar Terms, or Alternate Terms. If the defined term has synonyms, similar terms, or alternate terms associated with the main term that all are to be understood as having the same definition, the base term being defined shall be followed by the alternate term in parentheses. The panel added the searchable term to comply with the Manual of Style 2.2.2.3.1 Defined Term. To assist in electronic searching, the defined term shall then appear in parentheses as it would be found in the document. The added an acronym for Main Bonding Conductor to comply with the Manual of Style 3.2.3 Acronyms and Uncommon Abbreviations keeping the acronym Main Bonding Jumper as that is also a term used in manufacturing documentation. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter

Related Item

- Correlating Committee Note No. 413-NFPA 70-2021 [Definition: Bonding Conductor or Jumper.]

Submitter Information Verification

Submitter Full Name: Christine Porter
Organization: Intertek Testing Services
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jul 19 13:41:50 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected but held

Resolution: The impact of the changes proposed in the comment is extensive and the panel sees that a more holistic review of Article 250 and throughout the NEC regarding the use of the term main bonding jumper and its derivatives is warranted. Based on the amount of time involved in such a review this comment is held in accordance with 4.4.8.3.1(C) of the regulations.



Public Comment No. 64-NFPA 70-2021 [Definition: Bonding Jumper, Main (MBJ).]

Bonding Jumper, Main (MBJ) (Main Bonding Jumper) .

The connection between the grounded circuit conductor and the equipment grounding conductor, or the supply-side bonding jumper, or both, at the service. (CMP-5)

Statement of Problem and Substantiation for Public Comment

Adding the parenthetical will comply with the NEC Style Manual and facilitate searching for the term digitally.

Related Item

- PI-3013, PI-3327

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jul 01 13:34:20 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8056-NFPA 70-2021

Statement: The panel removed the acronym, added the searchable term in accordance with 2.2.2.3 of the NEC Style Manual



Public Comment No. 961-NFPA 70-2021 [Definition: Bonding Jumper, Main (MBJ).]

Bonding Jumper, Main- Service (MBJ SBJ).

The connection between the grounded circuit conductor and the equipment grounding conductor, or the supply-side bonding jumper, or both, at the service. (CMP-5)

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Case_in_Point.docx	Case in Point	
Bonding_Jumper_Service.docx	Public Comment explanation	

Statement of Problem and Substantiation for Public Comment

Public Input No. 1431-NFPA 70-2020 [Definition: Bonding Jumper, Main.]

Related Item

- Public Input No. 1431-NFPA 70-2020 [Definition: Bonding Jumper, Main.]

Submitter Information Verification

Submitter Full Name: Beau Burton

Organization: Detroit Electrical JATC

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 05 12:13:02 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but held

Resolution: The committee affirms that the word choice of Main to indicate the bonding conductor at the service is well established. The panel sees that a more thorough review of the NEC along with other codes and standards regarding the use of the term and its derivatives must be performed. Based on the amount of time involved in such a review this comment is held in accordance with 4.4.8.3.1(C) of the regulations.

Bonding Jumper, Service

Public Input No. 1431-NFPA 70-2020 [Definition: Bonding Jumper, Main.]

Resolution: The panel affirms that the term main bonding jumper is limited to the service. The term “main” is well understood.

The submitter of the proposed code change disagrees with the panel that the term “main” is well understood.

Having taught Grounding and Bonding through an IBEW/NECA JATC for over 13 years the submitter has often fielded questions from apprentices, journeymen, master electricians, inspectors, and estimators with regard to the location of bonding the grounded conductor, the grounding electrode conductor, and the equipment grounding conductor. See attached “Case in Point”.

There is often confusion when the service equipment is not in the same cabinet as the “main” panelboard. The regular code user and often electrical inspector will question whether the bonding point should be in the separate service disconnect or the “main” panelboard cabinet. The term “bonding jumper, main” is the root of the problem. The term “main” is not well understood or defined. Fortunately, the term “service” is defined.

It is common in the electrical industry to use the word main at locations other than the service equipment. The first disconnecting means at a separate building or structure is referred to as the main. The first or controlling breaker, or fuse, to a sub-panel is called the main breaker. The main can be used to describe the disconnect on industrial machinery. The word main is used in the definition of “service equipment”. Reading the definition of service equipment without the word main doesn’t affect the meaning of the term service equipment because main is not specific or clear in meaning. Fortunately, the term service is defined, specific, and clear in meaning.

Section 3.3.4 of the NEC style manual requires that,
“Words and terms used in the NEC shall be specific and clear in meaning,
and shall avoid jargon, trade terminology, industry-specific terms…”



Public Comment No. 1078-NFPA 70-2021 [Definition: Bonding Jumper, Supply-Side (SSBJ).]

Bonding Jumper, Supply-Side (SSBJ).

~~A conductor.~~ A nonflexible metal raceway, bus, or wire type conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected. (CMP-5)

Statement of Problem and Substantiation for Public Comment

PI 2973 should have been accepted. Maybe Article 100 isn't the appropriate place to dictate what items are acceptable to be used for a SSBJ but unfortunately this definition was relocated to Article 100 from 250.2 last code cycle.

If the only place in the NEC providing any clarity on what can be used as a SSBJ pertains to separately derived systems, then what code section prohibits using a flexible metal raceway as a SSBJ installed for other than a separately derived system?

Related Item

- PI 2973

Submitter Information Verification

Submitter Full Name: Jeff Simpson

Organization: ElectricalLicenseRenewal.com

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 09 10:00:45 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: In accordance with 2.2.2.2 of the NEC Style Manual, definitions shall be in alphabetical order and shall not contain the term that is being defined. Definitions shall not contain requirements or recommendations



Public Comment No. 277-NFPA 70-2021 [Definition: Bonding Jumper, Supply-Side (SSBJ).]

Bonding Jumper Conductor , Supply-Side (Supply-Side Bonding Jumper) (Supply-Side Bonding Conductor (SSBC)) (SSBJ).

A conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel added Supply-Side Bonding Jumper as a synonym to comply with Manual of Style 2.2.2.5 Synonyms, Similar Terms, or Alternate Terms, added electronic searchable terms to comply with 2.2.2.3.1 Defined Term. The panel added the acronym for Supply-Side Bonding Conductor per Manual of Style 3.2.3 Acronyms and Uncommon Abbreviations. The panel kept the acronym for Supply-Side Bonding Jumper as the term jumper is widely used and understood. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herro, Juan Lahera, Karin Manfredi, and Christine Porter

Related Item

- Public Input No. 2973-NFPA 70-2020 [Definition: Bonding Jumper, Supply-Side.]

Submitter Information Verification

Submitter Full Name: Christine Porter
Organization: Intertek Testing Services
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jul 19 13:51:23 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected but held

Resolution: The impact of the changes proposed in the comment is extensive and the panel sees that a more holistic review of Article 250 and throughout the NEC regarding the use of the term bonding jumper and its derivatives is warranted. Based on the amount of time involved in such a review this comment is held in accordance with 4.4.8.3.1(C) of the regulations.



Public Comment No. 66-NFPA 70-2021 [Definition: Bonding Jumper, Supply-Side (SSBJ).]

Bonding Jumper, Supply-Side (SSBJ) (Supply-Side Bonding Jumper) .

A conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected. (CMP-5)

Statement of Problem and Substantiation for Public Comment

Adding the parenthetical will comply with the NEC Style Manual and facilitate searching for the term digitally.

Related Item

- PI-3013, PI-3327

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jul 01 13:36:09 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8057-NFPA 70-2021

Statement: The panel removed the acronym, added the searchable term in accordance with 2.2.2.3 of the NEC Style of the NEC Manual.



Public Comment No. 909-NFPA 70-2021 [Definition: Bonding Jumper, Supply-Side (SSBJ).]

Bonding Conductor or Jumper, Supply-Side (SSBJ SSBC).

A conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected. (CMP-5)

Statement of Problem and Substantiation for Public Comment

I agree with the CMP that Supply Side Bonding Jumper is a term well understood by electricians familiar with the Code. However, we may not share that understanding. With 40-odd years in the trade, when I think of a MBJ, I think of a screw through a neutral bar, or a small clip attached to it, even though I know that theoretically it can be something else, and we have means to calculate that. I also agree with IAEI that at first glance, it does mislead less-experienced people to think of the dictionary meaning of "Jumper, Elect: a short length of conductor used to make a connection, . . ." Agin, the dictionary specifies "short." There is minimal cost to changing the term, compared to the benefit. Using "Conductor or Jumper" here, and in fact globally, will allow users who inherently understand "jumper" to imply something short to more easily recognize that that limit is not true, because "conductor" doesn't carry that implication.

The understanding of "Jumper" as meaning something that typically is short is documented by CMP 9 in their response to P.I. 1291. For 314.16, viz

"Statement: CMP-9 has decided to revisit the action taken in the comment period of the 1996 cycle, when the reference to equipment bonding jumpers was initially added (Comment 9-5). It was substantiated on the basis that these components can run within raceways. CMP-9 now concludes that any such application, if even possible, would constitute an extension of an equipment grounding conductor, and would be addressable as such. In general, such jumpers begin and end within the box. As such, counting them would conflict with the general principle of not counting such wires, as stated in the final sentence of 314.16(B)(1)"

Perhaps this is worth referring to the TCC to ensure consistent usage.

Related Item

- PI3413 • PI 1291

Submitter Information Verification

Submitter Full Name: David Shapiro

Organization: Safety First Electrical

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 16:58:42 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected but held

Action:

Resolution: The impact of the changes proposed in the comment is extensive and the panel sees that a more holistic review of Article 250 and throughout the NEC regarding the use of the term bonding jumper and its derivatives is warranted. Based on the amount of time involved in such a review this comment is held in accordance with 4.4.8.3.1(C) of the regulations



Public Comment No. 286-NFPA 70-2021 [Definition: Bonding Jumper, System (SBJ).]

Bonding Jumper Conductor , System (System Bonding Jumper)(System Bonding Conductor)(SBC)(SBJ).

The connection between the grounded circuit conductor and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel added System Bonding Jumper as a synonym to comply with Manual of Style 2.2.2.5 Synonyms, Similar Terms, or Alternate Terms, and added searchable terms to comply with Manual of Style 2.2.2.3.1 Defined Term. The panel added acronyms to make the code easier to use and comply with the Manual of Style 3.2.3 Acronyms and Uncommon Abbreviations. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Related Item

- First Revision No. 8280-NFPA 70-2020 [Global Input]

Submitter Information Verification

Submitter Full Name: Christine Porter

Organization: Intertek Testing Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 19:11:08 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but held

Resolution: The impact of the changes proposed in the comment is extensive and the panel sees that a more holistic review of Article 250 and throughout the NEC regarding the use of the term bonding jumper and its derivatives is warranted. Based on the amount of time involved in such a review this comment is held in accordance with 4.4.8.3.1(C) of the regulations



Public Comment No. 67-NFPA 70-2021 [Definition: Bonding Jumper, System (SBJ).]

Bonding Jumper, System (SBJ) (System Bonding Jumper) .

The connection between the grounded circuit conductor and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system. (CMP-5)

Statement of Problem and Substantiation for Public Comment

Adding the parenthetical will comply with the NEC Style Manual and facilitate searching for the term digitally.

Related Item

- PI-3013, PI-3327

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jul 01 13:37:56 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-8059-NFPA 70-2021](#)

Statement: The panel removed the acronym and added the searchable term in accordance with the NEC Style Manual.



Public Comment No. 287-NFPA 70-2021 [Definition: Ground-Fault Condition.]

Ground-Fault Condition .

An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non-current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel removed the word "condition" to add clarity for users of this code, as a ground-fault is an event not necessarily a condition . This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Addition of the word condition was submitted on behalf of a working task group on ground-faults, and noting that the term is used in both 240.92(C)(1) and (3).

Related Item

• First Revision No. 8243-NFPA 70-2020 [Definition: Ground Fault.]

• Correlating Committee Note No. 414-NFPA 70-2021 [Definition: Ground Fault.]

Submitter Information Verification

Submitter Full Name: Christine Porter

Organization: Intertek Testing Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 19:22:54 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-8026-NFPA 70-2021](#)

Statement: The panel removed the word "condition" to add clarity for users of this code, as a ground-fault is an event not necessarily a condition.

The word "metallic" is changed to "metal" to comply with the NEC Style Manual.



Public Comment No. 69-NFPA 70-2021 [Definition: Ground-Fault Condition.]

Ground - Fault- Condition .

An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non-current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth. (CMP-5)

Statement of Problem and Substantiation for Public Comment

Adding "Condition" to the title makes this definition incorrect. The previous definition correctly states a Ground Fault is "An unintentional, electrically conductive connection ...". After the ground fault occurs, the circuit becomes a ground-fault condition. Return the definition to its previous language.

Related Item

- FR-8243

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jul 01 13:57:55 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8026-NFPA 70-2021

Statement: The panel removed the word "condition" to add clarity for users of this code, as a ground-fault is an event not necessarily a condition.

The word "metallic" is changed to "metal" to comply with the NEC Style Manual.



Public Comment No. 764-NFPA 70-2021 [Definition: Ground-Fault Condition.]

Ground-Fault Condition.

An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non-current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth. (CMP-5)

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_414.pdf	5 CN414

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 414 appeared in the First Draft Report on First Revision No. 8243.

The Correlating Committee directs the panel to reconsider the title revision for this definition. Consideration should be given to the ballot comments for FR 8243 regarding clarity and that a Ground-Fault being an event rather than a condition. This proposed change does not add clarity or usability. The Correlating Committee also notes the use of the term "Metallic" should be considered to comply with Section 3.2.4 of the NEC Style Manual.

Related Item

- First Revision No. 8243

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 09:39:49 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8026-NFPA 70-2021

Statement: The panel removed the word "condition" to add clarity for users of this code, as a ground-fault is an event not necessarily a condition.

The word "metallic" is changed to "metal" to comply with the NEC Style Manual.

**Correlating Committee Note No. 414-NFPA 70-2021 [Definition: Ground Fault.]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Sun May 09 21:50:13 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs the panel to reconsider the title revision for this definition. Consideration should be given to the ballot comments for FR 8243 regarding clarity and that a Ground-Fault being an event rather than a condition. This proposed change does not add clarity or usability. The Correlating Committee also notes the use of the term "Metallic" should be considered to comply with Section 3.2.4 of the NEC Style Manual.

First Revision No. 8243-NFPA 70-2020 [Definition: Ground Fault.]

Ballot Results

✓ **This item has passed ballot**

12 Eligible Voters

0 Not Returned

12 Affirmative All

0 Affirmative with Comments

0 Negative with Comments

0 Abstention

Affirmative All

Ayer, Lawrence S.

Gallo, Ernest J.

Hickman, Palmer L.

Holub, Richard A.

Hunter, Dean C.

Johnston, Michael J.

Kendall, David H.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Porter, Christine T.

Williams, David A.



Public Comment No. 289-NFPA 70-2021 [Definition: Ground-Fault Current Path, Effective. (Effectiv...]

Ground-Fault Current Path, Effective. (Effective Ground-Fault Current Path)

An intentionally constructed, low-impedance electrically conductive path designed and intended to carry current ~~under~~ during ground-fault ~~conditions~~ events from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground-fault detectors. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel replaced the phrase "under ground-fault conditions" with the phrase "during ground-fault events" to better aid in understanding the term. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Related Item

- First Revision No. 8244-NFPA 70-2020 [Definition: Effective Ground-Fault Current Path.]

Submitter Information Verification

Submitter Full Name: Christine Porter
Organization: Intertek Testing Services
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jul 19 19:36:49 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-8029-NFPA 70-2021
Statement: The panel replaced the phrase "under ground-fault conditions" with the phrase "during ground-fault events" to add clarity.



Public Comment No. 290-NFPA 70-2021 [Definition: Grounded, Solidly.]

Grounded, Solidly. (Solidly Grounded)

Connected to ground without inserting any resistor or impedance device. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel added the searchable term to comply with the Manual of Style 2.2.2.3.1 Defined Term. To assist in electronic searching, the defined term shall then appear in parentheses as it would be found in the document. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Related Item

- First Revision No. 8280-NFPA 70-2020 [Global Input]

Submitter Information Verification

Submitter Full Name: Christine Porter

Organization: Intertek Testing Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 19:40:34 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8025-NFPA 70-2021

Statement: The Committee added the searchable term to comply with 2.2.2.3.1 of the NEC Style Manual.



Public Comment No. 23-NFPA 70-2021 [Definition: Grounding Conductor, Equipment (EGC).]

Grounding Conductor, Equipment (EGC) (Equipment Grounding Conductor) .

A conductive path(s) that is part of an effective ground-fault current path and connects normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. (CMP-5)

Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.

Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

Statement of Problem and Substantiation for Public Comment

The the term is added in parenthesis so it is searchable electronically.

Related Item

- PI-1757

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jun 29 19:42:19 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8030-NFPA 70-2021

Statement: The panel added the searchable term to comply with the NEC Style Manual 2.2.2.3.1 to assist in electronic searching.



Public Comment No. 291-NFPA 70-2021 [Definition: Grounding Conductor, Equipment (EGC).]

Grounding Conductor, Equipment (Equipment Grounding Conductor)(EGC).

A conductive path(s) that is part of an effective ground-fault current path and connects normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. (CMP-5)

Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.

Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

Statement of Problem and Substantiation for Public Comment

The panel added the searchable term to comply with the Manual of Style 2.2.2.3.1 Defined Term. To assist in electronic searching, the defined term shall then appear in parentheses as it would be found in the document. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Related Item

- First Revision No. 8280-NFPA 70-2020 [Global Input]

Submitter Information Verification

Submitter Full Name: Christine Porter

Organization: Intertek Testing Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 19:44:33 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-8030-NFPA 70-2021](#)

Statement: The panel added the searchable term to comply with the NEC Style Manual 2.2.2.3.1 to assist in electronic searching.



Public Comment No. 1269-NFPA 70-2021 [Definition: Likely to Become Energized.]

Likely to Become Energized.

Conductive material that could become energized ~~because-~~ due to the failure of electrical insulation or ~~electrical spacing- failure~~ . (CMP-5)

Statement of Problem and Substantiation for Public Comment

As currently written it can be argued that the issue of "failure" applies only to spacing, not insulation.

Related Item

- FR 8245

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 11 14:48:08 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8033-NFPA 70-2021

Statement: The panel re-ordered the term to locate it to follow the term "energized" and edited the definition for clarity.



Public Comment No. 199-NFPA 70-2021 [Definition: Likely to Become Energized.]

Likely to Become Energized.

Conductive material that could become energized because due to interaction with, connection to, or proximity to electrical equipment or wiring is likely to become energized in the event of electrical insulation or electrical spacing failure, or spacing failure. This includes conductive parts where the authority having jurisdiction determines that they would be expected to be rendered so likely by future modification or expansion of wiring. (CMP-5)

Statement of Problem and Substantiation for Public Comment

While it would be a positive development to add this definition, the definition as written may perpetuate, or at least fail to solve a common misunderstanding that leads some ahj's to require bonding of metallic parts that have almost no likelihood of becoming energized during a fault, simply since it "could" happen under some broad hypothetical. Bonding creates greater safety when there's a likelihood of energization in the event of wiring failure. In circumstances where this is unlikely, bonding may not offer this protection, and arguably could needlessly present other potential hazards, such as energization of the parts during an open neutral or utility fault event. It is thought that this proposed revision would better communicate that due to this, those scenarios where bonding should be required is limited. It would do so by:

- Clarifying that electrical equipment connected to (in this revision "interacting" with) a conductive object or system is one that would create this likelihood. An example could be an electrical solenoid on a pipe.
- Clarifying that it is the proximity or connection to electrical equipment (including proximity of non-associated cabling) that creates this likelihood.
- Replacing the word "could" with "likely," and clarifying that the likelihood exists due to proximity, interaction with, or connection to the equipment.

Lastly, the addition of the final sentence would enable the authority having jurisdiction to decide as to when conductive parts (such as "other" metal piping and structural metal per 250.1004, or metal parts per 250.110) may be so interconnected and prevalent throughout a premises or otherwise located such that during the initial construction or subsequent modification, avoidance of contact with cabling and/or the installation of addition of electrical components on the parts cannot be assured, and that thus a bond or connection to an equipment grounding conductor should occur.

Related Item

• First Revision No. 8245-NFPA 70-2020 [Detail]

• Public Input No. 3113-NFPA 70-2020 [New Part after I.]

Submitter Information Verification

Submitter Full Name: Josh Weaver

Organization: Not Applicable

Street Address:

City:

State:

Zip:

Submittal Date: Sun Jul 11 12:32:18 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Section 2.2.2.2 of the NEC Style Manual states that definitions shall not contain the term that is being defined. The phrases “proximity to electrical equipment or wiring” and “expected to be rendered so likely by future modification or expansion of wiring” are too broad and unenforceable.



Public Comment No. 295-NFPA 70-2021 [Definition: Likely to Become Energized.]

Energized, Likely to Become (Likely to Become Energized) .

Conductive material that could become energized because of electrical insulation or electrical spacing failure. (CMP-5)

Statement of Problem and Substantiation for Public Comment

The panel reordered the term to comply with the Manual of Style 2.2.2.3 Definition Title Structure. Definitions that have subparts shall be listed alphabetically by the base term, with a comma and then the modifying descriptor. to put Energized first, as that is the base term and likely to become energized is the modifier. The base term is the word Energized which is then modified by the phrase likely to become energized. This action will locate the term immediately following the definition of energized. This is the result of the work CMP-5 Task Group for Definitions consisting of: Trevor Bowmer, Jon Coulimore, Lee Herron, Juan Lahera, Karin Manfredi, and Christine Porter.

Related Item

- First Revision No. 8245-NFPA 70-2020 [Detail]

Submitter Information Verification

Submitter Full Name: Christine Porter

Organization: Intertek Testing Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 20:10:02 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8033-NFPA 70-2021

Statement: The panel re-ordered the term to locate it to follow the term “energized” and edited the definition for clarity.



Public Comment No. 70-NFPA 70-2021 [Definition: Likely to Become Energized.]

Likely to Become Energized.

Conductive material that could become energized because of the failure of electrical insulation or electrical spacing- ~~failure~~ . (CMP-5)

Statement of Problem and Substantiation for Public Comment

This is intended to be an editorial improvement in sentence syntax rather than a substantive change.

Related Item

- FR-8245

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jul 01 14:08:23 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8033-NFPA 70-2021

Statement: The panel re-ordered the term to locate it to follow the term “energized” and edited the definition for clarity.



Public Comment No. 27-NFPA 70-2021 [Definition: Separately Derived System.]

Separately Derived System.

An electrical power supply-~~output~~, other than a service, having no direct connection(s) to circuit conductors of any other electrical source other than those established by grounding and bonding connections. (CMP-5)

Statement of Problem and Substantiation for Public Comment

This is intended to be an editorial improvement to the revised definition. The word "output" is superfluous to the definition and can be confusing.

Related Item

- FR-8246

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jun 29 20:35:58 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Without the word "output," the definition is ambiguous and could include both the input and the output.



Public Comment No. 1500-NFPA 70-2021 [Section No. 200.4(A)]

(A) Installation.

Neutral conductors shall not be used for more than one branch circuit, for more than one multiwire branch circuit, or for more than one set of ungrounded feeder conductors unless specifically permitted elsewhere in this *Code*.

Informational Note: See 215.4 for information on common feeder neutrals. See 225.7(B) for information on common neutrals in lighting circuits .

Statement of Problem and Substantiation for Public Comment

the proposed informational note is revised for clarity. It is also noted that receptacle circuits sharing common neutrals are not addressed here, but probably should be. See 210.4.

Related Item

- FR 8274

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 15 16:23:57 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Although 300.3(B)(4) permits neutral conductors of circuits supplied from the column width panelboard to originate in the pull box, this is not related to the requirement of 200.4(A) which prohibits using a neutral conductor for more than one branch circuit. Adding the term "feeder" in the informational note does not add clarity as 215.4 is part of Article 215 for Feeders.



Public Comment No. 24-NFPA 70-2021 [Section No. 200.4(A)]

(A) Installation.

Neutral conductors shall not be used for more than one branch circuit, for more than one multiwire branch circuit, or for more than one set of ungrounded feeder conductors unless specifically permitted elsewhere in this *Code*.

Informational Note: See 215.4 for information on common neutrals. See 225.7(B) for information on common neutrals in lighting. See 300.3(B)(4) for common neutrals used with column width panelboards.

Statement of Problem and Substantiation for Public Comment

The Informational Note leaves out one of the permitted uses of a common neutral. It makes no sense for the note to only show two of the three permitted uses of a common neutral. It is not going to include all of them, the note should be deleted.

Related Item

- PI-3742 • FR-8274

Submitter Information Verification

Submitter Full Name: Don Ganiere

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jun 29 19:47:29 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Although 300.3(B)(4) permits neutral conductors of circuits supplied from the column width panelboard to originate in the pull box, this is not related to the requirement of 200.4(A) which prohibits using a neutral conductor for more than one branch circuit. Adding the term "feeder" in the informational note does not add clarity as 215.4 is part of Article 215 for Feeders.



Public Comment No. 910-NFPA 70-2021 [Section No. 200.4(A)]

(A) Installation.

Neutral conductors shall not be used for more than one branch circuit, for more than one multiwire branch circuit, or for more than one set of ungrounded feeder conductors unless specifically permitted elsewhere in this *Code*.

Informational Note: See 215.4 for information on common neutrals.- ~~See 225.7(B) for information on common neutrals in lighting.~~

Statement of Problem and Substantiation for Public Comment

Reference no longer is valid; Section was deemed redundant.

Related Item

• IN 2038 • FR7694 • FR8274

Submitter Information Verification

Submitter Full Name: David Shapiro

Organization: Safety First Electrical

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 17:12:30 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7910-NFPA 70-2021

Statement: The second sentence of the Informational Note of 200.4(A) is deleted as 225.7 is removed.



Public Comment No. 1217-NFPA 70-2021 [Section No. 200.7(C)]

(C) Circuits of 50 Volts or More.

The use of insulation that is white or gray or that has three continuous white or gray stripes for other than a grounded conductor for circuits of 50 volts or more shall be permitted only as in the following:

- (1) If part of a cable assembly that has the insulation permanently reidentified to indicate its use as an ungrounded conductor by marking tape, painting, or other effective means at its termination and at each location where the conductor is visible and accessible. Identification shall encircle the insulation and shall be a color other than white, gray, or green. If used for single-pole, 3-way or 4-way switch loops, the reidentified conductor with white or gray insulation or three continuous white or gray stripes shall be used only for the supply to the switch, but not as a return conductor from the switch to the outlet.
- (2) A flexible cord ~~having where~~ one conductor is identified by a white or gray outer finish or three continuous white or gray stripes, or by any other means in accordance with 400.22, that is used for connecting an appliance or equipment in accordance with 400.10. This shall apply to flexible cords connected to outlets whether or not the outlet is supplied by a circuit that has a grounded conductor.

Informational Note: The color gray may have been used in the past as an ungrounded conductor. Care should be taken when working on existing systems.

Statement of Problem and Substantiation for Public Comment

The current wording of section 200.7 (C) (2) can be read as applying to cables with ONLY one conductor. (Though I agree a 1 conductor cable would be pretty useless!)

Related Item

- FR-8275-NFPA 70-2020

Submitter Information Verification

Submitter Full Name: Ward Willats

Organization: Ward Willats Consulting

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 10 19:59:32 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The word "where" was not added because "where" is used to describe a location in the NEC Style manual.



Public Comment No. 739-NFPA 70-2021 [Section No. 250.1]

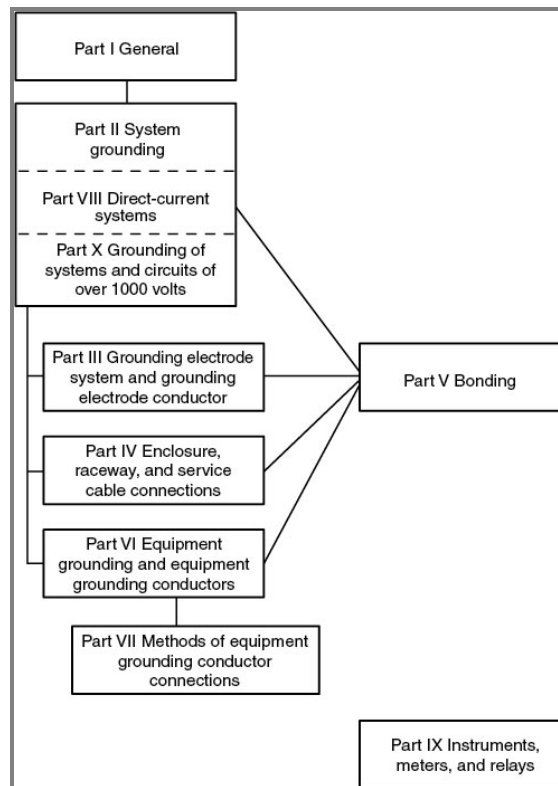
250.1 Scope.

This article covers general requirements for grounding and bonding of electrical installations and the following specific requirements:

- (1) Systems, circuits, and equipment required, permitted, or not permitted to be grounded
- (2) Circuit conductor to be grounded on grounded systems
- (3) Location of grounding connections
- (4) Types and sizes of grounding and bonding conductors and electrodes
- (5) Methods of grounding and bonding
- (6) Conditions under which isolation, insulation, or guards are permitted to be substituted for grounding

Informational Note: See Informational Note Figure 250.1 for information on the organization of this article covering grounding and bonding requirements.

Figure Informational Note Figure 250.1 Grounding and Bonding.



Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
5_CN_136.pdf	5 CN136	

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 136 appeared in the First Draft Report on First Revision No. 7985.

The Correlating Committee advises that article scope statements are the responsibility of the Correlating Committee and the Correlating Committee accepts the panel action.

Related Item

- First Revision No. 7985

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 03 15:38:57 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: CMP 5 acknowledges the Correlating Committee's acceptance of the First Draft revision to 250.1.

**Correlating Committee Note No. 136-NFPA 70-2021 [Section No. 250.1]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 16:21:42 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee advises that article scope statements are the responsibility of the Correlating Committee and the Correlating Committee accepts the panel action.

First Revision No. 7985-NFPA 70-2020 [Section No. 250.1]

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.

**Public Comment No. 572-NFPA 70-2021 [Section No. 250.6]****250.6** Objectionable Current.**(A)** Arrangement to Prevent Objectionable Current.

The grounding and bonding of electrical systems, circuit conductors, surge arresters, surge-protective devices, and conductive normally non-current-carrying metal parts of equipment shall be installed and arranged in a manner that will prevent objectionable current.

(B) Alterations to Stop Objectionable Current.

If the use of multiple grounding or bonding connections results in objectionable current and the requirements of 250.4(A)(5) or (B)(4) are met, one or more of the following alterations shall be permitted:

- (1) Discontinue one or more but not all of such grounding or bonding connections.
- (2) Change the locations of the grounding or bonding connections.
- (3) Interrupt the continuity of the conductor or conductive path causing the objectionable current.
- (4) Take other suitable remedial and approved action.

(C) Currents Not Classified as Objectionable Currents.

Currents resulting from abnormal conditions, such as ground faults, ~~and currents resulting from required grounding and bonding connections~~ shall not be classified as objectionable current for the purposes specified in 250.6(A) and (B).

(D) Limitations to Permissible Alterations.

This section shall not be considered as permitting electronic equipment to be operated on ac systems or branch circuits that are not connected to an equipment grounding conductor as required by this article. Currents that introduce electromagnetic interference or data errors in electronic equipment shall not be considered the objectionable currents addressed in this section.

(E) Isolation of Objectionable Direct-Current from Cathodic Protection Systems.

If isolation of objectionable direct currents from a cathodic protection system is required, a listed isolator device shall be permitted in the equipment grounding conductor path to provide an effective return path for ac ground-fault current while blocking the flow of direct currents.

Statement of Problem and Substantiation for Public Comment

Taking objection to the addition of the text:"and currents resulting from required grounding and bonding connections shall not be classified as objectionable current for the purposes specified in 250.6(A) and (B)."

I think in such a broad range of installations that the NEC regulates, there is a problem with saying that connections required by the NEC are never to be considered as objectionable. The prohibition on objectionable current was supposed to be a performance based rule. In the rule we have had, objectionable current is not allowed. If you install something per the NEC and still have objectionable current (since not defined in article 100, as defined by the AHJ), you have something that would be a violation and you can use one of the means in 250.6B to solve it. The NEC is not a perfect standard, and also imperfect are the interpretations of the qualified people tasked with following or interpreting it. This performance based rule helps to bridge the gap where the NEC may require (or be thought to require) something that might cause objectionable current. It would do so by giving the AHJ an ability to make a judgment call on when something may create objectionable current and also giving the

installers some allowed means (250.6B) to mitigate it.

No examples were given in the public input that led to this proposed change, of instances where the allowances of 250.8B wouldn't suffice.

The proposed change will, I believe make 250.6 of little use. If every code allowed connection never results in objectionable current because it can't be considered so, what circumstances might exist where something is installed per the code and would have objectionable current? If no such circumstances could exist, what would be the purpose of having section 250.6 at all in something that is not an instruction manual for untrained persons? I don't think the fact that the proposed language mentions only required connections (not allowed ones) can suffice to keep the rule useful either. There may be hypotheticals (none given here) where if a certain allowed method is used, a connection may be required that might cause parallel neutral current. Whether this would be a violation could be subject to debate under the new clause.

If the committee wishes to go forward with a revision that is consistent with the perceived problems mentioned by the original submitter of the public input, perhaps it should consider drafting a more restrictive text to clarify that current flowing on metallic conduits on the line side of the service may be allowable, or perhaps it should consider an informational note.

Related Item

- First Revision No. 7990-NFPA 70-2020 [Sections 250.6(A), 250.6(B), 250.6(C)]

Submitter Information Verification

Submitter Full Name: Josh Weaver

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Fri Jul 30 17:47:21 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected

Action:

Resolution: Currents resulting from required grounding and bonding connections are not classified as objectionable currents.

**Public Comment No. 740-NFPA 70-2021 [Sections 250.6(A), 250.6(B), 250.6(C)**

]

Sections 250.6(A), 250.6(B), 250.6(C)**(A) Arrangement to Prevent Objectionable Current.**

The grounding and bonding of electrical systems, circuit conductors, surge arresters, surge-protective devices, and conductive normally non-current-carrying metal parts of equipment shall be installed and arranged in a manner that will prevent objectionable current.

(B) Alterations to Stop Objectionable Current.

If the use of multiple grounding or bonding connections results in objectionable current and the requirements of 250.4(A)(5) or (B)(4) are met, one or more of the following alterations shall be permitted:

- (1) Discontinue one or more but not all of such grounding or bonding connections.
- (2) Change the locations of the grounding or bonding connections.
- (3) Interrupt the continuity of the conductor or conductive path causing the objectionable current.
- (4) Take other suitable remedial and approved action.

(C) Currents Not Classified as Objectionable Currents.

Currents resulting from abnormal conditions, such as ground faults, and currents resulting from required grounding and bonding connections shall not be classified as objectionable current for the purposes specified in 250.6(A) and (B).

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_137.pdf	5 CN137

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 137 appeared in the First Draft Report on First Revision No. 7990.

The Correlating Committee directs that FR-7990 be reviewed for compliance with the NEC Style Manual, with regard to the term "suitable" used in 250.6(8) list item 4. The terms contained in Table 3.2.1 of the NEC Style Manual shall be reviewed in context, and, if the resulting requirement is unenforceable or vague, the term shall not be used.

Related Item

- First Revision No. 7990

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:**Submittal Date:** Tue Aug 03 15:45:27 EDT 2021**Committee:** NEC-P05**Committee Statement****Committee Action:** Rejected but see related SR**Resolution:** [SR-7941-NFPA 70-2021](#)**Statement:** The word suitable is removed in accordance with Section 3.2.1 of the NEC Style manual

**Correlating Committee Note No. 137-NFPA 70-2021 [Sections 250.6(A), 250.6(B), 250.6(C)]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 16:22:40 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that FR-7990 be reviewed for compliance with the NEC Style Manual, with regard to the term "suitable" used in 250.6(B) list item 4. The terms contained in Table 3.2.1 of the NEC Style Manual shall be reviewed in context, and, if the resulting requirement is unenforceable or vague, the term shall not be used.

First Revision No. 7990-NFPA 70-2020 [Sections 250.6(A), 250.6(B), 250.6(C)]

Ballot Results

✓ **This item has passed ballot**

12 Eligible Voters

0 Not Returned

12 Affirmative All

0 Affirmative with Comments

0 Negative with Comments

0 Abstention

Affirmative All

Ayer, Lawrence S.

Gallo, Ernest J.

Hickman, Palmer L.

Holub, Richard A.

Hunter, Dean C.

Johnston, Michael J.

Kendall, David H.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Porter, Christine T.

Williams, David A.



Public Comment No. 741-NFPA 70-2021 [Section No. 250.20]

250.20 Alternating-Current Systems to Be Grounded.

Alternating-current systems shall be grounded in accordance with 250.20(A), (B), (C), or (D), unless prohibited elsewhere in this *Code*. Other systems shall be permitted to be grounded. If such systems are grounded, they shall comply with the applicable provisions of this article.

Informational Note No. 1: An example of a system permitted to be grounded is a corner-grounded delta transformer connection. See 250.26(4) for conductor to be grounded.

Informational Note No. 2: See 503.155, 517.61, 517.160, 668.10, and 680.23(A)(2) for examples of circuits prohibited to be grounded.

(A) Alternating-Current Systems of Less Than 50 Volts.

Alternating-current systems of less than 50 volts shall be grounded under any of the following conditions:

- (1) If supplied by transformers, if the transformer supply system exceeds 150 volts to ground
- (2) If supplied by transformers, if the transformer supply system is ungrounded
- (3) If installed outside as overhead conductors

(B) Alternating-Current Systems of 50 Volts to 1000 Volts.

Alternating-current systems of 50 volts to 1000 volts that supply premises wiring and premises wiring systems shall be grounded under any of the following conditions:

- (1) If the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts
- (2) If the system is 3-phase, 4-wire, wye connected in which the neutral conductor is used as a circuit conductor
- (3) If the system is 3-phase, 4-wire, delta connected in which the midpoint of one phase winding is used as a circuit conductor

Informational Note: According to Annex O of *NFPA 70E-2021, Standard for Electrical Safety in the Workplace*, high impedance grounding is an effective tool to reduce arc-flash hazards.

(C) Alternating-Current Systems of over 1000 Volts.

Alternating-current systems supplying mobile or portable equipment shall be grounded in accordance with 250.188. If supplying other than mobile or portable equipment, such systems shall be permitted to be grounded.

(D) Impedance Grounded Systems.

Impedance grounded systems shall be grounded in accordance with 250.36 or 250.187, as applicable.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_138.pdf	5 CN138

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 138 appeared in the First Draft Report on First Revision No.8159.

The Correlating Committee directs that FR-8159 be rewritten to comply with the NEC Style Manual, Section 4.1.3 Reference Structure. The structure of the Informational Note No. 1 in 250.20 should be revised to inform the users why they are being sent to other sections and the Informational Note in 250.20(8) should be revised to state "See NFPA 70E informative Annex O ... "

Related Item

- First Revision No. 8159

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 03 15:47:13 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-7951-NFPA 70-2021](#)

Statement: The last sentence of Informational Note 1 is removed for compliance with the NEC Style Manual.

**Correlating Committee Note No. 138-NFPA 70-2021 [Section No. 250.20]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 16:30:49 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that FR-8159 be rewritten to comply with the NEC Style Manual, Section 4.1.3 Reference Structure. The structure of the Informational Note No. 1 in 250.20 should be revised to inform the users why they are being sent to other sections and the Informational Note in 250.20(B) should be revised to state "See NFPA 70E informative Annex O..."

First Revision No. 8159-NFPA 70-2020 [Section No. 250.20]

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.



Public Comment No. 2142-NFPA 70-2021 [Section No. 250.20 [Excluding any Sub-Sections]]

Alternating-current systems shall be grounded in accordance with 250.20(A), (B), (C), or (D), unless prohibited elsewhere in this *Code*. Other systems shall be permitted to be grounded. If such systems are grounded, they shall comply with the applicable provisions of this article.

Informational Note No. 1: An example of a system permitted to be grounded is a corner-grounded delta transformer connection. See 250.26(4) for conductor to be grounded.

Informational Note No. 2: ~~See 503.155, 517.61, 517.160, 668.10, and 680.23(A)(2) for examples of circuits prohibited to be grounded.~~

Statement of Problem and Substantiation for Public Comment

This PC along with a correlating PC seeks to reverse the panel action and remove the new informational note and restore section 250.22 with any updated information.

The overall usability of the NEC has been reduced by the panel action to remove 250.22 and relocate some but not all of the valuable information in an informational note. For all users of the code, the general requirements of Chapters 1 through 4 are provided and sometimes for usability lists of other requirements or permissions found in other code sections related to a particular requirement are also provided. Changes should not be made the reduce usability for the general user in the field.

Sections 250.20, 250.21, 250.22 provided the users of the NEC a single location to find the general requirements of what systems are:

- required to be grounded (250.20),
- what systems are permitted to be grounded (250.21), and
- lastly what systems are prohibited from being grounded (250.22).

Section 250.22 consolidated the 6 locations found elsewhere in the NEC where this prohibition existed along with the reference pointer so that users would not have to search for those locations or make the mistake of applying the general requirement not realizing there was another mandatory opposing requirement. Using the panel's logic for removing 250.22, then the panel should look at 250.118 where some of those equipment grounding conductor requirements are also found in the chapter 3 wiring methods Articles. Having 250.118 gives greater usability because all of these various applications from the wiring method Articles along with additional conditions are provided in the single location for ease of use and reference.

In addition, the new informational note is incomplete, as 411.6(A)(1) still has a general prohibition for grounding low voltage lighting systems. CMP-18 added an exception for the class 2 systems where grounding would be optionally permitted, neither required or prohibited which addressed the need of the PI submitted. But they did not remove the existing prohibition for grounding of the secondary side of low voltage lighting systems, such as landscape lighting. Testing laboratories should be using the applicable product standard and not using the NEC for listing of products as was indicated in the PI substantiation.

Related Public Comments for This Document

Related Comment

[Public Comment No. 2147-NFPA 70-2021 \[Global Input\]](#)

[Public Comment No. 2147-NFPA 70-2021 \[Global Input\]](#)

Relationship

Correlating action

Related Item

- FR 8159

Submitter Information Verification

Submitter Full Name: Charles Mello

Organization: Cdcmello Consulting Llc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 19 13:49:09 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Informational Note 2 is retained because section 250.22 was not restored.



Public Comment No. 742-NFPA 70-2021 [Section No. 250.24]

250.24 Grounding of Service-Supplied Alternating-Current Systems.

(A) System Grounding Connections.

A premises wiring system supplied by a grounded ac service shall have a grounding electrode conductor connected to the grounded service conductor, at each service, in accordance with 250.24(A)(1) through (A)(4).

(1) General.

The grounding electrode conductor connection shall be made at any accessible point from the load end of the overhead service conductors, service drop, underground service conductors, or service lateral to the terminal or bus to which the grounded service conductor is connected at the service disconnecting means.

Informational Note: See definitions of *Service Conductors*, *Overhead*; *Service Conductors*, *Underground*; *Service Drop*; and *Service Lateral* in Article 100.

(2) Outdoor Transformer.

If the transformer supplying the service is located outside the building, at least one additional grounding connection shall be made from the grounded service conductor to a grounding electrode, either at the transformer or elsewhere outside the building.

Exception: The additional grounding electrode conductor connection shall not be made on impedance grounded systems. The system shall meet the requirements of 250.36 or 250.187, as applicable.

(3) Dual-Fed Services.

For services that are dual fed (double ended) in a common enclosure or grouped together in separate enclosures and employing a secondary tie, a single grounding electrode conductor connection to the tie point of the grounded conductor(s) from each power source shall be permitted.

(4) Main Bonding Jumper as Wire or Busbar.

If the main bonding jumper specified in 250.28 is a wire or busbar and is installed from the grounded conductor terminal bar or bus to the equipment grounding terminal bar or bus in the service equipment, the grounding electrode conductor shall be permitted to be connected to the equipment grounding terminal, bar, or bus to which the main bonding jumper is connected.

(B) Load-Side Grounding Connections.

A grounded conductor shall not be connected to normally non-current-carrying metal parts of equipment, to equipment grounding conductor(s), or be reconnected to ground on the load side of the service disconnecting means except as otherwise permitted in this article.

Informational Note: See 250.30 for separately derived systems, 250.32 for connections at separate buildings or structures, and 250.142 for use of the grounded circuit conductor for grounding equipment.

(C) Main Bonding Jumper.

For a grounded system, an unspliced main bonding jumper shall be used to connect the equipment grounding conductor(s) and the service-disconnect enclosure to the grounded conductor within the enclosure for each service disconnect in accordance with 250.28.

Exception No. 1: If more than one service disconnecting means is located in an assembly listed for use as service equipment, an unspliced main bonding jumper shall bond the grounded conductor(s) to the assembly enclosure.

Exception No. 2: Impedance grounded systems shall be permitted to be connected in accordance with 250.36 and 250.187.

(D) Grounded Conductor Brought to Service Equipment.

If an ac system operating at 1000 volts or less is grounded at any point, the grounded conductor(s) shall be routed with the ungrounded conductors to each service disconnecting means and shall be connected to each disconnecting means grounded conductor(s) terminal or bus. A main bonding jumper shall connect the grounded conductor(s) to each service disconnecting means enclosure. The grounded conductor(s) shall be installed in accordance with 250.24(D)(1) through (D)(4).

Exception: If two or more service disconnecting means are located in a single assembly listed for use as service equipment, it shall be permitted to connect the grounded conductor(s) to the assembly common grounded conductor(s) terminal or bus. The assembly shall include a main bonding jumper for connecting the grounded conductor(s) to the assembly enclosure.

(1) Sizing for a Single Raceway or Cable.

The grounded conductor shall not be smaller than specified in Table 250.102(C)(1).

(2) Conductors in Two or More Raceways or Cables Connected in Parallel.

If the ungrounded service-entrance conductors are connected in parallel in two or more raceways or cables, the grounded conductors shall also be installed in each raceway or cable and shall be connected in parallel. The size of the grounded conductor(s) in each raceway or cable shall be based on the largest ungrounded conductor in each raceway or cable, or the sum of the circular mil areas of the largest ungrounded conductors from each set connected in parallel in each raceway or cable in accordance with in 250.24(D)(1), but not smaller than 1/0 AWG.

Informational Note: See 310.10(G) for grounded conductors connected in parallel.

(3) Delta-Connected Service.

The grounded conductor of a 3-phase, 3-wire delta service shall have an ampacity not less than that of the ungrounded conductors.

(4) Impedance Grounded Service.

The impedance grounding conductor on an impedance grounded system shall be connected in accordance with 250.36 or 250.187, as applicable.

(E) Grounding Electrode Conductor.

A grounding electrode conductor shall be used to connect the equipment grounding conductors, the service-equipment enclosures, and, if the system is grounded, the grounded service conductor to the grounding electrode(s) required by Part III of this article. This conductor shall be sized in accordance with 250.66.

Impedance grounded system connections shall be made in accordance with 250.36 or 250.187, as applicable.

(F) Ungrounded System Grounding Connections.

A premises wiring system that is supplied by an ac service that is ungrounded shall have, at each service, a grounding electrode conductor connected to the grounding electrode(s) required by Part III of this article. The grounding electrode conductor shall be connected to a metal enclosure of the service conductors at any accessible point from the load end of the overhead service conductors, service drop, underground service conductors, or service lateral to the service disconnecting means.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_139.pdf	5 CN139

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 139 appeared in the First Draft Report on First Revision No. 8232.

The Correlating Committee directs that FR-8232 be rewritten to comply with the NEC Style Manual, Section 4.1.3 Reference Structure. The structure of the Informational Note 250.24(A)(1) needs to be revised and also consider informing the users why they are being directed to other sections. The Correlating Committee also notes that the second sentence in the exception in 250.24(A)(2) needs to be revised for clarity. In 250.24(0)(2) the first revision in the text that replaces the term "installed" with the term "connected" needs to be reconsidered for clarity.

Related Item

- First Revision No. 8232

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 03 15:49:02 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7954-NFPA 70-2021

Statement: Section 250.24(A)(1) Informational Note is revised to comply with Section 4.1.3 of the NEC Style Manual. The words "The system" are replaced with "Impedance grounded systems" in 250.24(A)(2) Exception for clarity. The term "impedance grounded systems" correlates with the changes made in 250.36. Section 250.24(D)(2) is revised to a list format for clarity of how the ungrounded and grounded service conductors are installed and connected for parallel installations.

**Correlating Committee Note No. 139-NFPA 70-2021 [Section No. 250.24]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 16:50:52 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that FR-8232 be rewritten to comply with the NEC Style Manual, Section 4.1.3 Reference Structure. The structure of the Informational Note 250.24(A)(1) needs to be revised and also consider informing the users why they are being directed to other sections. The Correlating Committee also notes that the second sentence in the exception in 250.24(A)(2) needs to be revised for clarity. In 250.24(D)(2) the first revision in the text that replaces the term "installed" with the term "connected" needs to be reconsidered for clarity.

First Revision No. 8232-NFPA 70-2020 [Section No. 250.24]

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.



Public Comment No. 1883-NFPA 70-2021 [Section No. 250.25]

250.25 Grounding Systems Permitted to Be Connected on the Supply Side of the Service

Disconnect.

The grounding of systems connected on the supply side of the service disconnect, as permitted in

accordance with

230.82, that are in enclosures separate from the service equipment enclosure shall comply with 250.25(A) or (B).

(A) Grounded System.

If the utility supply system is grounded, the grounding of systems permitted to be connected on the supply side of the service disconnect and are installed in one or more separate enclosures from the service equipment enclosure shall comply with the requirements of 250.24(A) through (D).

(B) Ungrounded Systems.

If the utility supply system is ungrounded, the grounding of systems permitted to be connected on the supply side of the service disconnect and are installed in one or more separate enclosures from the service equipment enclosure shall comply with the requirements of 250.24

F).

E) -

the following:

All metal enclosures, metallic wiring methods, and metal parts associated with the power source output circuit conductors shall be connected to the grounding electrode system for the service with only one of the following methods:

- (1) Grounded Conductor Brought to Power Source Disconnecting Means. Where a grounded service conductor is brought to the power source disconnecting means, the grounded conductor shall be connected to the disconnecting means grounded conductor terminal or bus. A bonding conductor shall connect the grounded service conductor to each metal enclosure for the power source output circuit conductors. This bonding conductor shall be sized in accordance with 250.102 based on the size of the power source output circuit conductors.
- (1) Grounded Conductor not Brought to Power Source Disconnecting Means. Where a grounded service conductor is not brought to the power source disconnecting means, each metal enclosure for the power source output circuit conductors shall be bonded using a separate bonding conductor sized in accordance with 250.102 based on the size the power source output circuit conductors. This separate bonding conductor shall be connected to the grounding electrode system

Statement of Problem and Substantiation for Public Comment

This is the same language that I submitted during the first revision process. This clarification is necessary for proper field application. Should this change or a similar one then 705.11 could be changed to simply refer to 250.25 for grounding and bonding.

Related Item

- PI4287

Submitter Information Verification

Submitter Full Name: James Rogers

Organization: Towns Of Oak Bluffs, Tisbury,

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 18 13:37:20 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The submitter has not provided any new substantiation for changing the current Code language.



Public Comment No. 409-NFPA 70-2021 [Section No. 250.25]

250.25 Grounding of Systems Permitted to Be Connected on the Supply Side of the Service Disconnect.

The grounding of systems connected on the supply side of the service disconnect, in accordance with 230.82, that are in enclosures separate from the service equipment enclosure shall comply with 250.25(A) or (B).

(A) Grounded System.

If the utility supply system is grounded, the grounding of systems permitted to be connected on the supply side of the service disconnect and are installed in one or more separate enclosures from the service equipment enclosure shall comply with the requirements of 250.24(A) through (D).

(B) Ungrounded Systems.

If the utility supply system is ungrounded, the grounding of systems permitted to be connected on the supply side of the service disconnect and are installed in one or more separate enclosures from the service equipment enclosure shall comply with the requirements of 250.24(F).

Statement of Problem and Substantiation for Public Comment

Upon further examination the committee will find that Section 250.25 is titled " Grounding Systems..." not "Grounding of Systems...".

The first sentence of section 250.25 also uses the word "of" as well as the title of section 250.24.

Public Input No. 893-NFPA 70-2020 [Section No. 250.25]

Related Item

• The committees response is erroneous. The title is not as stated in the committee response.

• Public Input No. 893-NFPA 70-2020 [Section No. 250.25]

Submitter Information Verification

Submitter Full Name: Beau Burton

Organization: Detroit Electrical JATC

Affiliation: IBEW/NECA

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jul 27 00:01:44 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7957-NFPA 70-2021

Statement: The word "of" is added in the title of 250.25 to be consistent with 250.24.



Public Comment No. 743-NFPA 70-2021 [Section No. 250.30]

250.30 Grounding Separately Derived Alternating-Current Systems.

In addition to complying with 250.30(A) for grounded systems, or as provided in 250.30(B) for ungrounded systems, separately derived systems shall comply with 250.20, 250.21, 250.22, or 250.26, as applicable. Multiple power sources of the same type that are connected in parallel to form one system that supplies premises wiring shall be treated as a single separately derived system and shall be installed in accordance with 250.30.

Informational Note No. 1: An alternate ac power source, such as an on-site generator, is not a separately derived system if the grounded conductor is solidly interconnected to a service-supplied system grounded conductor. An example of such a situation is if the alternate source transfer equipment does not include a switching action in the grounded conductor and allows it to remain solidly connected to the service-supplied grounded conductor when the alternate source is operational and supplying the load served.

Informational Note No. 2: See 445.13 for the minimum size of conductors that carry fault current.

(A) Grounded Systems.

A separately derived ac system that is grounded shall comply with 250.30(A)(1) through (A)(8). Except as otherwise permitted in this article, a grounded conductor shall not be connected to normally non-current-carrying metal parts of equipment, be connected to equipment grounding conductors, or be reconnected to ground on the load side of the system bonding jumper.

Informational Note: See 250.32 for connections at separate buildings or structures and 250.142 for use of the grounded circuit conductor for grounding equipment.

Exception: Impedance grounded system grounding connections shall be made in accordance with 250.36 or 250.187, as applicable.

(1) System Bonding Jumper.

An unspliced system bonding jumper shall comply with 250.28(A) through (D). This connection shall be made at any single point on the separately derived system from the source to the first system disconnecting means or overcurrent device, or it shall be made at the source of a separately derived system that has no disconnecting means or overcurrent devices, in accordance with 250.30(A)(1)(a) or (A)(1)(b). The system bonding jumper shall remain within the enclosure where it originates. If the source is located outside the building or structure supplied, a system bonding jumper shall be installed at the grounding electrode connection in compliance with 250.30(C).

Exception No. 1: For systems installed in accordance with 450.6, a single system bonding jumper connection to the tie point of the grounded circuit conductors from each power source shall be permitted.

Exception No. 2: If a building or structure is supplied by a feeder from an outdoor separately derived system, a system bonding jumper at both the source and the first disconnecting means shall be permitted if doing so does not establish a parallel path for the grounded conductor. If a grounded conductor is used in this manner, it shall not be smaller than the size specified for the system bonding jumper but shall not be required to be larger than the ungrounded conductor(s). For the purposes of this exception, connection through the earth shall not be considered as providing a parallel path.

Exception No. 3: The size of the system bonding jumper for a system that supplies a Class 1, Class 2, or Class 3 circuit, and is derived from a transformer rated not more than 1000 volt-amperes, shall not be smaller than the derived ungrounded conductors and shall not be smaller than 14 AWG copper or 12 AWG aluminum.

(a) *Installed at the Source.* The system bonding jumper shall connect the grounded conductor to the supply-side bonding jumper and the normally non-current-carrying metal enclosure.

(b) *Installed at the First Disconnecting Means.* The system bonding jumper shall connect the grounded conductor to the supply-side bonding jumper, the disconnecting means enclosure, and the equipment grounding conductor(s).

Exception: Separately derived systems consisting of multiple sources of the same type that are connected in parallel shall be permitted to have the system bonding jumper installed at the paralleling switchgear, switchboard, or other paralleling connection point instead of at the disconnecting means located at each separate source.

(2) Supply-Side Bonding Jumper.

If the source of a separately derived system and the first disconnecting means are located in separate enclosures, a supply-side bonding jumper shall be installed with the circuit conductors from the source enclosure to the first disconnecting means enclosure. A supply-side bonding jumper shall not be required to be larger than the derived ungrounded conductors. The supply-side bonding jumper shall be permitted to be of nonflexible metal raceway type or of the wire or bus type as follows:

- (1) A supply-side bonding jumper of the wire type shall comply with 250.102(C), based on the size of the derived ungrounded conductors.
- (2) A supply-side bonding jumper of the bus type shall have a cross-sectional area not smaller than a supply-side bonding jumper of the wire type as determined in 250.102(C).

Exception: A supply-side bonding jumper shall not be required between enclosures for installations made in compliance with 250.30(A)(1), Exception No. 2.

(3) Grounded Conductor.

If a grounded conductor is installed and the system bonding jumper connection is not located at the source, 250.30(A)(3)(a) through (A)(3)(d) shall apply. The grounded conductor shall not be required to be larger than the derived ungrounded conductors.

(a) *Sizing for a Single Raceway.* The grounded conductor shall not be smaller than specified in Table 250.102(C)(1).

(b) *Conductors Connected in Parallel in Two or More Raceways or Cables.* If the ungrounded conductors are connected in parallel in two or more raceways or cables, the grounded conductors shall also be installed in each raceway or cable and shall be connected in parallel. The size of the grounded conductor(s) in each raceway or cable shall be based on the largest derived ungrounded conductor in each raceway or cable, or the sum of the circular mil areas of the largest derived ungrounded conductors from each set connected in parallel in each raceway or cable, in accordance with 250.30(A)(3)(a), but not smaller than 1/0 AWG.

Informational Note: See 310.10(G) for grounded conductors connected in parallel.

(c) *Delta-Connected System.* The grounded conductor of a 3-phase, 3-wire delta system shall have an ampacity not less than that of the ungrounded conductors.

(d) *Impedance Grounded System.* The impedance grounding conductor of an impedance grounded system shall be installed in accordance with 250.36 or 250.187, as applicable.

(4) Grounding Electrode.

The building or structure grounding electrode system shall be used as the grounding electrode for the separately derived system. If located outdoors, the grounding electrode shall be in accordance with 250.30(C).

Exception: If a separately derived system originates in equipment that is listed and identified as suitable for use as service equipment, the grounding electrode used for the service or feeder equipment shall be permitted to be used as the grounding electrode for the separately derived system.

Informational Note No. 1: See 250.104(D) for bonding requirements for interior metal water piping in the area served by separately derived systems.

Informational Note No. 2: See 250.50 and 250.58 for requirements for bonding all electrodes together if located at the same building or structure.

(5) Grounding Electrode Conductor, Single Separately Derived System.

A grounding electrode conductor for a single separately derived system shall be sized in accordance with 250.66 for the derived ungrounded conductors. It shall be used to connect the grounded conductor of the derived system to the grounding electrode in accordance with 250.30(A)(4), or as permitted in 250.68(C)(1) and (C)(2). This connection shall be made at the same point on the separately derived system where the system bonding jumper is connected.

Exception No. 1: If the system bonding jumper specified in 250.30(A)(1) is a wire or busbar, it shall be permitted to connect the grounding electrode conductor to the equipment grounding terminal, bar, or bus if the equipment grounding terminal, bar, or bus is of sufficient size for the separately derived system.

Exception No. 2: If the source of a separately derived system is located within equipment listed and identified as suitable for use as service equipment, the grounding electrode conductor from the service or feeder equipment to the grounding electrode shall be permitted as the grounding electrode conductor for the separately derived system, if the grounding electrode conductor is of sufficient size for the separately derived system. If the equipment grounding bus internal to the equipment is not smaller than the required grounding electrode conductor for the separately derived system, the grounding electrode connection for the separately derived system shall be permitted to be made to the bus.

Exception No. 3: A grounding electrode conductor shall not be required for a system that supplies a Class 1, Class 2, or Class 3 circuit and is derived from a transformer rated not more than 1000 volt-amperes, provided the grounded conductor is bonded to the transformer frame or enclosure by a jumper sized in accordance with 250.30(A)(1), Exception No. 3, and the transformer frame or enclosure is grounded by one of the means specified in 250.134.

(6) Grounding Electrode Conductor, Multiple Separately Derived Systems.

A common grounding electrode conductor for multiple separately derived systems shall be permitted. If installed, the common grounding electrode conductor shall be used to connect the grounded conductor of each separately derived system to the grounding electrode as specified in 250.30(A)(4). A grounding electrode conductor tap shall then be installed from each separately derived system to the common grounding electrode conductor. Each tap conductor shall connect the grounded conductor of the separately derived system to the common grounding electrode conductor. This connection shall be made at the same point on the separately derived system where the system bonding jumper is connected.

Exception No. 1: If the system bonding jumper specified in 250.30(A)(1) is a wire or busbar, it shall be permitted to connect the grounding electrode conductor tap to the equipment grounding terminal, bar, or bus, provided the equipment grounding terminal, bar, or bus is of sufficient size for the separately derived system.

Exception No. 2: A grounding electrode conductor shall not be required for a system that supplies a Class 1, Class 2, or Class 3 circuit and is derived from a transformer rated not more than 1000 volt-amperes, provided the system grounded conductor is bonded to the transformer frame or enclosure by a jumper sized in accordance with 250.30(A)(1), Exception No. 3, and the transformer frame or enclosure is grounded by one of the means specified in 250.134.

Exception No. 3: If the source of a separately derived system is located within equipment listed and identified as suitable for use as service equipment, the grounding electrode conductor from the service or feeder equipment to the grounding electrode shall be permitted as the grounding electrode conductor for the separately derived system, if the grounding electrode conductor is of sufficient size for the separately derived system. If the equipment grounding bus internal to the equipment is not smaller than the required grounding electrode conductor for the separately derived system, the grounding electrode connection for the separately derived system shall be permitted to be made to the bus.

(a) **Common Grounding Electrode Conductor.** The common grounding electrode conductor shall be permitted to be one of the following:

- (1) A conductor of the wire type not smaller than 3/0 AWG copper or 250 kcmil aluminum
- (2) A metal water pipe in accordance with 250.68(C)(1)
- (3) The metal structural frame of the building or structure in accordance with 250.68(C)(2) or is connected to the grounding electrode system by a conductor not smaller than 3/0 AWG copper or 250 kcmil aluminum

(b) **Tap Conductor Size.** Each tap conductor shall be sized in accordance with 250.66 based on the derived ungrounded conductors of the separately derived system it serves.

Exception to (a)(1) and (b): If the only electrodes that are present are of the types in 250.66(A), (B), or (C), the size of the common grounding electrode conductor shall not be required to be larger than the largest conductor required by 250.66(A), (B), or (C) for the type of electrode that is present.

(c) **Connections.** All tap connections to the common grounding electrode conductor shall be made at an accessible location by one of the following methods:

- (1) A connector listed as grounding and bonding equipment.
- (2) Listed connections to aluminum or copper busbars not smaller than 6 mm thick × 50 mm wide (¼ in. thick × 2 in. wide) and of a length to accommodate the number of terminations necessary for the installation. If aluminum busbars are used, the installation shall also be in accordance with 250.64(A).
- (3) The exothermic welding process.

Tap conductors shall be connected to the common grounding electrode conductor in such a manner that the common grounding electrode conductor remains without a splice or joint.

(7) Installation.

The installation of all grounding electrode conductors shall comply with 250.64(A), (B), (C), and (E).

(8) Bonding.

Structural steel and metal piping shall be connected to the grounded conductor of a separately derived system in accordance with 250.104(D).

(B) Ungrounded Systems.

The equipment of an ungrounded separately derived system shall be grounded and bonded as specified in 250.30(B)(1) through (B)(3).

(1) Grounding Electrode Conductor.

A grounding electrode conductor, sized in accordance with 250.66 for the largest derived ungrounded conductor(s) or set of derived ungrounded conductors, shall be used to connect the metal enclosures of the derived system to the grounding electrode as specified in 250.30(A)(5) or (A)(6), as applicable. This connection shall be made at any point on the separately derived system from the source to the first system disconnecting means. If the source is located outside the building or structure supplied, a grounding electrode connection shall be made in compliance with 250.30(C).

(2) Grounding Electrode.

Except as permitted by 250.34 for portable and vehicle-mounted generators, the grounding electrode shall comply with 250.30(A)(4).

(3) Bonding Path and Conductor.

A supply-side bonding jumper shall be installed from the source of a separately derived system to the first disconnecting means in compliance with 250.30(A)(2).

(C) Outdoor Source.

If the source of the separately derived system is located outside the building or structure supplied, a grounding electrode connection shall be made at the source location to one or more grounding electrodes in accordance with 250.50. In addition, the installation shall be in accordance with 250.30(A) for grounded systems or with 250.30(B) for ungrounded systems.

Exception: The grounding electrode conductor connection for impedance grounded neutral systems shall be in accordance with 250.36 or 250.187, as applicable.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_140.pdf	5 CN140

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 140 appeared in the First Draft Report on First Revision No. 8233.

The Correlating Committee directs that the text of this FR-8233 be reconsidered for removal of the word "neutral" for correlation and consistency.

Related Item

- First Revision No. 8233

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 03 15:51:32 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-7965-NFPA 70-2021](#)

Statement: The word "neutral" was removed in 250.30(C) Exception for consistency.

**Correlating Committee Note No. 140-NFPA 70-2021 [Section No. 250.30]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 16:59:58 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that the text of this FR-8233 be reconsidered for removal of the word "neutral" for correlation and consistency.

First Revision No. 8233-NFPA 70-2020 [Section No. 250.30]

Ballot Results

✓ **This item has passed ballot**

12 Eligible Voters

0 Not Returned

12 Affirmative All

0 Affirmative with Comments

0 Negative with Comments

0 Abstention

Affirmative All

Ayer, Lawrence S.

Gallo, Ernest J.

Hickman, Palmer L.

Holub, Richard A.

Hunter, Dean C.

Johnston, Michael J.

Kendall, David H.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Porter, Christine T.

Williams, David A.



Public Comment No. 268-NFPA 70-2021 [Section No. 250.32(B)(1)]

(1) Supplied by a Feeder or Branch Circuit.

An equipment grounding conductor, as described in 250.118, shall be run with the supply conductors and be connected to the building or structure disconnecting means and to the grounding electrode(s). The equipment grounding conductor shall be used for grounding or bonding of equipment, structures, or frames required to be grounded or bonded. The equipment grounding conductor shall be sized in accordance with 250.122. Any installed grounded conductor shall not be connected to the equipment grounding conductor or to the grounding electrode(s).

Exception No. 1: For installations made in compliance with previous editions of this Code that permitted such connection, the grounded conductor run with the supply to the building or structure shall be permitted to serve as the ground-fault return path if all of the following requirements continue to be met:

- (1) *An equipment grounding conductor is not run with the supply to the building or structure.*
- (2) *There are no continuous metallic paths bonded to the grounding system in each building or structure involved.*
- (3) *Ground-fault protection of equipment has not been installed on the supply side of the feeder(s).*

If the grounded conductor is used for grounding in accordance with the provision of this exception, the size of the grounded conductor shall not be smaller than the larger of either of the following:

- (1) *The calculated neutral load in accordance with 220.61*
- (2) *The minimum equipment grounding conductor sized in accordance with 250.122*

Exception No. 2: If system bonding jumpers are installed in accordance with 250.30(A)(1), Exception No. 2, the feeder grounded circuit conductor at the building or structure served shall be connected to the equipment grounding conductors, grounding electrode conductor, and the enclosure for the first disconnecting means.

Statement of Problem and Substantiation for Public Comment

The text identified as underlined is incorrectly formatted as a part of Exception No. 1. Please remove all formatting for this text.

Related Item

- FR-8252

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Sun Jul 18 22:45:20 EDT 2021
Committee: NEC-P05

Committee Statement

**Committee
Action:** Rejected

Resolution: The text in 250.32(B)(1) Exception No. 1 is properly italicized as part of the exception.



Public Comment No. 921-NFPA 70-2021 [Section No. 250.34(C)]

(C) Grounded Conductor Bonding.

A conductor that is required to be grounded by 250.26 shall be connected to the generator frame if

(1) the generator is a component of a separately derived system.

(2) a grounding-type receptacle is mounted on the generator or frame without the marking "No equipment ground"

(3) a terminal or receptacle that is identified for equipment grounding purposes is mounted on the generator or frame without the marking "No equipment ground"

Informational Note: See 250.30 for grounding portable generators supplying fixed wiring systems.

Statement of Problem and Substantiation for Public Comment

With an unbonded neutral, there is no ground return path for fault current to trip an overcurrent or ground fault device. This is precisely the situation where the "no equipment ground" is specified in 406.4(D)(2). Even though with these generators a ground fault will not trip a GFCI, the warning could be useful and certainly is appropriate.

Related Item

- PI123

Submitter Information Verification

Submitter Full Name: David Shapiro

Organization: Safety First Electrical

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 20:59:41 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: It is common for unbonded generators to be connected to premises wiring for backup power as a non-separately derived system. In this case, there is a path for fault current to trip an overcurrent or ground fault device. This would make the proposed required marking incorrect and misleading.



Public Comment No. 1989-NFPA 70-2021 [Section No. 250.36(E)]

(E) Equipment- Impedance Grounding Bonding Jumper.

The ~~equipment- impedance grounding~~ bonding jumper (the connection between the equipment grounding conductors and the grounding impedance device) shall be an unspliced conductor run from the first system disconnecting means or overcurrent device to the grounded side of the grounding impedance device.

Statement of Problem and Substantiation for Public Comment

Change the term Equipment Bonding Jumper in 250.36 (E) to Impedance grounding bonding jumper in the title and text to be consistent with title and text in 250.36 (B) and (D). This will eliminate the incompatibility with term bonding jumper used elsewhere in the code.

Related Item

- FR 8235

Submitter Information Verification

Submitter Full Name: Daleep Mohla

Organization: DCM Electrical Consulting Serv

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 18 21:37:33 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8047-NFPA 70-2021

Statement: The phrase “to a low value” is removed because low is an ambiguous term that is not enforceable. Users of this section of the code understand the current in an impedance grounded system is limited to value below the rating of the applicable overcurrent circuit protective device.

The term “equipment bonding jumper” is replaced by “impedance bonding jumper” in multiple locations because in an impedance grounded system the subject conductor does not meet the definition of equipment bonding jumper in Article 100. The replacement term is consistent with changes made in the First Draft action and is explained in the text, making a new definition unnecessary.



Public Comment No. 1994-NFPA 70-2021 [Section No. 250.36(G)]

(G)– Equipment- Impedance Grounding Bonding Jumper Size.

The ~~equipment- impedance grounding~~ bonding jumper shall be sized in accordance with either of the following:

- (1) If the grounding electrode conductor connection is made at the grounding impedance device, the ~~equipment- impedance grounding~~ bonding jumper shall be sized in accordance with 250.66, based on the size of the service entrance conductors for a service or the derived phase conductors for a separately derived system.
- (2) If the grounding electrode conductor is connected at the first system disconnecting means or overcurrent device, the ~~equipment- impedance grounding~~ bonding jumper shall be sized the same as the impedance grounding conductor in 250.36(B).

Statement of Problem and Substantiation for Public Comment

Change the term Equipment bonding jumper to Impedance grounding bonding jumper size in the title and text to be consistent with the title and text in 250.36 (B) and (D) and new proposed change to 250.36 (E).

Related Item

- FR 8235

Submitter Information Verification

Submitter Full Name: Daleep Mohla

Organization: DCM Electrical Consulting Serv

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 18 21:45:26 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8047-NFPA 70-2021

Statement: The phrase “to a low value” is removed because low is an ambiguous term that is not enforceable. Users of this section of the code understand the current in an impedance grounded system is limited to value below the rating of the applicable overcurrent circuit protective device.

The term “equipment bonding jumper” is replaced by “impedance bonding jumper” in multiple locations because in an impedance grounded system the subject conductor does not meet the definition of equipment bonding jumper in Article 100. The replacement term is consistent with changes made in the First Draft action and is explained in the text, making a new definition unnecessary.





Public Comment No. 1313-NFPA 70-2021 [Section No. 250.36 [Excluding any Sub-Sections]]

Impedance grounded systems in which a grounding impedance device, typically a resistor, limits the ground-fault current to a low value shall be permitted for 3-phase ac systems of 480 volts to 1000 volts if all the following conditions are met:

- (1) The conditions of maintenance and supervision ensure that only qualified persons service the installation.
- (2) Ground detectors are installed on the system.
- (3) Line-to-neutral loads are not served.

Impedance grounded systems shall comply with 250.36(A) through (G).

Informational Note: According to Annex O of NFPA 70E-2021, *Standard for Electrical Safety in the Workplace*, impedance grounding is an effective tool to reduce arc-flash hazards.

Statement of Problem and Substantiation for Public Comment

A low-impedance grounding system limits the current to a lower value, but not necessarily a "low" value.

Related Item

- FR 8235

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 11 18:08:42 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8047-NFPA 70-2021

Statement: The phrase "to a low value" is removed because low is an ambiguous term that is not enforceable. Users of this section of the code understand the current in an impedance grounded system is limited to value below the rating of the applicable overcurrent circuit protective device.

The term "equipment bonding jumper" is replaced by "impedance bonding jumper" in multiple locations because in an impedance grounded system the subject conductor does not meet the definition of equipment bonding jumper in Article 100. The

replacement term is consistent with changes made in the First Draft action and is explained in the text, making a new definition unnecessary.



Public Comment No. 269-NFPA 70-2021 [Section No. 250.50]

250.50 Grounding Electrode System.

All grounding electrodes as described in 250.52(A)(1) through (A)(7) that are present at each building or structure served shall be bonded together to form the grounding electrode system. If none of these grounding electrodes exist, one or more of the grounding electrodes specified in 250.52(A)(4) through (A)(8) shall be installed and used.

Exception: Concrete-encased electrodes of existing buildings or structures shall not be required to be part of the grounding electrode system if the ~~steel reinforcing bars or rods are not~~ rebar is not accessible for use without disturbing the concrete.

Statement of Problem and Substantiation for Public Comment

This Comment is intended to be editorial in nature and to harmonize the term "steel reinforcing bars" with "rebar" to be consistent with the language preferred in 250.68(C). See PI-126.

Related Item

- FR-8254, PI-126

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Sun Jul 18 23:04:14 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7968-NFPA 70-2021

Statement: The term "steel reinforcing bars or rods" was replaced with the term "rebar" for consistency.



Public Comment No. 2203-NFPA 70-2021 [Section No. 250.52(A)(3)]

(3) Concrete-Encased Electrode.

A concrete-encased electrode shall consist of at least 6.0 m (20 ft) of concrete, horizontal or vertical, encasing either of the following:

- (1) One or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm (½ in.) in diameter, installed in one continuous 6.0 m (20 ft) length, or if in multiple pieces connected together by steel tie wires, exothermic welding, welding, or other effective means to create a 6.0 m (20 ft) or greater length
- (2) ~~Bare~~ A 20 foot length of bare copper conductor not smaller than 4 AWG

Metal components shall be encased by at least 50 mm (2 in.) of concrete and shall be located horizontally within that portion of a concrete foundation or footing that is in direct contact with the earth or within vertical foundations or structural components or members that are in direct contact with the earth. If multiple concrete-encased electrodes are present at a building or structure, it shall be permissible to bond only one into the grounding electrode system.

Informational Note: Concrete installed with insulation, vapor barriers, films, or similar items separating the concrete from the earth is not considered to be in "direct contact" with the earth.

Statement of Problem and Substantiation for Public Comment

The effectiveness of a grounding electrode is based on a specified area of conductive object in contact with a volume of earth. This is borne out in the descriptive requirements for the accepted grounding electrodes in 250.52(A) and several IEEE standards as well as extensive studies. For example:

- The metal water pipe must be at least 10 feet long and in continuous direct contact with the earth
- The structural metal must be at least 10 feet deep in contact with the earth or encased in concrete that is in direct contact with the earth
- The ground ring must be buried 30 inches deep, encircle the building and be at least 20 feet long
- Ground rods and pipes must be at least 8 feet in direct contact with the earth either driven vertically or as last option resort laid in a trench 30 inches deep.
- Ground plates must have at least 2 square feet of surface area and be buried in direct contact with the earth 30 inches deep.

Each of these examples establishes some minimum length or area for contact with the earth.

The following is a summary of the Ufer studies:

The studies published by Herbert Ufer, AIEE CP 61-978, August 24 1961 and IEEE Transactions paper 63-1505 published May 5, 1964, show the testing that was done to establish the validity of a concrete encased electrode and was the primary basis to accept it into the NEC. In the Arizona study the metal rods were installed spaced apart vertically through the footing but there was no connection horizontally within the footing. The connection horizontally was above the footing for the structure. The second study from Southern California and Portland, Oregon tested copper conductors of various lengths from 22 feet to 100 feet installed in the concrete footings of 10 different buildings in different areas. Most of these were in Southern California. These different conductors were then tested for resistance to earth over a period of time to determine the final results. The conclusion from the 20-year history of the military installations in Arizona and the other testing in commercial and residential buildings in Southern California and Oregon found the concrete encased electrode to be adequate where no metal water pipe electrode was available and also that the conductor within the concrete (rebar or wire) should be placed about 2 inches above the base of the concrete foundation footing.

When the code panel accepted the vertical application in the 2011 cycle there was no study or other technical substantiation provided that allowed reduction of the 20 foot length as has been provided from the Ufer studies and accepted in practice for many decades. The panel acted on an “equivalency” of vertical to horizontal.

In looking at each of the elements in the present text from the First Draft for the rebar, the first statement is “One or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm (½ in.) in diameter installed in one continuous 6.0 m (20 ft) length...” One would have to be very imaginative to install these one or more rebars in “one continuous 20 foot length”, to be in less than 20 feet of horizontal to vertical concrete. The next statement provides an alternative to accommodate typical foundation construction “...or if in multiple pieces connected together by the usual steel tie wires, exothermic welding, welding, or other effective means to create a 6.0 m (20 ft) or greater length...” The implication of this is that one can take more than a single piece of rebar and connect it together to then form to create a 20 foot length. It must be remembered this installation is typically by a general or concrete contractor in compliance with the building code.

The panel has no testing or evidence submitted that a single pier that has 3 to 5 feet of concrete in contact with the earth with several closely tied rebars contained within is even as effective as two ground rods. Panel 5 has been very consistent in rejecting other proposed grounding electrodes requiring testing and technical substantiation and not recognizing what has been years of field experience. The lack of reported field problems then cannot be a technical justification for continuing an installation that does not have technical supporting evidence. In discussions, a statement was made that some industrial sites have years of testing concrete piers used for pipe racks and similar structures. Those tests very likely show acceptable connection to earth, but these piers are all interconnected, not a single pier that would presently be allowed. It is unlikely that the testing was completed on isolated single piers to remote earth.

If the panel believes that pier type construction should be allowed, and I can agree with that possibility, then it needs to establish some minimum construction of concrete and rebar to be an effective grounding electrode. While the example provided in the public input was considered ridiculous it does point out that the present code text is lacking in setting the minimum like any other electrode has. As ridiculous as it was, that assembly would still be legal under the present interpretation being accepted. This may necessitate modifying the present allowance for only connecting to one concrete encased electrode when several are present. If multiples, for example 3 or 4, of these 5-foot-deep piers were bonded together, similar to multiple ground rods of 6 foot spacing bonded together as in 250.53(B) may be a solution.

Related Item

- FR 8066 PI 4489

Submitter Information Verification

Submitter Full Name: Charles Mello

Organization: Cdcmello Consulting Llc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 19 16:34:31 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected

Action:

Resolution: No technical substantiation was provided to demonstrate that a minimum of 20' of concrete is required to establish an effective grounding electrode.



Public Comment No. 270-NFPA 70-2021 [Section No. 250.52(A)(3)]

(3) Concrete-Encased Electrode.

A concrete-encased electrode shall consist of at least 6.0 m (20 ft) of either of the following:

- (1) One or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of rebar of not less than 13 mm (½ in.) in diameter, installed in one continuous 6.0 m (20 ft) length, or if in multiple pieces, the rebar shall be connected together by steel tie wires, exothermic welding, welding, or other effective means to create a 6.0 m (20 ft) or greater length
- (2) Bare copper conductor not smaller than 4 AWG

Metal components shall be encased by at least 50 mm (2 in.) of concrete and shall be located horizontally within that portion of a concrete foundation or footing that is in direct contact with the earth or within vertical foundations or structural components or members that are in direct contact with the earth. If multiple concrete-encased electrodes are present at a building or structure, it shall be permissible to bond only one into the grounding electrode system.

Informational Note: Concrete installed with insulation, vapor barriers, films, or similar items separating the concrete from the earth is not considered to be in "direct contact" with the earth.

Statement of Problem and Substantiation for Public Comment

This Comment is intended to be editorial in nature and to harmonize the term "reinforcing bars or rods" with "rebar" to be consistent with the language preferred in 250.68(C). See PI-126.

Related Item

- FR-8066, PI-126

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

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City:

State:

Zip:

Submittal Date: Sun Jul 18 23:09:47 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7969-NFPA 70-2021

Statement: The term "steel reinforcing bars or rods" was replaced with the term "rebar" for consistency.

**Public Comment No. 575-NFPA 70-2021 [Section No. 250.52(A)(3)]****(3) Concrete-Encased Electrode.**

A concrete-encased electrode shall consist of at least 6.0 m (20 ft) of either of the following:

- (1) One or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm (½ in.) in diameter, installed in one continuous 6.0 m (20 ft) length, or if in multiple pieces connected together by the usual steel tie wires, exothermic welding, welding, or other effective means to create a 6.0 m (20 ft) or greater length
- (2) Bare copper conductor not smaller than 4 AWG

Metal components shall be encased by at least 50 mm (2 in.) of concrete and shall be located horizontally within that portion of a concrete foundation or footing that is in direct contact with the earth or within vertical foundations or structural components or members that are in direct contact with the earth. If multiple concrete-encased electrodes are present at a building or structure, it shall be permissible to bond only one into the grounding electrode system.

Informational Note: Concrete installed with insulation, vapor barriers, films, or similar items separating the concrete from the earth is not considered to be in “direct contact” with the earth.

Statement of Problem and Substantiation for Public Comment

Removing "the usual" might create needless tension between the installation and inspection communities, regarding what is an approved steel wire tie. If "the usual" must go, I suggest something else be added in its place. Or perhaps, an FPN should be added to clarify that standard ties may be sufficient.

Related Item

- First Revision No. 8066-NFPA 70-2020 [Section No. 250.52(A)(3)]

Submitter Information Verification

Submitter Full Name: Josh Weaver

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Fri Jul 30 19:15:28 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Adding “usual” does not improve the NEC language. The “usual tie wires” installed by others are acceptable means for tying rebar together.



Public Comment No. 337-NFPA 70-2021 [Section No. 250.52(A)(4)]

(4) Ground Ring.

A ground ring encircling the building or structure, in direct contact with the earth, consisting of at least 6.0 m (20 ft) of bare copper and 40% copper-clad steel conductor not smaller than 2 AWG.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	Panel Statement CMP 16 on CCS as GEC	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
SubstantiationPoints.Graph.Images..pdf	Facts To Consider Regarding CCS 40% for Article 250 Applications	
ATS_ShearTestRpt.pdf	Shear and UTS Data from Third Party Test Lab	
CCS40_SubstantiationStatement.pdf	CCS 40% Substantiation Statement	

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, "Tesla's Quarterly Profit Soars to a Record \$1.1 Billion" in the second quarter of 2021. Positive earnings will attract more manufacturers of EV's, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC's, GE's and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation's distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building's OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal

copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections

of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wire drawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire.

Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech’s report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor’s only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD’s are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system’s service equipment and the grounding electrode system. “The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page

128.” In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system’s earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. “One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

- PI 2459

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 23 14:01:48 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than those required in UL 467. The current carrying capability of 40% copper clad steel is less

than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

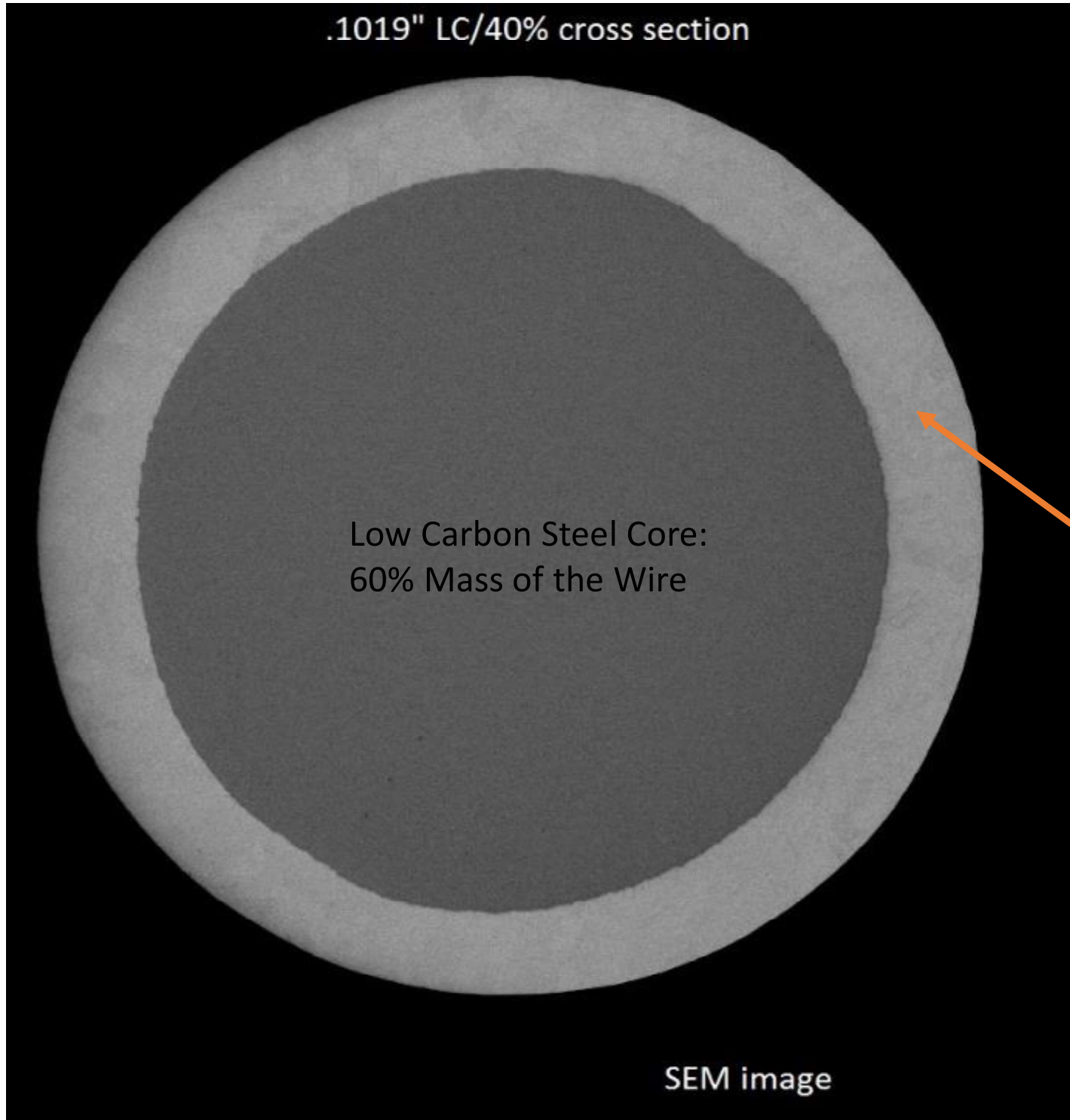
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

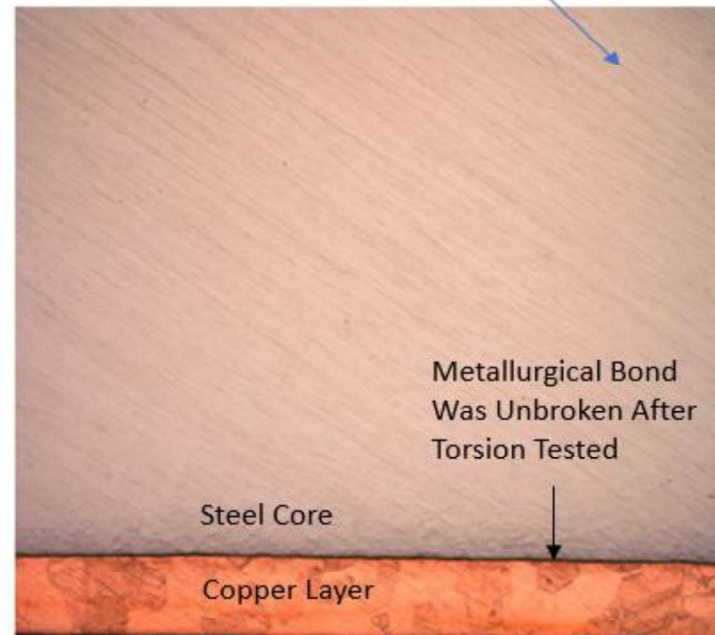
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
 DN: C=ATS, CN=Rodney Allen,
 E=rallen@atslab.com
 Reason: I have reviewed this document
 Location:
 Date: 2021-08-05 12:29:52
 Email: rallen@atslab.com, n 4



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the

short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult due to its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

Submitter Information Verification

Submitter Full Name: Peter Graser

Organization: Copperweld

Affiliation: American Bimetallic Association

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

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



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



Public Comment No. 271-NFPA 70-2021 [Section No. 250.52(B)]

(B) Not Permitted for Use as Grounding Electrodes.

The following systems and materials shall not be used as grounding electrodes:

- (1) Metal underground gas piping systems
- (2) Aluminum
- (3) The structures and structural ~~reinforcing steel described~~ rebar described in 680.26(B)(1) and (B)(2)

Informational Note: See 250.104(B) for bonding requirements of gas piping.

Statement of Problem and Substantiation for Public Comment

This Comment is intended to be editorial in nature and to harmonize the term "reinforcing steel" to "rebar" to be consistent with the language preferred in 250.68(C). See PI-126.

Related Item

- PI-1256

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Sun Jul 18 23:14:39 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7972-NFPA 70-2021

Statement: The term "reinforcing steel" was replaced with the term "rebar" for consistency.

**Public Comment No. 744-NFPA 70-2021 [Section No. 250.53(A)]****(A) Rod, Pipe, and Plate Electrodes.**

Rod, pipe, and plate electrodes shall meet the requirements of 250.53(A)(1) through (A)(3). Rod, pipe, and plate electrodes shall be free from nonconductive coatings such as paint or enamel.

(1) Below Permanent Moisture Level.

If practicable, rod, pipe, and plate electrodes shall be embedded below permanent moisture level.

(2) Supplemental Electrode Required.

A single rod, pipe, or plate electrode shall be supplemented by an additional electrode of a type specified in 250.52(A)(2) through (A)(8). The supplemental electrode shall be permitted to be bonded to one of the following:

- (1) Rod, pipe, or plate electrode
- (2) Grounding electrode conductor
- (3) Grounded service-entrance conductor
- (4) Nonflexible grounded service raceway
- (5) Any grounded service enclosure

Exception: If a single rod, pipe, or plate grounding electrode has a resistance to earth of 25 ohms or less, the supplemental electrode shall not be required.

(3) Supplemental Electrode.

If multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 1.8 m (6 ft) apart.

Informational Note: The paralleling efficiency of rods is increased by spacing them twice the length of the longest rod.

(4) Rod and Pipe Electrodes.

The electrode shall be installed such that at least 2.44 m (8 ft) of length is in contact with the soil. It shall be driven to a depth of not less than 2.44 m (8 ft) except that, where rock bottom is encountered, the electrode shall be driven at an oblique angle not to exceed 45 degrees from the vertical or, where rock bottom is encountered at an angle up to 45 degrees, the electrode shall be permitted to be buried in a trench that is at least 750 mm (30 in.) deep. The upper end of the electrode shall be flush with or below ground level unless the aboveground end and the grounding electrode conductor attachment are protected against physical damage as specified in 250.10.

(5) Plate Electrode.

Plate electrodes shall be installed not less than 750 mm (30 in.) below the surface of the earth.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_141.pdf	5 CN141

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 141 appeared in the First Draft Report on First Revision No. 8068.

The Correlating Committee directs that FR 8068 be reconsidered for clarity. The panel should consider making the new second sentence the opening sentence of the requirement for clarity.

Related Item

- First Revision No. 8068

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 03 15:53:42 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-7974-NFPA 70-2021](#)

Statement: The order of the sentences was modified for clarity.

**Correlating Committee Note No. 141-NFPA 70-2021 [Section No. 250.53(A)]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 17:04:03 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that FR 8068 be reconsidered for clarity. The panel should consider making the new second sentence the opening sentence of the requirement for clarity.

First Revision No. 8068-NFPA 70-2020 [Section No. 250.53(A)]

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.



Public Comment No. 911-NFPA 70-2021 [Section No. 250.53(A)(3)]

(3) Supplemental Electrode.

If multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than than 2.4 m (8 ft) apart where practicable, and a minimum of 1.8 m (6 ft) apart.

Informational Note: The paralleling efficiency of rods is increased by spacing them twice the length of the longest rod.

Statement of Problem and Substantiation for Public Comment

The CMP has not argued with the concept that installing them further apart enhances safety, but rather has pointed out that requiring greater distance may not work in all installations. The proposed revision may eliminate that conflict. "At least twice the length" has a technical advantage, but 8 ft" has the advantage of simplicity.

Related Item

• PI519 • PI965

Submitter Information Verification

Submitter Full Name: David Shapiro

Organization: Safety First Electrical

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 17:18:34 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: No technical substantiation was provided for requiring 8' separation between ground rods.



Public Comment No. 700-NFPA 70-2021 [Section No. 250.53(E)]

(E) Supplemental Grounding Electrode Bonding Jumper Size.

If the supplemental electrode is a rod, pipe, or plate electrode, that portion of the bonding jumper that is the sole connection to the supplemental grounding electrode shall not be required to be larger than 6 AWG copper or copper-clad steel 40% wire or 4 AWG aluminum or copper-clad aluminum wire.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	CCS Suitable Per CMP 16	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
SubstantiationPoints.Graph.Images..pdf	Facts To Consider Regarding CCS 40% for Article 250 Applications	
ATS_ShearTestRpt.pdf	Shear and UTS Data from Third Party Test Lab	
CCS40_SubstantiationStatement.pdf	40% CCS Substantiation Statement	

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings: If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, "Tesla's Quarterly Profit Soars to a Record \$1.1 Billion" in the second quarter of 2021. Positive earnings will attract more manufacturers of EV's, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC's, GE's and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation's distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building's OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its

continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated

grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a "Process" annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

"Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wire drawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

"Ferrous Wire Handbook," Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing."

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to

make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech’s report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor’s only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD’s are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system’s service equipment and the grounding electrode system. “The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and

non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128.” In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system’s earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. “One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

- PI 2460

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 03 11:37:38 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than

those required in UL 467. The current carrying capability of 40% copper clad steel is less than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

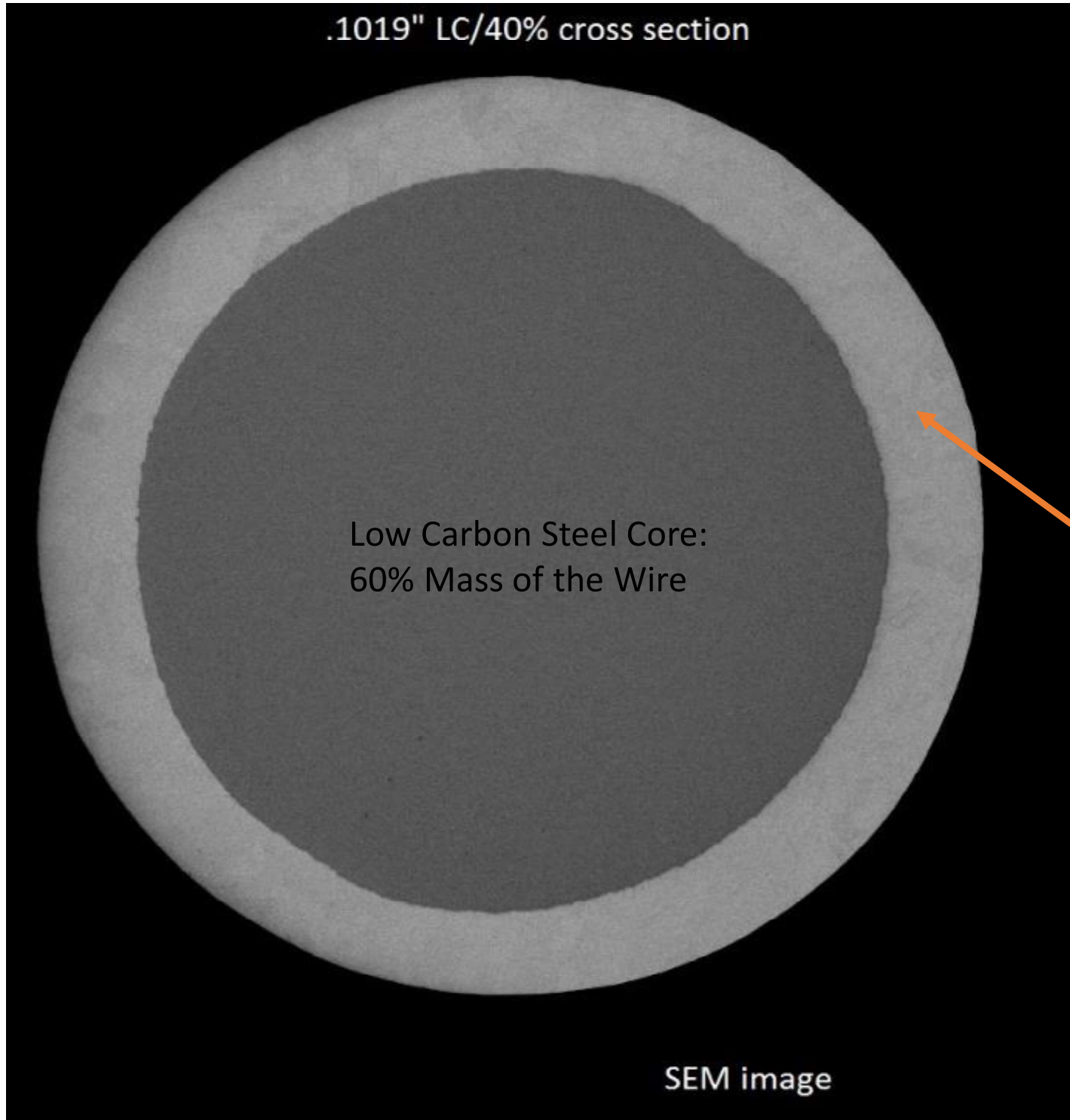
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

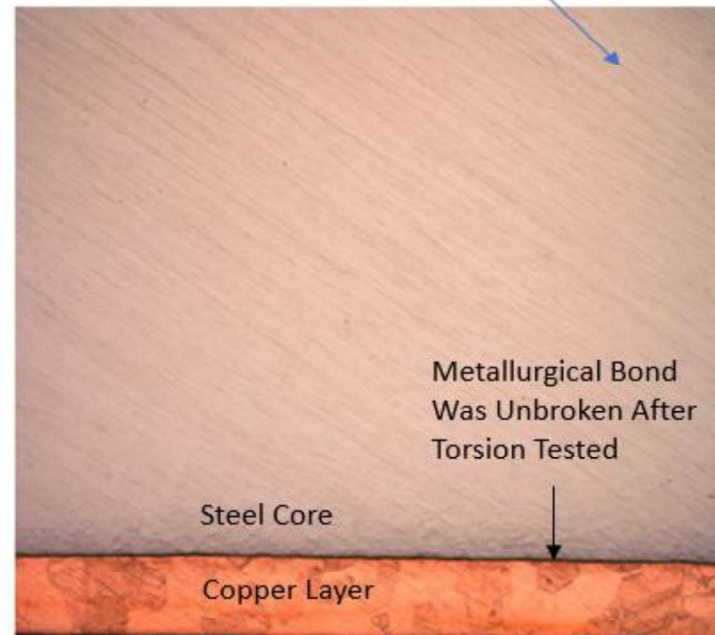
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
 DN: C=ATS, CN=Rodney Allen,
 E=rallen@atslab.com
 Reason: I have reviewed this document
 Location:
 Date: 2021-08-05 12:29:52
 Date: 2021-08-05 12:29:52



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the

short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult due to its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

Submitter Information Verification

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Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

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



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Public Comment No. 490-NFPA 70-2021 [Section No. 250.62]

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, copper-clad steel 40%, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	CMP 16 Committee Statement Reconfirmation in FR 2023 as CCS as GEC	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
SubstantiationPoints.Graph.Images..pdf	Facts To Consider Regarding CCS 40% for Article 250 Applications	
ATS_ShearTestRpt.pdf	Shear and UTS Data from Third Party Test Lab	
CCS40_SubstantiationStatement.pdf	CCS40% Substantiation Statement	

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings:
If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, "Tesla's Quarterly Profit Soars to a Record \$1.1 Billion" in the second quarter of 2021. Positive earnings will attract more manufacturers of EV's, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC's, GE's and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation's distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building's OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE,

for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical

termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its

core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 - 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a

proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

"One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short

distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building's electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility's investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

- PI 2462

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jul 28 13:40:42 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not

replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than those required in UL 467. The current carrying capability of 40% copper clad steel is less than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

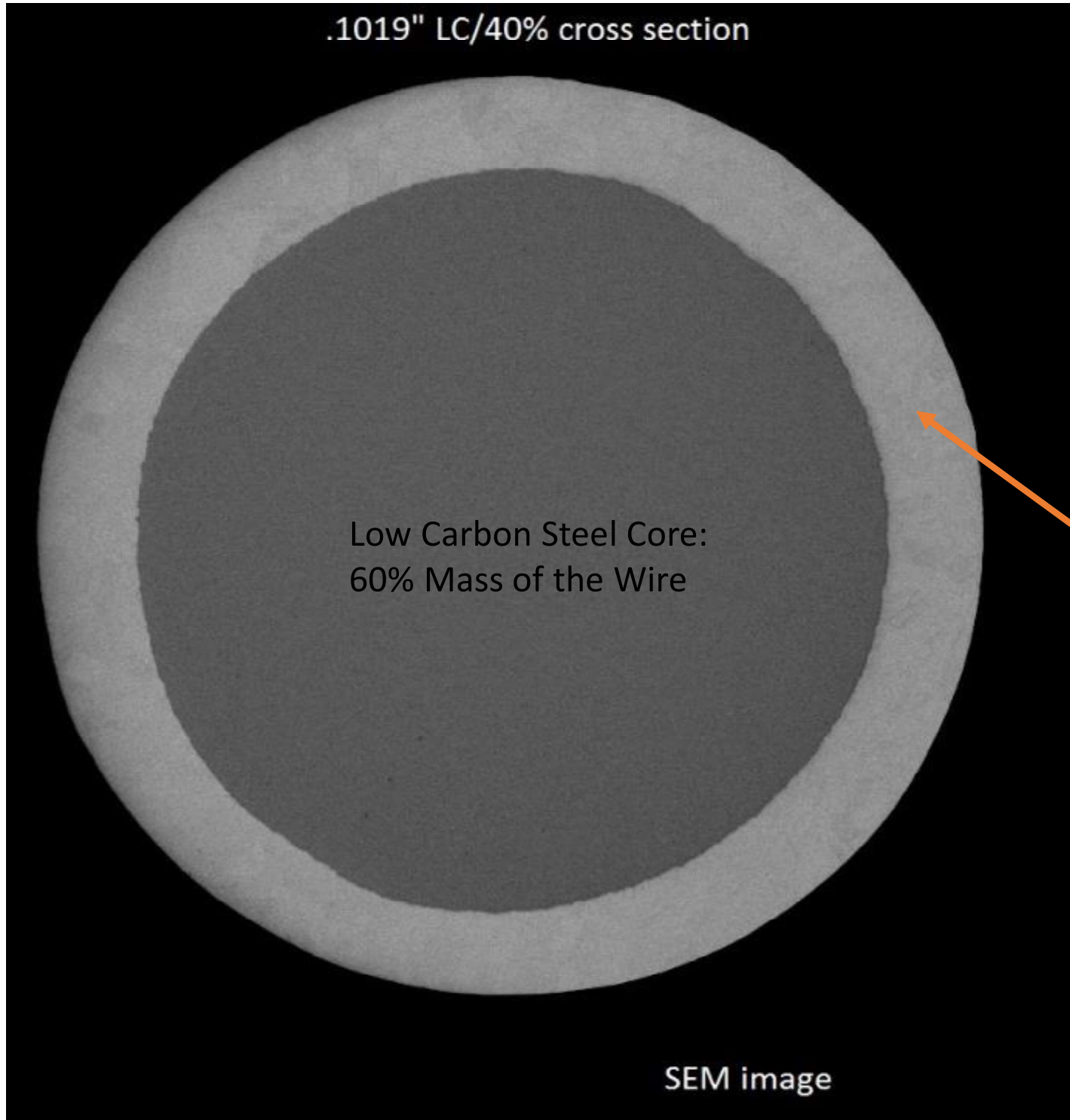
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

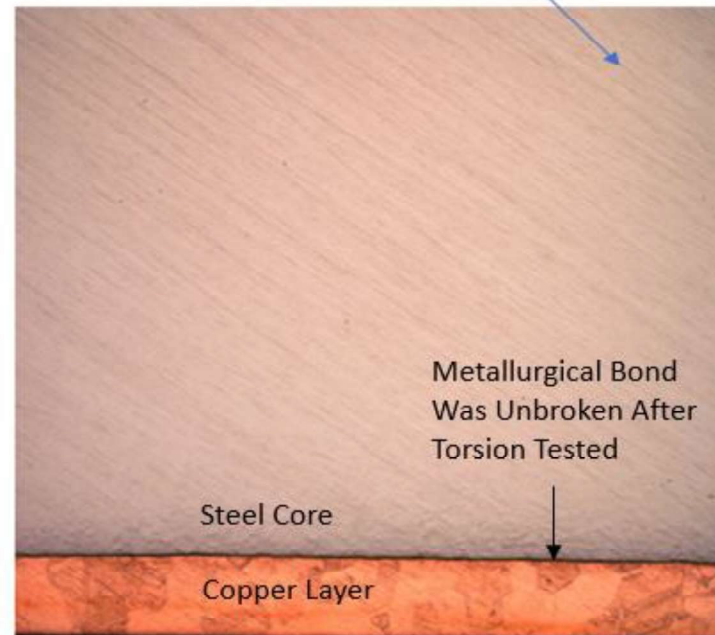
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
 DN: C=ATS, CN=Rodney Allen,
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 Reason: I have reviewed this document
 Location:
 Date: 2021-08-05 12:29:52
 Date: 2021-08-05 12:29:52



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the

short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

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Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

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



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Public Comment No. 578-NFPA 70-2021 [Section No. 250.64(B)]

(B) Securing and Protection Against Physical Damage.

If exposed, a grounding electrode conductor or its enclosure shall be securely fastened to the surface on which it is carried. Grounding electrode conductors shall be permitted to be installed on or through framing members.

(1) Not Exposed to Physical Damage.

A 6 AWG or larger copper-clad steel 40% , copper, copper-clad aluminum, or aluminum grounding electrode conductor not exposed to physical damage shall be permitted to be run along the surface of the building construction without metal covering or protection.

(2) Exposed to Physical Damage.

A 6 AWG or larger copper-clad steel 40% , copper, copper-clad aluminum, or aluminum grounding electrode conductor exposed to physical damage shall be protected in rigid metal conduit (RMC), intermediate metal conduit (IMC), Schedule 80 rigid polyvinyl chloride conduit (PVC), reinforced thermosetting resin conduit Type XW (RTRC-XW), electrical metallic tubing (EMT), or cable armor.

(3) Smaller Than 6 AWG.

Grounding electrode conductors smaller than 6 AWG shall be protected in RMC, IMC, Schedule 80 PVC, RTRC-XW, EMT, or cable armor.

(4) In Contact with the Earth.

Grounding electrode conductors and grounding electrode bonding jumpers in contact with the earth shall not be required to comply with 300.5 or 305.15, but shall be buried or otherwise protected if subject to physical damage.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	CCS Suitable Grounding Material CMP 16	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
ATS_ShearTestRpt.pdf	Shear and UTS Data from Third Party Test Lab	
SubstantiationPoints.Graph.Images..pdf	Substantiation.Graph.Points	
CCS40_SubstantiationStatement.pdf	40% CCS Substantiation Statement	

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section PI #

250.52(A)(4) 2459

250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, "Tesla's Quarterly Profit Soars to a Record \$1.1 Billion" in the second quarter of 2021. Positive earnings will attract more manufacturers of EV's, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the

years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC's, GE's and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation's distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building's OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or

stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a "Process" annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

"Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

"Ferrous Wire Handbook," Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing."

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG

sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than

even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

"One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building's electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility's investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

- PI 2463, PI 2465

Submitter Information Verification

Submitter Full Name: Peter Graser

Organization: Copperweld

Affiliation: American Bimetallic Association

Street Address:

City:**State:****Zip:****Submittal Date:** Sat Jul 31 06:47:05 EDT 2021**Committee:** NEC-P05

Committee Statement

Committee Rejected**Action:**

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than those required in UL 467. The current carrying capability of 40% copper clad steel is less than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

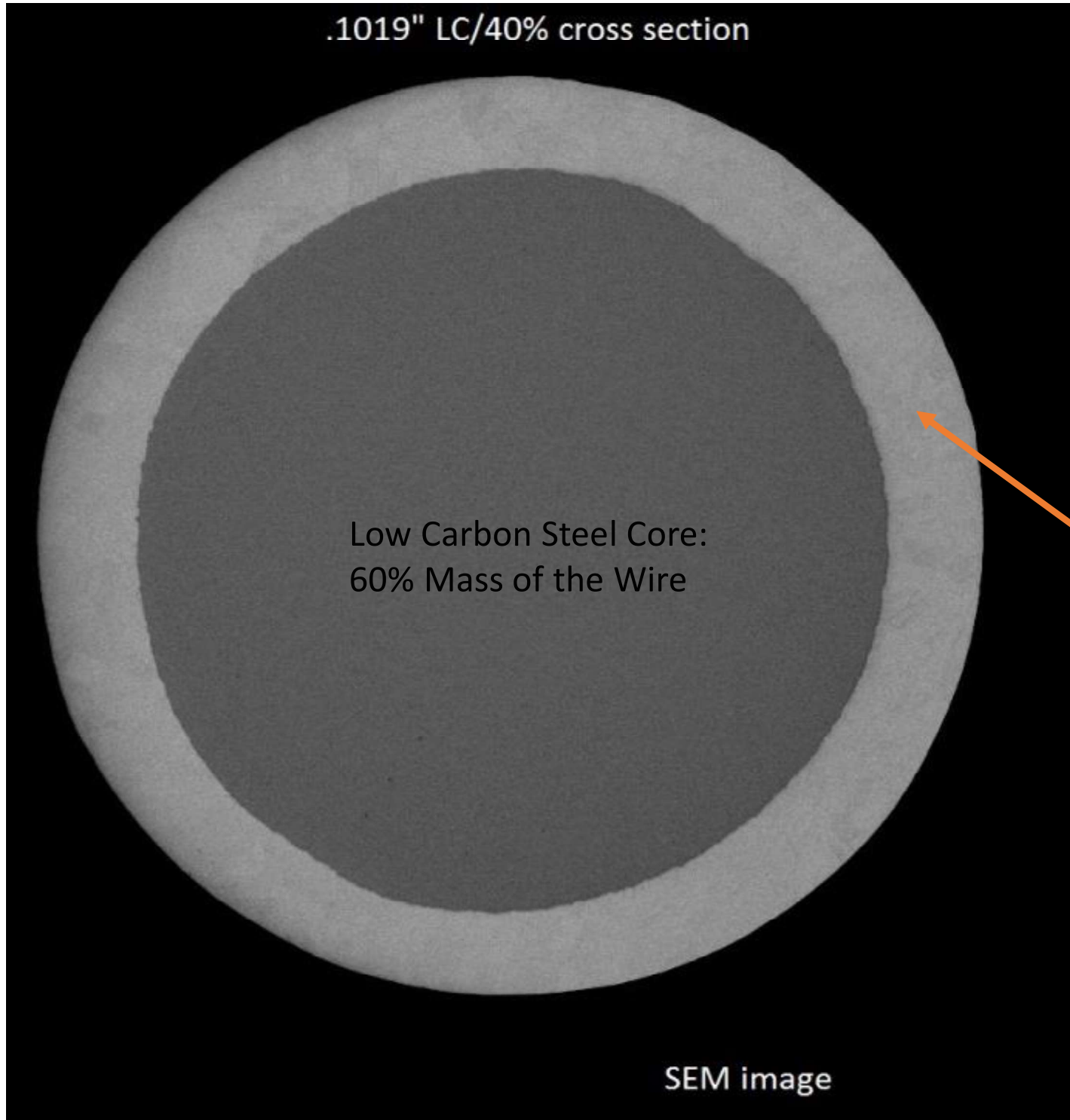
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

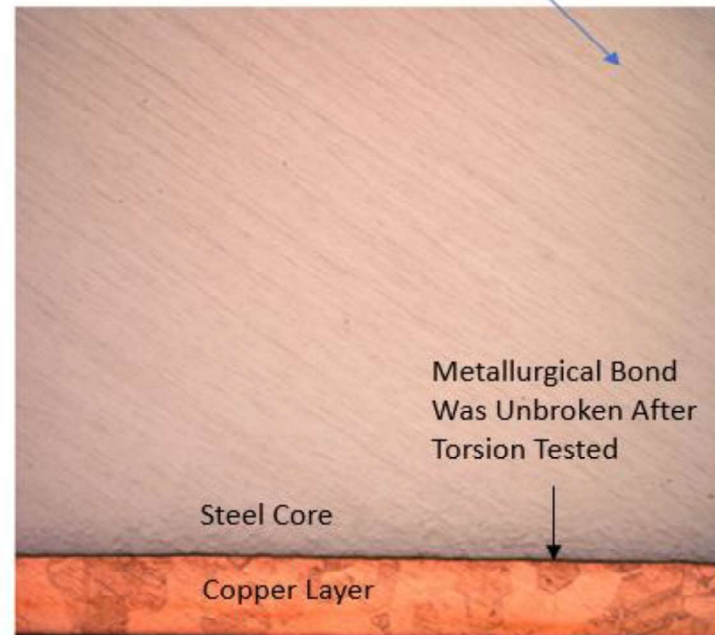
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
 DN: C=ATS, CN=Rodney Allen,
 E=rallen@atslab.com
 Reason: I have reviewed this document
 Location:
 Date: 2021-08-05 12:29:52
 Date: 2021-08-05 12:29:52



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the

short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult due to its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

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Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

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Public Comment No. 579-NFPA 70-2021 [Section No. 250.66]

250.66 Size of Alternating-Current Grounding Electrode Conductor.

The size of the grounding electrode conductor and bonding jumper(s) for connection of grounding electrodes shall not be smaller than given in Table 250.66, except as permitted in 250.66(A) through (C).

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

<u>Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors</u>		<u>Size of Grounding Electrode Conductor</u>		
<u>(AWG/kcmil)</u>		<u>(AWG/kcmil)</u>		
<u>Copper</u>	<u>Aluminum or Copper- Clad Aluminum</u>	-	<u>Copper Copper or Copper-Clad Steel 40%</u>	<u>Aluminum or Copper-Clad Aluminum</u>
2 or smaller	1/0 or smaller	-	8	6
1 or 1/0	2/0 or 3/0	-	6	4
2/0 or 3/0	4/0 or 250	-	4	2
Over 3/0 through 350	Over 250 through 500	-	2	1/0
Over 350 through 600	Over 500 through 900	-	1/0	3/0
Over 600 through 1100	Over 900 through 1750	-	2/0	4/0
Over 1100	Over 1750	-	3/0	250

Notes:

1. If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set.
2. If there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.
3. See installation restrictions in 250.64.

(A) Connections to a Rod, Pipe, or Plate Electrode(s).

If the grounding electrode conductor or bonding jumper connected to a single or multiple rod, pipe, or plate electrode(s), or any combination thereof, as described in 250.52(A)(5) or (A)(7), does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor shall not be required to be larger than 6 AWG copper-clad steel 40% or copper wire or 4 AWG aluminum or copper-clad aluminum wire.

(B) Connections to Concrete-Encased Electrodes.

If the grounding electrode conductor or bonding jumper connected to a single or multiple concrete-encased electrode(s), as described in 250.52(A)(3), does not extend on to other types of electrodes that require a larger size of conductor, the grounding electrode conductor shall not be required to be larger than 4 AWG copper-clad steel 40% or copper wire.

(C) Connections to Ground Rings.

If the grounding electrode conductor or bonding jumper connected to a ground ring, as described in 250.52(A)(4), does not extend on to other types of electrodes that require a larger size of conductor, the grounding electrode conductor shall not be required to be larger than the conductor used for the ground ring.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	CCS Suitable Grounding Material Per CMP16	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
SubstantiationPoints.Graph.Images..pdf	Facts To Consider Regarding CCS 40% for Article 250 Applications	
ATS_ShearTestRpt.pdf	Shear and UTS Data from Third Party Test Lab	
CCS40_SubstantiationStatement.pdf	CCS 40% Substantiation Statement	

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, "Tesla's Quarterly Profit Soars to a Record \$1.1 Billion" in the second quarter of 2021. Positive earnings will attract more manufacturers of EV's, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC's, GE's and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation's distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building's OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal

copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections

of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wire drawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire.

Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech’s report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor’s only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD’s are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system’s service equipment and the grounding electrode system. “The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page

128.” In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system’s earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. “One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

- PI 2468, PI 2470, PI 2467

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Sat Jul 31 06:51:18 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than those required in UL 467. The current carrying capability of 40% copper clad steel is less

than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

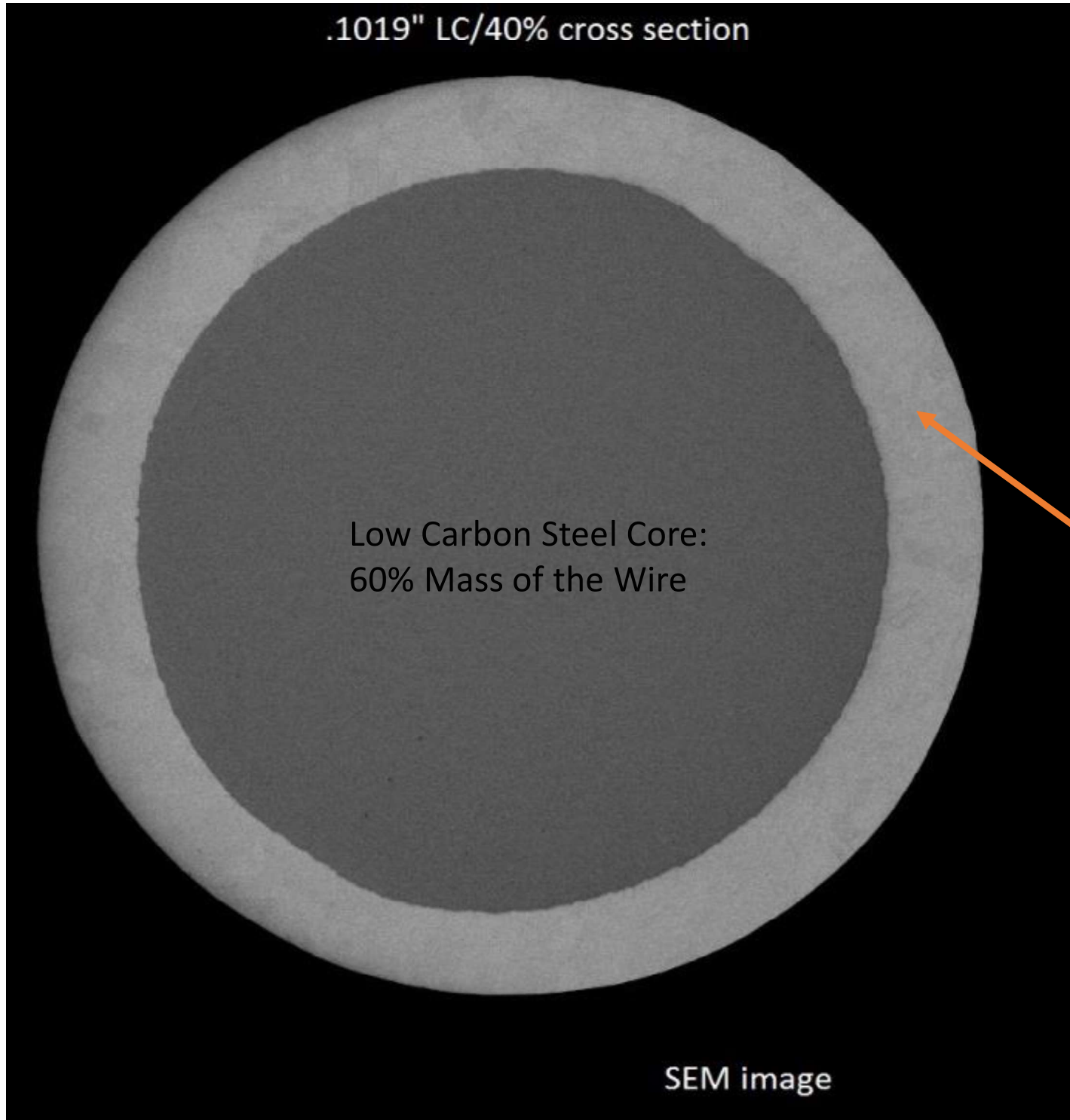
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

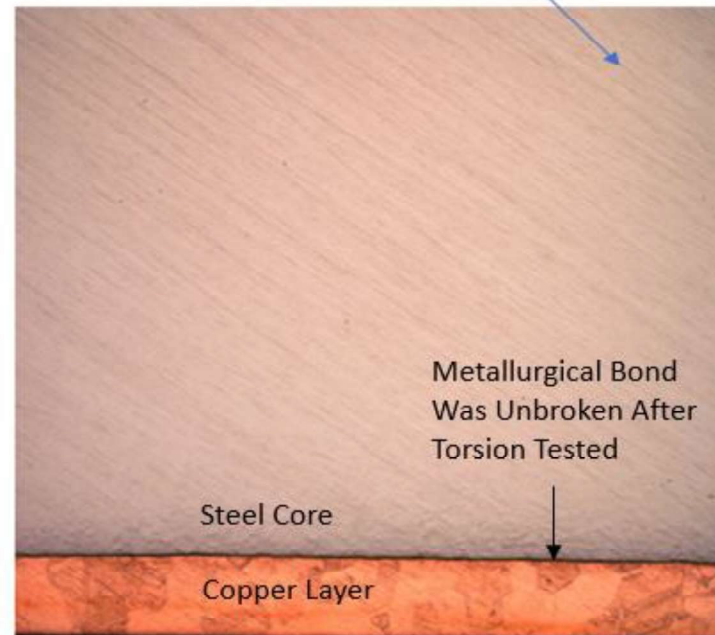
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
 DN: C=ATS, CN=Rodney Allen,
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 Reason: I have reviewed this document
 Location:
 Date: 2021-08-05 12:29:52
 Email: rallen@atslab.com, n 4



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the

short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

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40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult due to its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

Submitter Information Verification

Submitter Full Name: Peter Graser

Organization: Copperweld

Affiliation: American Bimetallic Association

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

Copyright Assignment

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



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



Public Comment No. 576-NFPA 70-2021 [Section No. 250.68(C)]

(C) Grounding Electrode Conductor Connections.

Grounding electrode conductors and bonding jumpers shall be permitted to be connected at the following locations and used to extend the connection to an electrode(s):

- (1) Interior metal water piping that is electrically continuous with a metal underground water pipe electrode and is located not more than 1.52 m (5 ft) from the point of entrance to the building, as measured along the water piping, shall be permitted to extend the connection to an electrode(s). Interior metal water piping located more than 1.52 m (5 ft) from the point of entrance to the building, as measured along the water piping, shall not be used as a conductor to interconnect electrodes of the grounding electrode system.

Exception: In industrial, commercial, and institutional buildings or structures, if conditions of maintenance and supervision ensure that only qualified persons service the installation, interior metal water piping located more than 1.52 m (5 ft) from the point of entrance to the building, as measured along the water piping, shall be permitted as a bonding conductor to interconnect electrodes that are part of the grounding electrode system, or as a grounding electrode conductor, if the entire length, other than short sections passing perpendicularly through walls, floors, or ceilings, of the interior metal water pipe that is being used for the conductor is exposed.

- (2) The metal structural frame of a building shall be permitted to be used as a conductor to interconnect electrodes that are part of the grounding electrode system, or as a grounding electrode conductor. Hold-down bolts securing the structural steel column that are connected to a concrete-encased electrode complying with 250.52(A)(3) and located in the support footing or foundation shall be permitted to connect the metal structural frame of a building or structure to the concrete-encased grounding electrode. The hold-down bolts shall be connected to the concrete-encased electrode by welding, exothermic welding, the usual steel tie wires, or other approved means.
- (3) A rebar-type concrete-encased electrode installed in accordance with 250.52(A)(3) with an additional rebar section extended from its location within the concrete foundation or footing to an accessible location that is not subject to corrosion shall be permitted for connection of grounding electrode conductors and bonding jumpers in accordance with the following:
 - (4) The additional rebar section shall be continuous with the grounding electrode rebar or shall be connected to the grounding electrode rebar and connected together by the usual steel tie wires, exothermic welding, welding, or other effective means.
 - (5) The rebar extension shall not be exposed to contact with the earth without corrosion protection.
 - (6) Rebar shall not be used as a conductor to interconnect the electrodes of grounding electrode systems.

Statement of Problem and Substantiation for Public Comment

Removing "the usual" might create needless tension between the installation and inspection communities, regarding what is an approved steel wire tie. If "the usual" must go, I suggest something else be added in its place. Or perhaps, an FPN should be added to clarify that standard ties may be sufficient.

Related Item

- First Revision No. 8157-NFPA 70-2020 [Section No. 250.68(C)]

Submitter Information Verification

Submitter Full Name: Josh Weaver

Organization:

Street Address:

City:

State:

Zip:

Submittal Date: Fri Jul 30 19:25:33 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Adding "usual" does not improve the NEC language. The "usual tie wires" installed by others are acceptable means for tying rebar together.



Public Comment No. 272-NFPA 70-2021 [Section No. 250.94(A)]

(A) The Intersystem Bonding Termination Device.

An intersystem bonding termination (IBT) for connecting intersystem bonding conductors shall be provided external to enclosures at the service equipment or metering equipment enclosure and at the disconnecting means for any buildings or structures that are supplied by a feeder or branch circuit. If an IBT is used, it shall comply with the following:

- (1) Be accessible for connection and inspection
- (2) Consist of a set of terminals with the capacity for connection of not less than three intersystem bonding conductors
- (3) Not interfere with opening the enclosure for a service, building or structure disconnecting means, or metering equipment
- (4) Be securely mounted as follows:
 - (a) At the service equipment, ~~be a~~ to a metal enclosure for the service equipment, to a metal meter enclosure, or to an exposed nonflexible metal service raceway, or be connected to the metal enclosure ~~or to the~~ for the grounding electrode conductor with a minimum 6 AWG copper conductor
 - (b) At the disconnecting means for a building or structure that is supplied by a feeder or branch circuit, be electrically connected to the metal enclosure for the building or structure disconnecting means, or be connected to the metal enclosure ~~or to the~~ for the grounding electrode conductor with a minimum 6 AWG copper conductor
- (5) Be listed as grounding and bonding equipment

Exception: In existing buildings or structures, if any of the intersystem bonding and grounding electrode conductors required by 770.100(B)(2), 800.100(B)(2), 810.21(F)(2), and 820.100 exist, installation of an IBT shall not be required. An accessible means external to enclosures for connecting intersystem bonding and grounding electrode conductors shall be permitted at the service equipment and at the disconnecting means for any buildings or structures that are supplied by a feeder or branch circuit by at least one of the following means:

- (1) *Exposed nonflexible metal raceways*
- (2) *An exposed grounding electrode conductor*
- (3) *Approved means for the external connection of a copper or other corrosion-resistant bonding or grounding electrode conductor to the grounded raceway or equipment*

Informational Note No. 1: A 6 AWG copper conductor with one end bonded to the grounded nonflexible metallic raceway or equipment and with 150 mm (6 in.) or more of the other end made accessible on the outside wall is an example of the approved means covered in 250.94, Exception item (3).

Informational Note No. 2: See 770.100, 800.100, 810.21, and 820.100 for intersystem bonding and grounding requirements for conductive optical fiber cables, communications circuits, radio and television equipment, CATV circuits and network-powered broadband communications systems, respectively.

Statement of Problem and Substantiation for Public Comment

This is intended to be an editorial revision of existing text rather than substantive.

Related Item

- FR-8257

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Sun Jul 18 23:31:53 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-8087-NFPA 70-2021](#)

Statement: Editorial revisions are made to add clarity. Item (4)(a) was changed to clarify that an IBT must be securely mounted and not only to a grounding electrode conductor. Informational Note 1 is deleted to comply with the NEC Style Manual 4.1.3.

**Public Comment No. 760-NFPA 70-2021 [Section No. 250.94(A)]****(A) The Intersystem Bonding Termination Device.**

An intersystem bonding termination (IBT) for connecting intersystem bonding conductors shall be provided external to enclosures at the service equipment or metering equipment enclosure and at the disconnecting means for any buildings or structures that are supplied by a feeder or branch circuit. If an IBT is used, it shall comply with the following:

- (1) Be accessible for connection and inspection
- (2) Consist of a set of terminals with the capacity for connection of not less than three intersystem bonding conductors
- (3) Not interfere with opening the enclosure for a service, building or structure disconnecting means, or metering equipment
- (4) Be securely mounted as follows:
 - (a) At the service equipment, be a metal enclosure for the service equipment, to a metal meter enclosure, or to an exposed nonflexible metal service raceway, or be connected to the metal enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor
 - (b) At the disconnecting means for a building or structure, be electrically connected to the metal enclosure for the building or structure disconnecting means, or be connected to the metal enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor
- (5) Be listed as grounding and bonding equipment

Exception: In existing buildings or structures, if any of the intersystem bonding and grounding electrode conductors required by 770.100(B)(2), 800.100(B)(2), 810.21(F)(2), and 820.100 exist, installation of an IBT shall not be required. An accessible means external to enclosures for connecting intersystem bonding and grounding electrode conductors shall be permitted at the service equipment and at the disconnecting means for any buildings or structures that are supplied by a feeder or branch circuit by at least one of the following means:

- (1) *Exposed nonflexible metal raceways*
- (2) *An exposed grounding electrode conductor*
- (3) *Approved means for the external connection of a copper or other corrosion-resistant bonding or grounding electrode conductor to the grounded raceway or equipment*

Informational Note No. 1: A 6 AWG copper conductor with one end bonded to the grounded nonflexible metallic raceway or equipment and with 150 mm (6 in.) or more of the other end made accessible on the outside wall is an example of the approved means covered in 250.94, Exception item (3).

Informational Note No. 2: See 770.100, 800.100, 810.21, and 820.100 for intersystem bonding and grounding requirements for conductive optical fiber cables, communications circuits, radio and television equipment, CATV circuits and network-powered broadband communications systems, respectively.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_142.pdf	5 CN142

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 142 appeared in the First Draft Report on First Revision No.8527.

The Correlating Committee directs that the Informational Note No. 1 be written to comply with 4.1.3 of the NEC Style Manual.

Related Item

- First Revision No. 8257

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 09:24:59 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: [SR-8087-NFPA 70-2021](#)

Statement: Editorial revisions are made to add clarity. Item (4)(a) was changed to clarify that an IBT must be securely mounted and not only to a grounding electrode conductor. Informational Note 1 is deleted to comply with the NEC Style Manual 4.1.3.

**Correlating Committee Note No. 142-NFPA 70-2021 [Section No. 250.94(A)]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 17:06:02 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that the Informational Note No. 1 be written to comply with 4.1.3 of the NEC Style Manual.

First Revision No. 8257-NFPA 70-2020 [Section No. 250.94(A)]

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.



Public Comment No. 301-NFPA 70-2021 [Section No. 250.94(B)]

(B) Other Means.

Connections to an aluminum or copper busbar not less than 6 mm thick × 50 mm wide (¼ in. thick × 2 in. wide) and of a length to accommodate at least three terminations for communication systems in addition to other connections. The busbar shall be securely fastened and shall be installed in an accessible location. Connections shall be made by a listed connector. If aluminum busbars are used, the installation shall also comply with 250.64(A). The busbar shall be connected to the grounding electrode system by a conductor that is the larger of the following:

- (1) - ~~Not smaller than the~~ The largest grounding electrode conductor that is connected to the busbar
- (2) As required or permitted in 250.94(A)

Exception to (A) and (B): Means for connecting intersystem bonding conductors are not required if communications systems are not likely to be used in or on the building or structure .

Informational Note: The use of an IBT can reduce electrical noise on communication systems.

Statement of Problem and Substantiation for Public Comment

This Comment is intended to be an editorial improvement.

The sentence just before the list contains the requirement that the conductor used to connect the busbar be not smaller than the following two choices. It does not seem to begin list item No. 1 with a similar phrase.

The text at the end of the exception is intended to be a clarification of the intended scope of the exception.

Related Item

- FR-8166

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 22:18:42 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7986-NFPA 70-2021

Statement: The editorial changes add clarity.



Public Comment No. 525-NFPA 70-2021 [Section No. 250.102(A)]

(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, copper-clad steel or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	CMP16 Reconfirms CCS as a Bonding Conductor Material	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
SubstantiationPoints.Graph.Images..pdf	Facts To Consider Regarding CCS 40% for Article 250 Applications	
ATS_ShearTestRpt.pdf	Shear and UTS Data from Third Party Test Lab	
CCS40_SubstantiationStatement.pdf	CCS 40% Substantiation Statement	

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings: If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, "Tesla's Quarterly Profit Soars to a Record \$1.1 Billion" in the second quarter of 2021. Positive earnings will attract more manufacturers of EV's, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC's, GE's and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation's distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building's OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its

continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated

grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a "Process" annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

"Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wire drawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

"Ferrous Wire Handbook," Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing."

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to

make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech’s report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor’s only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD’s are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system’s service equipment and the grounding electrode system. “The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and

non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128.” In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system’s earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. “One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

- PI 2471

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jul 29 05:34:08 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than

those required in UL 467. The current carrying capability of 40% copper clad steel is less than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

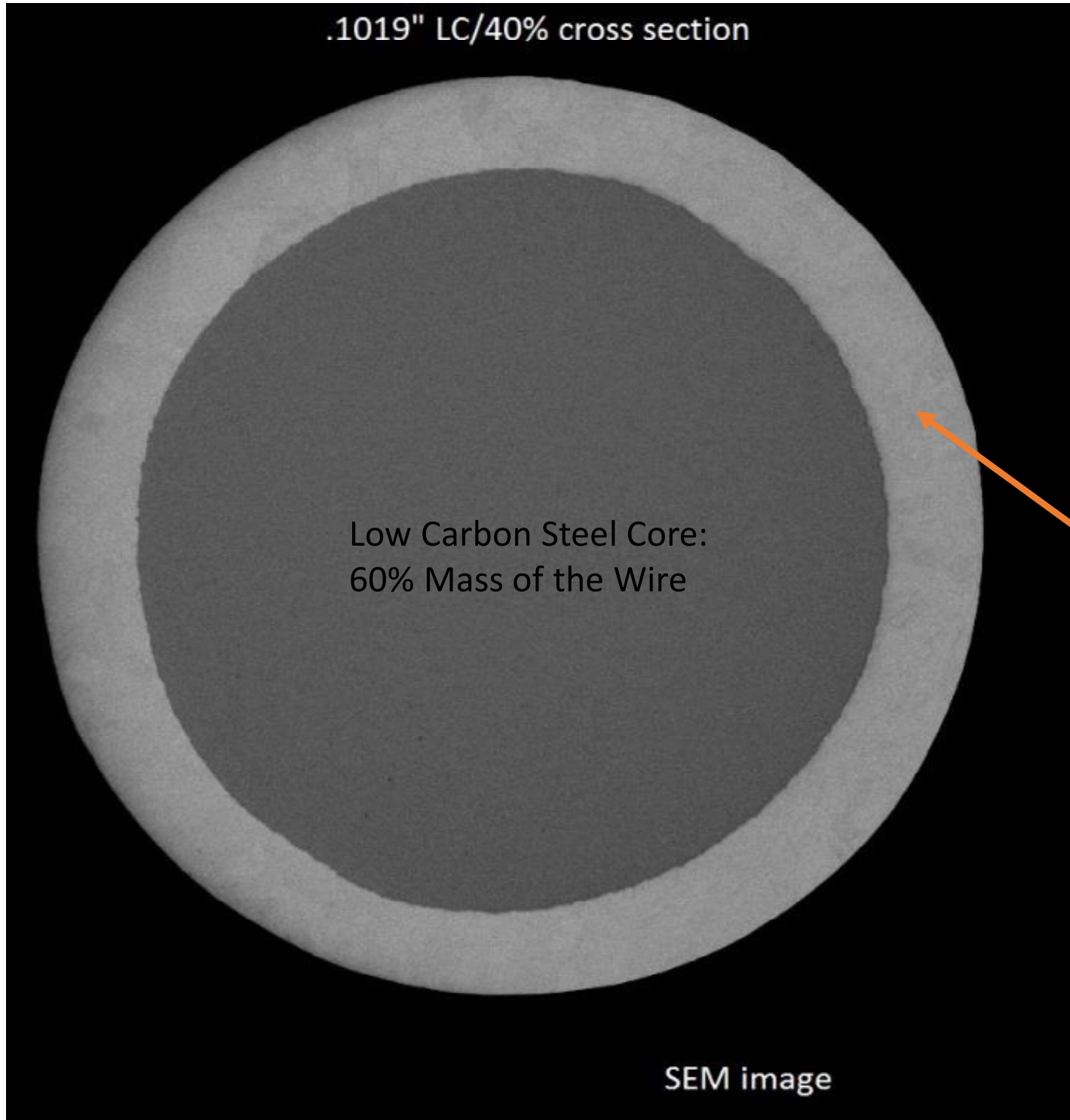
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

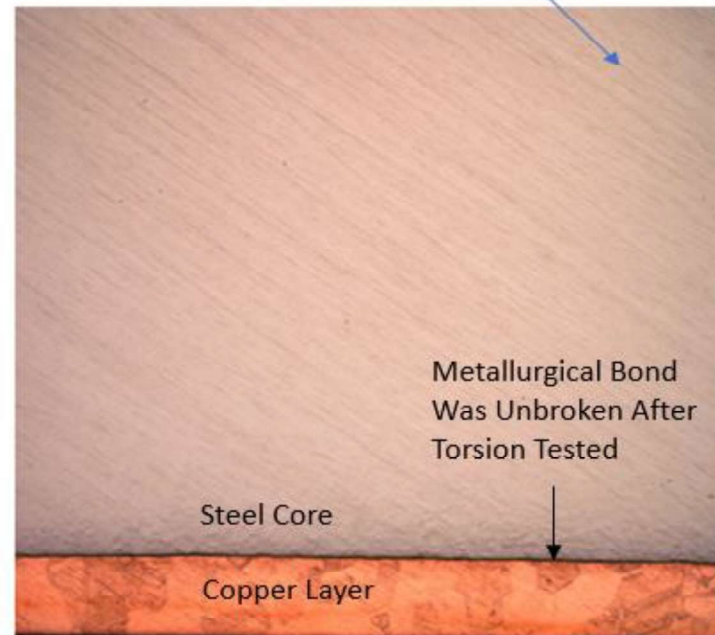
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
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 Reason: I have reviewed this document
 Location:
 Date: 2021-08-05 12:29:52
 Email: rallen@atslab.com, n 4



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

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The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult due to its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

Submitter Information Verification

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Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

Copyright Assignment

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



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Public Comment No. 761-NFPA 70-2021 [Section No. 250.106]

250.106 Lightning Protection Systems.

The lightning protection system ground terminals shall be bonded to the building or structure grounding electrode system.

Informational Note No. 1: See 250.60 for use of strike termination devices. For further information, see NFPA 780-2020, *Standard for the Installation of Lightning Protection Systems*, which contains detailed information on grounding, bonding, and sideflash distance from lightning protection systems.

Informational Note No. 2: Metal raceways, enclosures, frames, and other non-current-carrying metal parts of electrical equipment installed on a building equipped with a lightning protection system may require bonding or spacing from the lightning protection conductors in accordance with NFPA 780-2020, *Standard for the Installation of Lightning Protection Systems*.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_143.pdf	5 CN143

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 143 appeared in the First Draft Report on First Revision No. 8259.

The Correlating Committee directs that the Informational Notes be written to comply with 4.1.3 of the NEC Style Manual.

Related Item

- First Revision No. 8259

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
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Street Address:
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Submittal Date: Wed Aug 04 09:26:41 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-7989-NFPA 70-2021

Statement: The informational Notes are written to comply with the NEC Style Manual 4.1.3. The date of the NFPA 780 edition is deleted as permitted by the new 90.5(C).

**Correlating Committee Note No. 143-NFPA 70-2021 [Section No. 250.106]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 17:07:37 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that the Informational Notes be written to comply with 4.1.3 of the NEC Style Manual.

First Revision No. 8259-NFPA 70-2020 [Section No. 250.106]

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.



Public Comment No. 1314-NFPA 70-2021 [Section No. 250.109]

250.109 Metal Enclosures.

Metal enclosures shall be permitted to be used to connect bonding jumpers or equipment grounding conductors, or both, together to become a part of an effective ground-fault current path. If installed, metal covers, ~~mud-rings~~ plaster rings, extension rings, and metal fittings shall be attached to these metal enclosures to ensure an effective ground-fault current path or shall be connected with bonding jumpers or equipment grounding conductors, or both.

Statement of Problem and Substantiation for Public Comment

This revision would correlate with the term used in 314.16(A), 314.24(B), 314.27(A)(1), 314.27(D), 314.44, and 590.4(G).

Related Item

- FR 8177

Submitter Information Verification

Submitter Full Name: Ryan Jackson

Organization: Ryan Jackson

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 11 18:16:15 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-7998-NFPA 70-2021

Statement: The change correlates terminology with other sections of the NEC.



Public Comment No. 1726-NFPA 70-2021 [Section No. 250.109]

250.109 Metal Enclosures.

Metal enclosures shall be permitted to be used to connect bonding jumpers or equipment grounding conductors, or both, together to become a part of an effective ground-fault current path. If installed, metal covers, mud rings, extension rings, and metal fittings shall be attached to these metal enclosures to ensure an effective ground-fault current path or shall be connected with bonding jumpers or equipment grounding conductors, or both. This rule shall not interfere with and shall be subordinate to other rules in this Code that specify a wired bonding connection, or a wired equipment grounding return path.

Statement of Problem and Substantiation for Public Comment

The panel resolved this input by citing 90.3. Apparently the panel failed to notice the implicit reference to that rule in the substantiation: "admittedly these are in chapters capable of amending Chapter two." The substantiation further pointed out that the rule is indirect conflict with 250.97. This is not a conflict that 90.3 can resolve. CMP 5, in this cycle, must resolve this conflict, if not with the wording in this comment, then in some other manner.

Related Item

- PI-3904

Submitter Information Verification

Submitter Full Name: Frederic Hartwell

Organization: Hartwell Electrical Services, Inc.

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 17 15:17:26 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The text of this section does not prevent the use of other bonding means that may be required in other NEC sections such as 250.97.



Public Comment No. 1433-NFPA 70-2021 [Section No. 250.114]

250.114 Equipment Connected by Cord and Plug.

Exposed, normally non-current-carrying metal parts of cord-and-plug-connected equipment shall be connected to the equipment grounding conductor under any of the following conditions:

Exception: Listed tools, listed appliances, and listed equipment covered in 250.114, list items 2 through 4, shall not be required to be connected to an equipment grounding conductor if protected by a system of double insulation or its equivalent. Double-insulated equipment shall be distinctively marked.

- (1) In hazardous (classified) locations
- (2) If operated at over 150 volts to ground

Exception No. 1 to (2): Motors, if guarded, shall not be required to be connected to an equipment grounding conductor.

Exception No. 2 to (2): Metal frames of electrically heated appliances, exempted by special permission, shall not be required to be connected to an equipment grounding conductor, in which case the frames shall be permanently and effectively insulated from ground.

- (3) In residential occupancies:

- (4) Refrigerators, freezers, icemakers, and air conditioners
- (5) Clothes-washing, clothes-drying, and dish-washing machines; ranges; kitchen waste disposers; information technology equipment; sump pumps; and electrical aquarium equipment
- (6) Hand-held motor-operated tools, stationary and fixed motor-operated tools, and light industrial motor-operated tools
- (7) Motor-operated appliances of the following types: hedge clippers, lawn mowers, snow blowers, and wet scrubbers
- (8) Portable

handlamps and portable luminaires

- a. handlamps

- (9) In other than residential occupancies:

- (10) Refrigerators, freezers, icemakers, and air conditioners
- (11) Clothes-washing, clothes-drying, and dish-washing machines; information technology equipment; sump pumps; and electrical aquarium equipment
- (12) Hand-held motor-operated tools, stationary and fixed motor-operated tools, and light industrial motor-operated tools
- (13) Motor-operated appliances of the following types: hedge clippers, lawn mowers, snow blowers, and wet scrubbers
- (14) Portable

handlamps and portable luminaires

- a. handlamps
- b. Cord-and-plug-connected appliances used in damp or wet locations or by persons standing on the ground, standing on metal floors, or working inside of metal tanks or boilers
- c. Tools likely to be used in wet or conductive locations

Exception: Tools and portable handlamps

and portable luminaires likely

a.

likely to be used in wet or conductive locations shall not be required to be connected to an equipment grounding conductor if supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

Statement of Problem and Substantiation for Public Comment

The phrase “and portable luminaires” was added during the 2020 cycle (FR 8040, based on PI 1200) to both 250.114(3)(e) and (4)(e). The FR substantiation (carried forward from the PI) states: “Portable handlamps were originally covered by UL 298, titled “Portable Electric Hand Lamps”. UL 298 was withdrawn in 2004, and has been superseded by UL 153, titled “Portable Electric Luminaires”. Devices that were once called “Portable Handlamp” on their label are now being labeled as “Portable Luminaire” but are the same product. Therefore, 3(e) and 4(e) should include “portable luminaires” to continue to cover the grounding need for these products.”

The substantiation conflated the certification organization label designation (“Portable Luminaire”) with the requirements in the standard that apply to the specific product type (a portable hand light). UL 153 (clause 138.6.1) explicitly requires portable hand lights, which are typically used in garages and similar environments, to use a grounding type attachment plug when they have accessible metal that may become energized. UL 153 applies a similar grounding plug requirement on other types of portable luminaires, such as those for wet locations. But there are many indoor use (residential and commercial) portable luminaire types that have always been permitted, by UL 153 and NEC 410.82, to use a polarized, 2-wire supply plug. Polarized portable luminaires compliant with UL 153 have a well-established acceptable field record of adequately managing the associated risks. The substantiation for FR 8040 did not claim otherwise but appears to have inadvertently removed this longstanding design option.

During the 2020 cycle, NEC 410.42 was revised (PI 2473, FR 8426) to reinforce the longstanding permission (in 410.82) for portable luminaires to use a polarized plug.

The result is that NEC 250.114(3) and (4), which now require all portable luminaires with accessible metal (and without double insulation) to be grounded, is in conflict with 410.82 which permits a polarized plug and 410.42 which says those with a polarized plug do not require grounding. This public comment therefore proposes that 250.114(3)(e) and (4)(e) be returned to their 2017 edition status to eliminate this conflict. The objective of PI 1200 / FR 8040, to maintain the grounding requirement for portable hand lights (despite their requirements shifting from UL 298 to UL 153) was never in jeopardy so the PI / FR was never needed.

Related Item

- This Public Comment is related to FR No. 8179

Submitter Information Verification

Submitter Full Name: Christopher Jensen

Organization: UL LLC

Affiliation: UL LLC

Street Address:

City:

State:

Zip:

Submittal Date: Fri Aug 13 11:20:11 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected but held

Action:

Resolution: No action is taken as this public comment is considered new material per 4.4.8.3 of the NFPA regulations.



Public Comment No. 1327-NFPA 70-2021 [Section No. 250.118(A)]

(A) Permitted.

Each equipment grounding conductor run with or enclosing the circuit conductors shall be one or more or a combination of the following:

- (1) A copper, aluminum, or copper-clad aluminum conductor. This conductor shall be solid or stranded; insulated, covered, or bare; and in the form of a wire or a busbar of any shape.
- (2) Rigid metal conduit.
- (3) Intermediate metal conduit.
- (4) Electrical metallic tubing.
- (5) Listed flexible metal conduit meeting all the following conditions:
 - (6) The conduit is terminated in listed fittings.
 - (7) The circuit conductors contained in the conduit are protected by overcurrent devices rated at 20 amperes or less.
 - (8) The size of the conduit does not exceed metric designator 35 (trade size $1\frac{1}{4}$).
 - (9) The combined length of flexible metal conduit, flexible metallic tubing, and liquidtight flexible metal conduit in the same effective ground-fault current path does not exceed 1.8 m (6 ft).
 - (10) If flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor or a bonding jumper in accordance with 250.102(E)(2) shall be installed.
- (11) Listed liquidtight flexible metal conduit meeting all the following conditions:
 - (12) The conduit is terminated in listed fittings.
 - (13) For metric designators 12 through 16 (trade sizes $\frac{3}{8}$ through $1\frac{1}{2}$), the circuit conductors contained in the conduit are protected by overcurrent devices rated at 20 amperes or less.
 - (14) For metric designators 21 through 35 (trade sizes $\frac{3}{4}$ through $1\frac{1}{4}$), the circuit conductors contained in the conduit are protected by overcurrent devices rated not more than 60 amperes and there is no flexible metal conduit, flexible metallic tubing, or liquidtight flexible metal conduit in metric designators 12 through 16 (trade sizes $\frac{3}{8}$ through $1\frac{1}{2}$) in the effective ground-fault current path.
 - (15) The combined length of flexible metal conduit, flexible metallic tubing, and liquidtight flexible metal conduit in the same effective ground-fault current path does not exceed 1.8 m (6 ft).
 - (16) If flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor or a bonding jumper in accordance with 250.102(E)(2) shall be installed.
 - (17) If liquidtight flexible metal conduit contains a stainless steel core, a wire-type equipment grounding conductor or a bonding jumper in accordance with 250.102(E)(2) shall be installed.
- (18) Flexible metallic tubing if the tubing is terminated in listed fittings and meeting the following conditions:
 - (19) The circuit conductors contained in the tubing are protected by overcurrent devices rated at 20 amperes or less.
 - (20) The combined length of flexible metal conduit, flexible metallic tubing, and liquidtight flexible metal conduit in the same effective ground-fault current path does not exceed

1.8 m (6 ft).

(21) If flexible metal conduit contains a stainless steel core, a wire-type equipment grounding conductor or a bonding jumper in accordance with 250.102(E)(2), shall be installed

(22) Armor of Type AC cable as provided in 320.108.

(23) The copper sheath of mineral-insulated, metal-sheathed cable Type MI.

(24) Type MC cable that provides an effective ground-fault current path in accordance with one or more of the following:

(25) It contains an insulated or uninsulated equipment grounding conductor in compliance with 250.118 (1).

(26) The combined metallic sheath and uninsulated equipment grounding/bonding conductor of interlocked metal tape-type MC cable that is listed and identified as an equipment grounding conductor

(27) The metallic sheath or the combined metallic sheath and equipment grounding conductors of the smooth or corrugated tube-type MC cable that is listed and identified as an equipment grounding conductor

(28) Cable trays as permitted in 392.10 and 392.60.

(29) Cablebus framework as permitted in 370.60(1).

(30) Other listed electrically continuous metal raceways and listed auxiliary gutters.

(31) Surface metal raceways listed for grounding.

Informational Note: See Article 100 for a definition of *effective ground-fault current path*.

Statement of Problem and Substantiation for Public Comment

Although we do not agree with First Revision 8184 requiring stainless Liquid-tight Flexible Metal Conduit to have a separate wire type equipment grounding conductor pulled inside we suggest that standard flexible metal conduit with a stainless-steel core should also require a separate wire type equipment grounding conductor to keep the code consistent. Both products are made with similar manufacturing procedures and of the same steel the only difference between them is that Liquid Tight flex will have a non-metallic cover/jacket on the outside of the conduit. If one of these products is required to have an EGC installed so should the other product.

Related Item

- 8184

Submitter Information Verification

Submitter Full Name: Dale Crawford

Organization: Steel Tube Institute

Street Address:

City:

State:

Zip:

Submission Date: Wed Aug 11 20:08:37 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected but see related SR

Action:

Resolution: [SR-8022-NFPA 70-2021](#)

Statement: The change to flexible metal conduit constructed of stainless steel was made to match what was done with stainless steel liquidtight flexible metal conduit in the first revision in 250.118(A)(6)(f) because the electrical characteristics of the stainless steel used in both products are similar.



Public Comment No. 302-NFPA 70-2021 [Section No. 250.118(A)]

(A) Permitted.

Each equipment grounding conductor run with or enclosing the circuit conductors shall be one or more or a combination of the following:

- (1) A copper, aluminum, or copper-clad aluminum conductor. This conductor shall be solid or stranded; insulated, covered, or bare; and in the form of a wire or a busbar of any shape.
- (2) Rigid metal conduit.
- (3) Intermediate metal conduit.
- (4) Electrical metallic tubing.
- (5) Listed flexible metal conduit meeting all the following conditions:
 - (6) The conduit is terminated in listed fittings.
 - (7) The circuit conductors contained in the conduit are protected by overcurrent devices rated at 20 amperes or less.
 - (8) The size of the conduit does not exceed metric designator 35 (trade size $1\frac{1}{4}$).
 - (9) The combined length of flexible metal conduit, flexible metallic tubing, and liquidtight flexible metal conduit in the same effective ground-fault current path does not exceed 1.8 m (6 ft).
 - (10) If flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor

~~or a bonding jumper in accordance with 250.102(E)(2)~~

- a. shall be installed.

- (11) Listed liquidtight flexible metal conduit meeting all the following conditions:

- (12) The conduit is terminated in listed fittings.
- (13) For metric designators 12 through 16 (trade sizes $\frac{3}{8}$ through $1\frac{1}{2}$), the circuit conductors contained in the conduit are protected by overcurrent devices rated at 20 amperes or less.
- (14) For metric designators 21 through 35 (trade sizes $\frac{3}{4}$ through $1\frac{1}{4}$), the circuit conductors contained in the conduit are protected by overcurrent devices rated not more than 60 amperes and there is no flexible metal conduit, flexible metallic tubing, or liquidtight flexible metal conduit in metric designators 12 through 16 (trade sizes $\frac{3}{8}$ through $1\frac{1}{2}$) in the effective ground-fault current path.
- (15) The combined length of flexible metal conduit, flexible metallic tubing, and liquidtight flexible metal conduit in the same effective ground-fault current path does not exceed 1.8 m (6 ft).
- (16) If flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor

~~or a bonding jumper in accordance with 250.102(E)(2)~~

- a. shall be installed.
- b. If liquidtight flexible metal conduit contains a stainless steel core, a wire-type equipment grounding conductor

~~or a bonding jumper in accordance with 250.102(E)(2)~~

- a. shall be installed.

- (17) Flexible metallic tubing if the tubing is terminated in listed fittings and meeting the following conditions:
- (18) The circuit conductors contained in the tubing are protected by overcurrent devices rated at 20 amperes or less.
- (19) The combined length of flexible metal conduit, flexible metallic tubing, and liquidtight flexible metal conduit in the same effective ground-fault current path does not exceed 1.8 m (6 ft).
- (20) Armor of Type AC cable as provided in 320.108.
- (21) The copper sheath of mineral-insulated, metal-sheathed cable Type MI.
- (22) Type MC cable that provides an effective ground-fault current path in accordance with one or more of the following:
- (23) It contains an insulated or uninsulated equipment grounding conductor in compliance with 250.118 (1).
- (24) The combined metallic sheath and uninsulated equipment grounding/bonding conductor of interlocked metal tape-type MC cable that is listed and identified as an equipment grounding conductor
- (25) The metallic sheath or the combined metallic sheath and equipment grounding conductors of the smooth or corrugated tube-type MC cable that is listed and identified as an equipment grounding conductor
- (26) Cable trays as permitted in 392.10 and 392.60.
- (27) Cablebus framework as permitted in 370.60(1).
- (28) Other listed electrically continuous metal raceways and listed auxiliary gutters.
- (29) Surface metal raceways listed for grounding.

Informational Note: See Article 100 for a definition of *effective ground-fault current path*.

Statement of Problem and Substantiation for Public Comment

The only changes proposed in this Comment is removal of "or a bonding jumper in accordance with 250.102(E)(2)". I apologize that Terra has confused this recommendation.

The text is proposed to be removed because 250.102(E)(2) applies irrespective of 250.118(A). Section 250.102(E)(2) is in Part V, Bonding of Article 250 and 250.118 is in Part VI Equipment Grounding and Equipment Grounding Conductors. Including a bonding requirement in Part VI is inappropriate.

Related Item

- FR-8184

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jul 19 22:54:31 EDT 2021

Committee: NEC-P05

Committee Statement

**Committee
Action:** Rejected

Resolution: The reference to 250.102(E) provides needed guidance for the user and makes it clear that either a wire type EGC or a bonding conductor is permitted.



Public Comment No. 3-NFPA 70-2021 [Section No. 250.119(A)]

(A) General.

Unless required elsewhere in this *Code*, equipment grounding conductors shall be permitted to be bare, covered, or insulated. Individually covered or insulated equipment grounding conductors of the wire type shall have a continuous outer finish that is either green or green with one or more yellow stripes except as permitted in this section. Conductors with insulation or individual covering that is green, green with one or more yellow stripes, or otherwise identified as permitted by this section shall not be used for ungrounded or grounded circuit conductors.

Exception No.

~~1: Power-limited Class 2 or Class 3 cables, power-limited fire alarm cables, or communications cables containing only circuits operating at less than 50 volts ac or 60 volts dc if connected to equipment not required to be grounded shall be permitted to use a conductor with green insulation or green with one or more yellow stripes for other than equipment grounding purposes. Exception No. 2:~~

1: Flexible cords having an integral insulation and jacket without an equipment grounding conductor shall be permitted to have a continuous outer finish that is green.

Informational Note: An example of a flexible cord with integral-type insulation is Type SPT-2, 2 conductor.

Exception No.

~~3~~

2: Conductors with green insulation shall be permitted to be used as ungrounded signal conductors where installed between the output terminations of traffic signal control and traffic signal indicating heads. Signaling circuits installed in accordance with this exception shall include an equipment grounding conductor in accordance with 250.118. Wire-type equipment grounding conductors shall be bare or have insulation or covering that is green with one or more yellow stripes.

Statement of Problem and Substantiation for Public Comment

Section 90.3 permits Chapter 7 to modify the requirements of Chapter 2. That's precisely what Sections 725.3(P) and 760.3(O) do.

Section 725.3(P) in the 2020 NEC, and 722.3(N) in the First Draft of the 2023 NEC, permit all Class 2 and Class 3 cables to have green wires used as ungrounded signal conductors.

Section 760.3(O) permits all power-limited fire alarm cables to have green wires used as ungrounded signal conductors.

Section 90.3 states that the requirements of Chapters 1 through 7 apply to communications systems only if they are specifically referenced in Chapter 8. Section 250.119 is not referenced in Chapter 8.

Exception No.1 to 250.119(A) should be deleted because it has different requirements from the exceptions in Article 725 (moving to new Article 722) and Article 760. Having different requirements for the same application is not user friendly; only a Code expert will know to ignore the exception in 250.119(A), which imposes a voltage limitation, because the exceptions on Chapter 7 override the exception in 250.119(A).

Likewise, only a Code expert would know Chapter 8 sufficiently well to realize that Chapter 8 has no limitation on the use of green wires, which are part of the standard color-code for communications cables, and to ignore the voltage limitation in Exception No. 1 to 250.119(A).

Related Item

- PI 235

Submitter Information Verification

Submitter Full Name: David Kiddoo

Organization: CCCA

Affiliation: CCCA

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jun 29 08:26:04 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: CMP-5 reaffirms its conclusion that the appropriate rules in other Chapters are permitted to amend the general requirements of Chapter Two.



Public Comment No. 1515-NFPA 70-2021 [Section No. 250.120(A)]

(A) Raceway, Cable Trays, Cable Armor, Cablebus, or Cable Sheaths.

If it consists of a raceway, cable tray, cable armor, cablebus framework, or cable sheath or if it is a wire within a raceway or cable, it shall be installed in accordance with the applicable provisions in this *Code* using fittings for joints and terminations ~~approved for~~ designed and listed for use with the type of raceway or cable used. All connections, joints, and fittings shall be made tight using suitable tools.

If electrical metallic tubing is installed for direct earth burial without supplementary corrosion protection, it shall contain a copper equipment grounding conductor of the wire type.

Informational Note: See the UL Guide Information for Electrical Circuit Integrity Systems (FHIT) for equipment grounding conductors installed in a raceway that are part of a listed electrical circuit protective system or a listed fire-resistive cable system.

Statement of Problem and Substantiation for Public Comment

- For replacement of "approved" with "designed and listed", see the second paragraph of 300.15. There, fittings and connectors are required to be used with the specific wiring methods for which they are designed and listed.
- For the sentence on an equipment grounding conductor required in EMT that is directly buried in the earth without supplemental corrosion protection, see FR-9323 on Table 300.5 and FR-7591 on 358-10(A)(4) (New). I don't see a PI on the addition to Table 300.5 so it must have been a committee action.
- CMP-5 should have been notified of these actions in the First Draft so appropriate action could be taken.
- In checking the UL Guide card information, it seems unchanged and generally requires EMT to have supplemental corrosion protection for direct burial applications.
- The UL Guide information on Electrical Metallic Tubing FJMX (mentioned in the Public Input but not quoted) reads, "Galvanized or stainless steel EMT installed in concrete on grade or above generally requires no supplementary corrosion protection. Galvanized steel EMT in concrete slab below grade level may require supplementary corrosion protection. In general, galvanized steel EMT in contact with soil requires supplementary corrosion protection. Where galvanized steel EMT without supplementary corrosion protection extends directly from concrete encasement to soil burial, severe corrosive effects are likely to occur on the metal in contact with the soil."
- Not only do I think directly burying EMT without supplementary corrosion protection is not permitted, I think it is unsafe to do so. There is no requirement to include an equipment grounding conductor in the EMT if directly buried. If it fails due to corrosion, the equipment ground-fault path is lost. The failure of EMT in direct earth burial installations without supplementary corrosion protection is very common.

Related Item

- FR-8219

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 16 00:31:46 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Listing is only one criterion for accepting equipment by the Authority Having Jurisdiction. The uses permitted for electrical metallic tubing (EMT) is covered in other articles and permits EMT, if installed compliantly, to be the equipment grounding conductor without a supplemental wire-type conductor.



Public Comment No. 912-NFPA 70-2021 [Section No. 250.122(A)]

(A) General.

Copper, aluminum, or copper-clad aluminum equipment grounding conductors of the wire type shall not be smaller than shown in Table 250.122. The equipment grounding conductor shall not be required to be larger than the largest circuit conductor, or sum of the circular mil area for parallel conductors, supplying the equipment. If a cable tray, a raceway, or a cable armor or sheath is used as the equipment grounding conductor, as provided in 250.118 and 250.134(1), it shall comply with 250.4(A)(5) or (B)(4).

Exception: When a branch circuit is protected at its origin by a GFCI, the size of the equipment grounding

conductor shall be permitted to be 12AWG, regardless of the ampacity of the upstream overcurrent

device or the size of the current carrying conductors.

Equipment grounding conductors shall be permitted to be sectioned within a multiconductor cable, provided the combined circular mil area complies with Table 250.122.

Statement of Problem and Substantiation for Public Comment

This revision should eliminate concerns about adjustability and about upstream protection, by specifying Class A protection at the origin.

Related Item

- PI 4569

Submitter Information Verification

Submitter Full Name: David Shapiro

Organization: Safety First Electrical

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 18:03:03 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The submitter has not provided data to reduce the size of the equipment grounding conductor.



Public Comment No. 1332-NFPA 70-2021 [Section No. 250.122(B)]

(B) Increased in Size.

If ungrounded conductors are increased in size for any reason other than as required in 310.15(B) or 310.15(C), wire-type equipment grounding conductors, if installed, shall be increased in size proportionately to the increase in circular mil area of the ungrounded conductors.

Exception: Equipment grounding conductors shall be permitted to be sized under engineering supervision or by a qualified person using industry practices to meet the performance objectives of 250.4(A)(5) or (B)(4). Documentation of the method used and the equipment grounding conductor size shall be made available to the authority having jurisdiction upon request.

Informational Note: See *Grounding and Electromagnetic Interference (GEMI) Software for an industry practice method of determining acceptable equipment grounding conductor sizes.*

Statement of Problem and Substantiation for Public Comment

Informational note shows an acceptable way to meet the exception put in under FR 8281.

Related Item

- FR 8281

Submitter Information Verification

Submitter Full Name: Dale Crawford

Organization: Steel Tube Institute

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 11 20:26:02 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8071-NFPA 70-2021

Statement: An informational note is added to provide guidance on a method for calculating equipment grounding conductor sizes.



Public Comment No. 304-NFPA 70-2021 [Section No. 250.122(B)]

(B) Increased in Size.

If ungrounded conductors are increased in size for any reason other than as required in 310.15(B) or 310.15(C), wire-type equipment grounding conductors, if installed, shall be increased in size proportionately to the increase in circular mil area of the ungrounded conductors.

Exception: Equipment grounding conductors shall be permitted to be sized under engineering supervision ~~or by a qualified person using industry practices~~ to meet the performance objectives of 250.4(A)(5) or (B)(4). Documentation of the method used and the calculation of the equipment grounding conductor size shall be made available to the authority having jurisdiction upon request.

Statement of Problem and Substantiation for Public Comment

Inadequate substantiation has been submitted to CMP-5 to allow a qualified person to make a determination of a properly sized equipment grounding conductor without using Table 250.122. Though not specifically limited to a journeyman electrician, the definition of qualified person is commonly interpreted by the authority having jurisdiction as a journeyman electrician. (I suppose for some, "journeyperson" may be preferred.)

CMP-5 should adopt the concept in NFPA 70E (Electrical Safety in the Workplace) that a person can be considered qualified for one task and unqualified for another. It is safe to say that no electrician training programs, such as apprenticeship programs, train persons how to calculate an alternate size of equipment grounding conductor to meet the requirements of 250.4(A)(5) or (B)(4).

A representative of a steel conduit manufacturers association has suggested that their proprietary software can be used to make this calculation and should be recognized by this exception.

Adjustments by a trained electrical engineer must be made while using the software to obtain an acceptable result. This software has not been processed under the procedures of ANSI. Procedures in the NFPA Regs prevent recognizing procedures or software such as this in the NEC.

The safest procedure for sizing equipment grounding conductors of the wire type is use Table 250.122. This table has been satisfactorily used for many decades and has survived the test of time.

It is unclear why the exception is needed at all. This commenter fully supports the elimination of the exception.

Related Item

- FR-8281

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jul 20 00:08:25 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected

Action:

Resolution: The Authority Having Jurisdiction may determine whether the person performing the evaluation is qualified for a particular task and determine what information is needed to support the evaluation.



Public Comment No. 305-NFPA 70-2021 [Section No. 250.130(C)]

(C) Replacement of Nongrounding Receptacle or Snap Switch and Branch Circuit Extensions.

The equipment grounding conductor ~~of that is connected to~~ a grounding-type receptacle, a ~~snap switch with or to~~ an equipment grounding terminal of a snap switch, or a branch-circuit extension shall be permitted to be connected to any of the following:

- (1) Any accessible point on the grounding electrode system as described in 250.50
- (2) Any accessible point on the grounding electrode conductor
- (3) The equipment grounding terminal bar within the enclosure where the branch circuit for the receptacle, snap switch or branch circuit originates
- (4) An equipment grounding conductor that is part of another branch circuit that originates from the enclosure where the branch circuit for the receptacle, snap switch or branch circuit originates
- (5) For grounded systems, the grounded service conductor within the service equipment enclosure
- (6) For ungrounded systems, the grounding terminal bar within the service equipment enclosure

Informational Note No. 1: See 406.4(D) for the use of a ground-fault circuit-interrupting type of receptacle.

Informational Note No. 2: See 404.9(B) for requirements regarding grounding of snap switches.

Statement of Problem and Substantiation for Public Comment

This comment is intended to be editorial rather than substantive. In reality, the subject equipment grounding conductor connects to the equipment grounding terminal of a grounding type receptacle or to the equipment grounding terminal of a snap switch that has a metal yoke. This comment makes those changes.

Related Item

- FR-8228

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jul 20 00:45:04 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action:	Rejected but see related SR
Resolution:	<u>SR-8073-NFPA 70-2021</u>
Statement:	The revised language improves clarity and readability without changing the intent of the rule.



Public Comment No. 315-NFPA 70-2021 [Section No. 250.136]

250.136 Equipment Secured to a Metal Rack- ~~or Structure~~ .

If a metal rack ~~or structure~~ is connected to an equipment grounding conductor in accordance with 250.134, it shall be permitted to serve as the equipment grounding conductor for electrical equipment secured to and in electrical contact with the metal rack- ~~or structure~~ .

Statement of Problem and Substantiation for Public Comment

The phrase "or structure" must be deleted from this section. The intention of this rule is to allow electrical equipment that is rack mounted to be grounded by the metal rack that is grounded. To leave "structure" in place would allow the metal framing or structural members of a structure to be used as the equipment grounding conductor and thus create a high-impedance EGC path. For example, an equipment grounding conductor could be connected to one location of a metal structure and electrical equipment mounted to the structure at any distance away. To do would also violate 250.121(B) of the 2020 NEC.

Related Item

- FR-8230

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization: Simmons Electrical Services

Street Address:

City:

State:

Zip:

Submittal Date: Tue Jul 20 22:58:33 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: Metal racks and structures properly connected to an equipment grounding conductor serve the same purpose as intended in this section.



Public Comment No. 2090-NFPA 70-2021 [Section No. 250.140]

250.140 Frames of Ranges and Clothes Dryers.

Frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet or junction boxes that are part of the circuit for these appliances shall be connected to the equipment grounding conductor in the manner specified by 250.134 or 250.138.

Exception No. 1 : For existing branch-circuit installations only if an equipment grounding conductor is not present in the outlet or junction box, the frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet or junction boxes that are part of the circuit for these appliances shall be permitted to be connected to the grounded circuit conductor if all the following conditions are met.

- (1) *The supply circuit is 120/240-volt, single-phase, 3-wire; or 208Y/120-volt derived from a 3-phase, 4-wire, wye-connected system.*
- (2) *The grounded conductor is not smaller than 10 AWG copper or 8 AWG aluminum or copper-clad aluminum.*
- (3) *The grounded conductor is insulated, or the grounded conductor is uninsulated and part of a Type SE service-entrance cable and the branch circuit originates at the service equipment.*
- (4) *Grounding contacts of receptacles furnished as part of the equipment are bonded to the equipment.*

Exception No. 2: For existing branch-circuit installations only where the equipment supplies a dwelling unit(s) and there is no equipment grounding conductor present in the outlet or junction box, the frames of the appliances specified in Exception No. 1 shall be permitted to be connected to the grounded conductor provided all the conditions specified in (1), (2) and (4) of Exception No. 1 are met, the grounded conductor of the circuit supplying the appliance(s) is part of a nonmetallic sheathed cable and it is insulated or covered within the supply enclosure so it does not make contact with any normally non-current-carrying metal parts.

Statement of Problem and Substantiation for Public Comment

This Public Comment seeks to have CMP5 reverse their resolve position on PI 4020. In the resolve statement the Panel noted the PI did not provide any evidence that neutral currents would not be on unintended pathways when, in fact, the PI did provide such evidence. The following text is directly from the substantiation in PI 4020: "The hazard addressed by 250.142(B), having neutral current flowing on the metal normally non-current-carrying parts, is addressed by the requirement to insulate or cover an uninsulated grounded conductor within the supply enclosure so it does not contact metal parts that are normally non-current-carrying." Because the neutral bus will be isolated from the enclosure, the uninsulated conductor must be insulated or covered and the proposed exception is only for existing installations of nonmetallic sheathed cables, there will be no contact with the metal enclosure and, therefore, no parallel path for objectional neutral current.

It is also understood that 250.24(A)(5) prohibits grounded conductors from being connected to normally non-current-carrying metal parts on the load side of the service disconnecting means, except where it is elsewhere permitted in the Article 250. If the exception is accepted, it would be permitted elsewhere in Article 250. Would there not be a similar situation if an emergency (230.85) disconnect was installed on the outside of a single-family dwelling but it was not called the service equipment? In that case the grounded conductor could be bonded to the both the enclosure for the emergency disconnecting means on the outside of the dwelling and the service equipment enclosure possibly

creating a parallel path.

As also noted in the substantiation in PI 4020, this exception is needed to provide relief for situations where existing 3-wire branch circuits to electric ranges or dryers are connected to panelboards that were formerly service equipment but are now feeder supplied (e.g. when a whole house transfer switch installed or when a service is changed and the original installation of the service disconnecting means did not meet the location requirements of 230.70(A)). This is especially true where the existing cable(s) is installed behind the building's finish.

The State of New Hampshire recently approved the proposed exception as an amendment to the 2017 NEC that will carry over to the 2020 NEC when it is adopted.

Related Item

- PI 4020

Submitter Information Verification

Submitter Full Name: Mark Hilbert

Organization: MR Hilbert Electrical Inspections & Training

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 19 11:30:58 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR

Resolution: SR-8053-NFPA 70-2021

Statement: The section was revised by changing the main requirement and the former exception into two titled subdivisions. Section 250.140(A) address new installations and, other than the titled subdivision and mandatory text requiring the supply circuit to include an equipment grounding conductor, it remains unchanged from the 2020 NEC.

Section 250.140(B) incorporates the former exception for existing branch circuits that originated at the service equipment and it was expanded to recognize existing branch circuits originating at other than service equipment. The expansion was necessary to provide relief for situations where existing 3-wire branch circuits to electric ranges or dryers are connected to equipment that was formerly service equipment but is now feeder supplied.

The hazard addressed by 250.142(B) and 250.140(A), having neutral current on the metal normally non-current-carrying parts (objectionable current), is addressed by the requirement in 250.140(B)(5) to insulate or cover an uninsulated grounded conductor within the supply enclosure so it does not contact metal parts that are normally non-current-carrying. Because the neutral bus will be isolated from the enclosure, the uninsulated conductor must be insulated or covered, so there will be no contact with the metal enclosure and, therefore, no parallel path for objectionable neutral current.



Public Comment No. 914-NFPA 70-2021 [Section No. 250.140]

250.140 Frames of Ranges and Clothes Dryers.

Frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet or junction boxes that are part of the circuit for these appliances shall be connected to the equipment grounding conductor in the manner specified by 250.134 or 250.138.

Exception: For existing branch-circuit installations only if an equipment grounding conductor is not present in the outlet or junction box, the frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet or junction boxes that are part of the circuit for these appliances shall be permitted to be connected to the grounded circuit conductor if all the following conditions are met.

- (1) *The supply circuit is 120/240-volt, single-phase, 3-wire; or 208Y/120-volt derived from a 3-phase, 4-wire, wye-connected system.*
- (2) *The grounded conductor is not smaller than 10 AWG copper or 8 AWG aluminum- or copper-clad aluminum .*
- (3) *The grounded conductor is insulated, or the grounded conductor is uninsulated and part of a Type SE service-entrance cable and the branch circuit originates at the service equipment or at a panelboard that serves the entire dwelling load .*
- (4) *Grounding contacts of receptacles furnished as part of the equipment are bonded to the equipment.*

Statement of Problem and Substantiation for Public Comment

Copper-clad aluminum is generally acceptable as a conductor, but this is an exceptional case. Laundry equipment is notorious for vibration, which can fatigue these conductors. At the least, where there is the slightest nick this can expose aluminum to a termination intended to contain copper, degrading contact in what is typically far from the least corrosive environment. Such degradation is less likely to be noticed in a bonding conductor, whose integrity is unlikely to affect equipment operation. An analogous case can be found in product standards that allow push-in connections for circuit wiring but require wire-binding screw connection of grounding/bonding conductors.

I believe the added wording will accommodate the concerns of Messrs Hilbert, Cook, and Dollard, while not adding any risk. Whether all current flows on three conductors from a firefighter's disconnect to the service switch in the distribution panelboard, or from an actual service disconnect to the distribution panelboard, we're not altering risk.

Related Item

• PI 4020 • PI 4693 • PI 3853 • PI 3571 • PI 2473

Submitter Information Verification

Submitter Full Name: David Shapiro

Organization: Safety First Electrical

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 18:18:40 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The submitter has not provided technical data to support prohibiting copper-clad aluminum as an acceptable grounded conductor. There is no justification to permit a panelboard supplying the entire dwelling load in lieu of service equipment to permit the use of a neutral conductor to connect to the equipment grounding conductor.



Public Comment No. 580-NFPA 70-2021 [Section No. 250.166]

250.166 Size of the Direct-Current Grounding Electrode Conductor.

The size of the grounding electrode conductor for a dc system shall be as specified in 250.166(A) and (B), except as permitted by 250.166(C) through (E). The grounding electrode conductor for a dc system shall meet the sizing requirements in this section but shall not be required to be larger than 3/0 copper-clad steel 40% or copper or 250 kcmil aluminum or copper-clad aluminum.

(A) Not Smaller Than the Neutral Conductor.

If the dc system consists of a 3-wire balancer set or a balancer winding with overcurrent protection as provided in 445.12(D), the grounding electrode conductor shall not be smaller than the neutral conductor and not smaller than 8 AWG copper-clad steel 40% or copper or 6 AWG aluminum or copper-clad aluminum.

(B) Not Smaller Than the Largest Conductor.

If the dc system is other than as in 250.166(A), the grounding electrode conductor shall not be smaller than the largest conductor supplied by the system and not smaller than 8 AWG copper-clad steel 40% or copper or 6 AWG aluminum or copper-clad aluminum.

(C) Connected to Rod, Pipe, or Plate Electrodes.

If connected to rod, pipe, or plate electrodes as in 250.52(A)(5) or (A)(7), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than 6 AWG copper-clad steel 40% or copper wire or 4 AWG aluminum or copper-clad aluminum wire.

(D) Connected to a Concrete-Encased Electrode.

If connected to a concrete-encased electrode as in 250.52(A)(3), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than 4 AWG copper-wire-clad steel 40% or copper wire.

(E) Connected to a Ground Ring.

If connected to a ground ring as in 250.52(A)(4), that portion of the grounding electrode conductor that is the sole connection to the grounding electrode shall not be required to be larger than the conductor used for the ground ring.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	CMP16 Reconfirms Suitability of CCS for Grounding	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
SubstantiationPoints.Graph.Images..pdf	Facts To Consider Regarding CCS 40% for Article 250 Applications	
ATS_ShearTestRpt.pdf	Shear and UTS Data from Third Party Test Lab	
CCS40_SubstantiationStatement.pdf	CCS 40% Substantiation Statement	

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings:
If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26,

2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS’s legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: “Adding the wording ‘or other corrosion-resistant material’ is consistent with other Sections of the NEC and would be inclusive of copper-clad steel.” See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be “copper or other corrosion-resistant conductive material, stranded or solid.”

“Copper-Clad Steel” is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct

contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a "Process" annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

"Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing

- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

"Ferrous Wire Handbook," Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing."

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

"One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground,

these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building's electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility's investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

• PI 2476, PI 2477, PI 2478, PI 2479, PI 2474

Submitter Information Verification

Submitter Full Name: Peter Graser

Organization: Copperweld

Affiliation: American Bimetallic Association

Street Address:

City:

State:

Zip:

Submittal Date: Sat Jul 31 06:54:51 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected

Action:

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than those required in UL 467. The current carrying capability of 40% copper clad steel is less than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

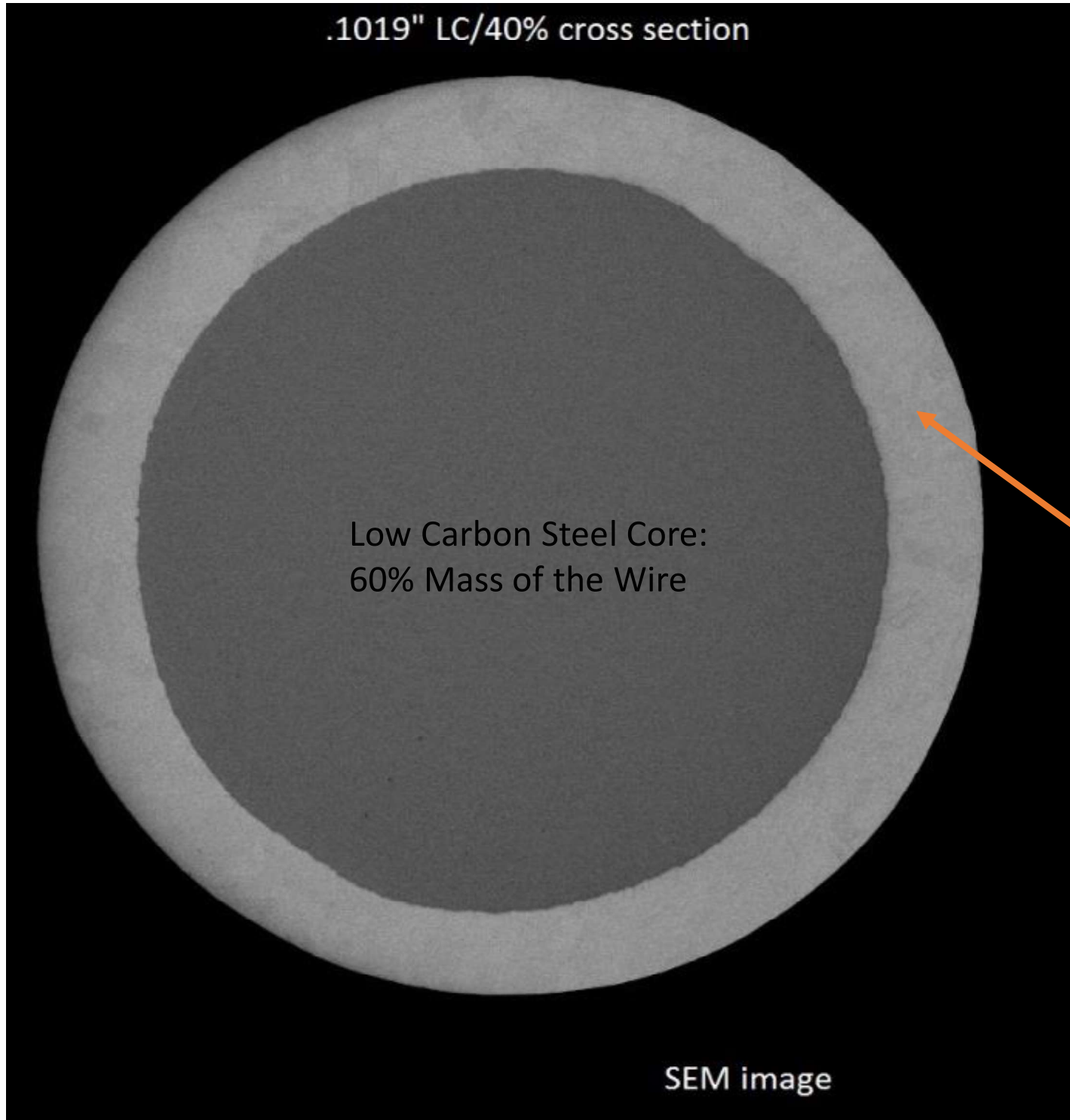
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

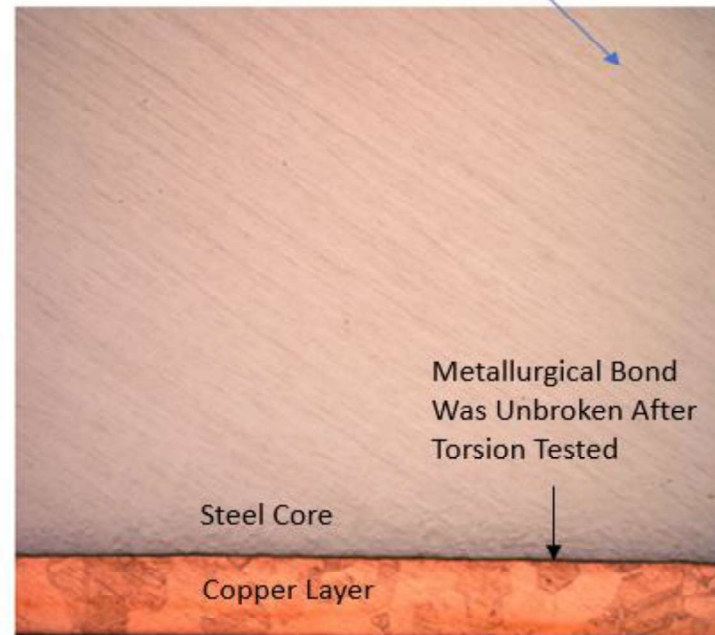
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
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 Date: 2021-08-05 12:29:52
 Email: rallen@atslab.com, n 4



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the

short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

Submitter Information Verification

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Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

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



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**Public Comment No. 577-NFPA 70-2021 [Section No. 250.190]****250.190** Grounding of Equipment.**(A)** Equipment Grounding.

All non-current-carrying metal parts of fixed, portable, and mobile equipment and associated fences, housings, enclosures, and supporting structures shall be grounded.

Exception: If isolated from ground and located such that any person in contact with ground cannot contact such metal parts when the equipment is energized, the metal parts shall not be required to be grounded.

Informational Note: See 250.110, Exception No. 2, for pole-mounted distribution apparatus.

(B) Grounding Electrode Conductor.

If a grounding electrode conductor connects non-current-carrying metal parts to ground, the grounding electrode conductor shall be sized in accordance with Table 250.66, based on the size of the largest ungrounded service, feeder, or branch-circuit conductors supplying the equipment. The grounding electrode conductor shall not be smaller than 6 AWG copper-clad steel 40% or copper, or 4 AWG aluminum or copper-clad aluminum.

(C) Equipment Grounding Conductor.

Equipment grounding conductors shall comply with 250.190(C)(1) through (C)(3).

(1) General.

Equipment grounding conductors that are not an integral part of a cable assembly shall not be smaller than 6 AWG copper-clad steel 40% or copper or 4 AWG aluminum or copper-clad aluminum.

(2) Shielded Cables.

The metallic insulation shield encircling the current-carrying conductors shall be permitted to be used as an equipment grounding conductor, if it is rated for clearing time of ground-fault current protective device operation without damaging the metallic shield. The metallic tape insulation shield and drain wire insulation shield shall not be used as an equipment grounding conductor for solidly grounded systems.

(3) Sizing.

Equipment grounding conductors shall be sized in accordance with Table 250.122 based on the current rating of the fuse or the overcurrent setting of the protective relay.

Informational Note: The overcurrent rating for a circuit breaker is the combination of the current transformer ratio and the current pickup setting of the protective relay.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
Section_770.100_A_2_Committee_Statement_CMP16.doc	CMP 16 Reconfirms CCS Suitable for Grounding	
WSJ.TeslaQ2.Profits.pdf	Wall Street Journal. Tesla \$1.1 Billion Q2 Profit	
SubstantiationPoints.Graph.Images..pdf	Facts To Consider Regarding CCS 40% for Article 250 Applications	

ATS_ShearTestRpt.pdf

Shear and UTS Data from
Third Party Test Lab

CCS40_SubstantiationStatement.pdf

CCS 40% Substantiation
Statement

Statement of Problem and Substantiation for Public Comment

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement in Attached PDF)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

THE PUBLIC SAFETY THREAT- The Clear and Present Danger for Occupants of Buildings:
If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even

electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, "Tesla's Quarterly Profit Soars to a Record \$1.1 Billion" in the second quarter of 2021. Positive earnings will attract more manufacturers of EV's, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC's, GE's and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation's distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building's OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc. The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or other corrosion-resistant conductive material, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a "Process" annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

"Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable

temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wire drawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65% (basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could

apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND REPORT)

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper. (SEE CHART IN ATTACHED SUBSTANTIATION AND TEST REPORT)

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers. (SEE CHART IN ATTACHED SUBSTANTIATION)

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder, stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

"One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice. Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the Statement of Problem and Substantiation for Public Input.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines." SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building's electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers

reside along every major step-down of the distribution system to keep safe not only the utility's investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Related Item

- PI 2481, PI 2482

Submitter Information Verification

Submitter Full Name: Peter Graser

Organization: Copperweld

Affiliation: American Bimetallic Association

Street Address:

City:

State:

Zip:

Submittal Date: Sat Jul 31 06:42:28 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Action: Rejected

Resolution: The code making panel reaffirms there is no technical substantiation provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The ASTM standards referenced do not replicate actual wire type conductor routing, pulling and termination. The current values used in the short time current tests provided with the original Public Input were less than those required in UL 467. The current carrying capability of 40% copper clad steel is less than copper. The public comment proposes the use of equal sized copper clad steel conductors to copper conductors which lowers the level of safety and performance of the grounding system without technical substantiation. Copper-clad steel needs to be listed to ensure acceptable performance.

Relationship Between Electrocutions and the Price of Copper:

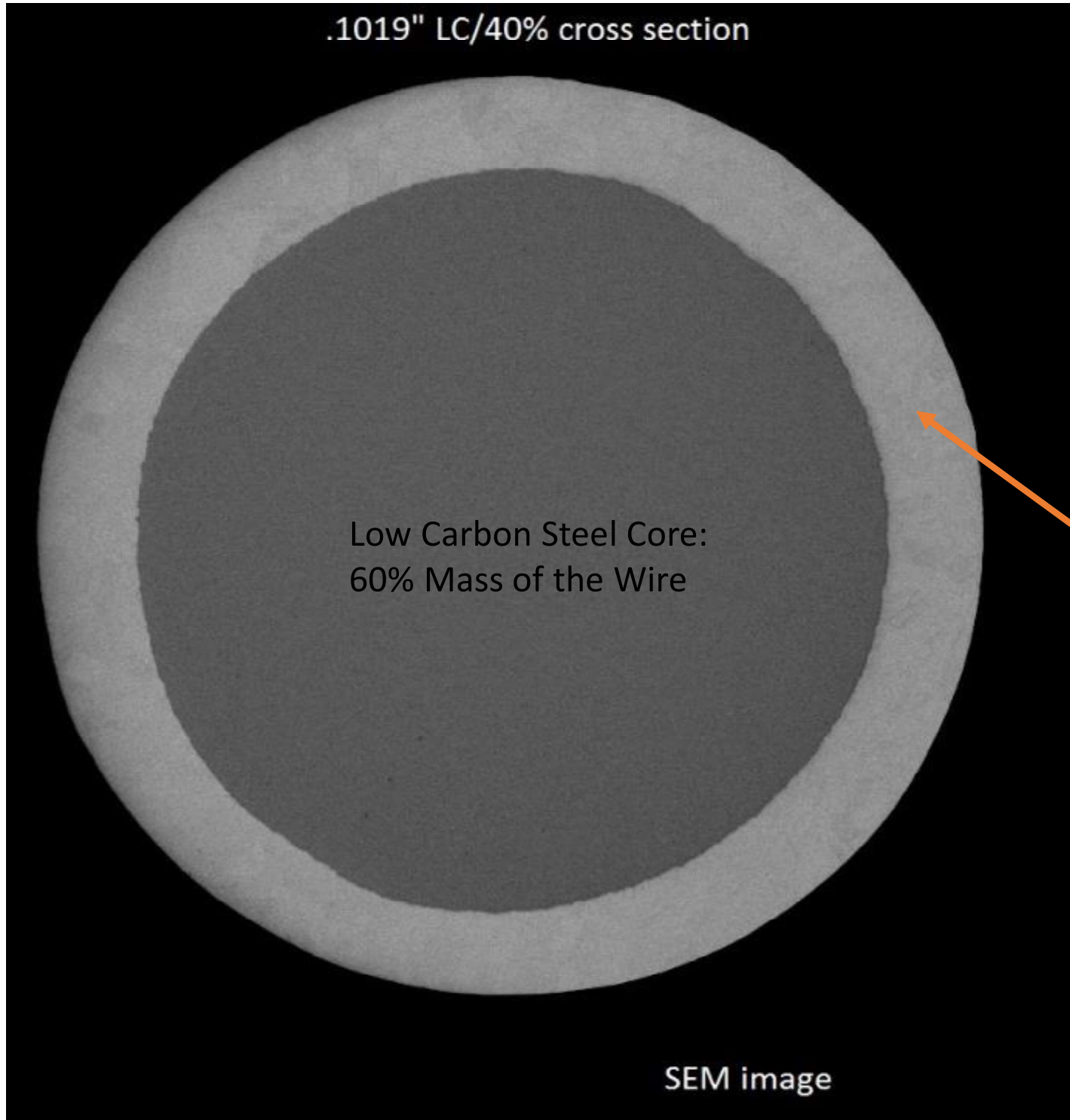
Electrocutions In Sync with Copper Prices. Theft of Copper GEC's and GE's Increases When Copper Prices High. Public at Risk.



Blue Line: Electrocutions. Yellow Boxes: Electrocutions in the Calendar Year. Red & Green Lines: Price of Copper

Data: US Bureau of Statistics

.1019" LC/40% cross section



**Copper-Clad
Steel Wire 40%**

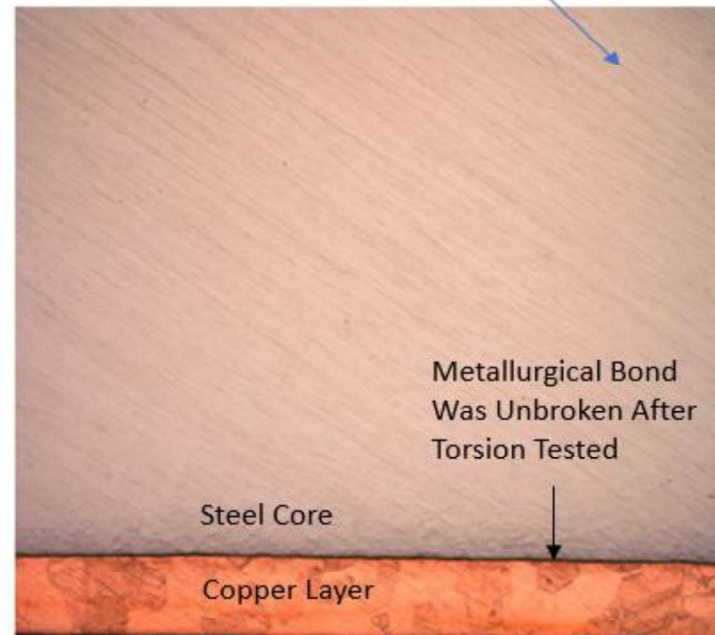
Low Carbon Steel Core:
60% Mass of the Wire

Copper Cladding:
40% Mass of
The Wire

SEM image

Piece of # 4 CCS 40% Torsion Tested for Adhesion per 7.4 of ASTM B910. Note how the metallurgical bond allows the two metals to move as one. No delamination Permitted.

Both Images
Are of the Same
Sample After
Torsion Tested
For Adhesion and
Cohesion of Copper



Micro Photo of Cross-section of CCS 40% After Torsion-Tested

TEST REPORT 359379

Contact: Bill Lewey
Customer: Copperweld Bimetallics LLC
 254 Cotton Mill Road
 Fayetteville, TN 37334

Date: 8-4-21
Purchase Order: 054689

Summary

Four (4) groups of copper rods were submitted for double shear testing in accordance with the customer provided instructions of using ASTM B769 as a guide. The copper material and the diameter of the #6 rod was a deviation from the requirements of the specification. Two specimens from each group were tested in a fixture like the one shown in Figure 1 of ASTM B769-11. Testing was also in accordance with ATS QA Manual Rev. 18 dated 10/16/20.

Sample Table

ATS#	P/N	Description	Pass/Fail
N/A	#6 Copper Clad Rod (Samples 1&2)	Rod	No requirements provided
N/A	#6 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Solid Copper Rod (Samples 1&2)	Rod	No requirements provided
N/A	#4 Copper clad Rod (Samples 1&2)	Rod	No requirements provided

Reviewed by  Dennis Johnson
 2021.08.05
 12:20:50 -04'00'
 D. Johnson, Mechanical Testing

Reviewed by  Rodney Allen
 W.R. Allen Mechanical Testing

Original signed by Rodney Allen
 DN: C=ATS, CN=Rodney Allen,
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 Reason: I have reviewed this document
 Location:
 Date: 2021-08-05 12:29:52
 Date: 2021-08-05 12:29:52



This report may not be reproduced except in full without the written approval of ATS. This report represents interpretation of the results obtained from the test specimen and is not to be construed as a guarantee or warranty of the condition of the entire material lot. If the method used is a customer provided, non-standard test method, ATS does not assume responsibility for validation of the method. Measurement uncertainty available upon request where applicable.

Table 1: Double Shear Testing

Sample	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (double shear) (in ²)
#6-1 Copper Clad	38,644	1,603	0.1625	0.0415
#6-2 Copper Clad	37,032	1,533	0.1624	0.0414
#6-1 Solid Copper	23,842	960	0.1601	0.0403
#6-2 Solid Copper	24,565	992	0.1604	0.0404
#4-1 Solid Copper	24,611	1,602	0.2036	0.0651
#4-2 Solid Copper	24,914	1,618	0.2034	0.0650
#4-1 Copper Clad	36,518	2,374	0.2035	0.0650
#4-2 Copper Clad	38,506	2,504	0.2035	0.0650

(For Easier Reading and Viewing of Data Tables, Please See This Same Substantiation Statement Attached)

Copper-Clad Steel 40%: Seeking Referencing in Article 250 as a Grounding Electrode Conductor, Grounding Electrode Ring and Bonding Conductor:

Affiliated Public Inputs:

Section	PI #
250.52(A)(4)	2459
250.53(E)	2460
250.62	2462
250.64(B)(1)	2463
250.64(B)(2)	2465
250.66(A)	2468
250.66(B)	2470
Table 250.66	2467
250.102(A)	2471
250.166(A)	2476
250.166(B)	2477
250.166©	2478
250.166(D)	2479
250.166	2474
250.190(B)	2481
250.190©(1)	2482

For Reference, CMP-5 Resolve Statement from First Revision:

No technical substantiation was provided to ensure that under expected conditions of use the copper layer will not delaminate, the steel core stiffness and strength is sufficient to prevent failure, and that it can be bent and installed without stressing terminations within equipment. The Public Input does not require 40% copper-clad steel which was used in all of the submitted testing reports. The current values used in the

short time current test are less than those required in UL 467. Copper-clad steel needs to be listed to ensure acceptable performance.

The Reason for this Public Comment:

This Public Comment seeks to provide users of Code the choice of employing Copper-clad Steel 40% grounding wire and strand (CCS 40%) as an alternative for use as a GEC, GE Ring and Bonding Conductor. Sixteen public inputs in the First Revision of the 2023 cycle in promotion of CCS 40% were submitted and resolved by CMP-5. This PC is in response to those specific points of resolve, points which were published by CMP-5 in a general resolve statement for all 16 public inputs. Given the gravity of the safety concern to the Public, a reconsideration of the consequences of omitting CCS 40% from Article 250 is merited. Below are 9 points of substantiation that address the current safety hazard as well as the panel's points of resolve from First Revision.

The Public Safety Threat:

The Clear and Present Danger for Occupants of Buildings:

If absent, a GEC, GE Ring or Bonding Conductor will fail to keep the Public safe. From its all-time high of \$ 4.90/lb. reached in May of 2021, the price of copper is expected to double by the end of the decade. This is due not only to the scarcity of the resource and the growing frequency of labor strikes at essential mines, but more importantly, to the unprecedented global demand put on copper from the advance of the EV motor. A solitary copper GEC is most times the only link between the electrical system of an occupancy (residence, factory, retail shopping plaza, hospital, etc.) and its grounding electrode system. For a GEC to disappear for any reason puts the Public in danger of shock or even electrocution. Although theft was highlighted in the associated Public Inputs from First Revision, the resulting Public Comments seeks to underscore and amplify it for the members of CMP-5. It seeks to bring the consequences of copper theft to the attention of those keeping Article 250 in front of such crises. Driven by global macro-economic forces of titanic scale, copper theft has already forced many code

makers to adapt. As cited in a recent Wall Street Journal article by Rebecca Elliott from July 26, 2021, “Tesla’s Quarterly Profit Soars to a Record \$1.1 Billion” in the second quarter of 2021. Positive earnings will attract more manufacturers of EV’s, create greater supply of them, and thus induce an even greater scarcity of copper. As our nation moves from the combustion engine to the copper-dependent EV motor, driving up copper prices at every production milestone and earnings announcement, public safety should not take a back seat.

According to data published by the Electrical Safety Foundation International (ESFi) and the Bureau of Labor Statistics, there exists a direct relationship between copper pricing and electrocutions. The year 2011 saw the most occupational fatalities caused by electrocution in this century. Not coincidentally, 2011 also saw copper surge in price to over \$ 4.50 / lb. for the first time in history, unleashing an epidemic of copper theft across the nation. As jurisdictions spent the subsequent years putting in place tougher criminal sentencing to deal with the crisis, copper prices also steadily fell through the years 2012 to 2017, decreasing the incentive to steal, but also masking the problem. Thankfully, the number of electrocutions fell in sync with copper prices over those years. In 2018, however, copper prices began to rise again, and as grimly predicted, the downward trend of electrocutions reversed its course. The years 2018 and 2019 saw more electrocutions than in any year but 2011. Sadly, due to the historically high price levels of copper in 2020 and 2021, the new number of severe injuries and deaths caused by electrocution is expected to top 2011 by a wide margin. In short, making sure that GEC’s, GE’s and bonding conductors stay connected, decreasing the incentive to steal them, and creating Code to better ensure that they not disappear, will aid in driving down the occurrences of shock and electrocution for the greater Public.

Reclosers and Switches have been a mainstay of the Nation’s distribution system for decades. These devices provide effective protection for GEC and GE systems from sustained fault current from the distribution side. A building’s OCPDs also provide protection. As a result, GEC and GE systems have never been safer from damage caused by abnormal power originating from distribution. Even so, a typical copper GEC or ground ring receives little protection from damage or

removal by mechanical means. Grounding and bonding conductors made with soft metals exacerbates the problem. A GE, for example, is often openly exposed and visible to all sorts. In other cases, a GEC may be hidden from view within a protective conduit, not allowing an occupant or technician to visually confirm its continuity from terminal to terminal. Given the modern economy of copper, the risk of single-metal copper grounding conductors failing to do their jobs has never been greater.

Points of Substantiation:

1. NFPA Precedence for Copper-Clad Steel as a GEC:

In both Chapters 7 and 8 of NFPA 70, Code Making Panel 16 has long recognized CCS as a material suitable for use as a GEC and Bonding Conductor. As recently as January 2021 during the First Revision of this 2023 cycle, CMP 16 reconfirmed CCS's legitimacy as both a GEC and bonding material. Note the Committee Statement from FR 8888, Public Input 2491: "Adding the wording 'or other corrosion-resistant material' is consistent with other Sections of the NEC and would be inclusive of copper-clad steel." See attached Section 770.100(A)(2) Committee Statement CMP16.doc.

The language consistently chosen to describe GEC, GE and bonding materials in Chapters 7 and 8 is also consistent with the language in Article 250. The GEC shall be "copper or other corrosion-resistant conductive material, stranded or solid."

"Copper-Clad Steel" is even referenced by name for use as a GEC in Section 810.21 (A). Please note NFPA 70 section references below.

770.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

800.100(A)(2) Material.

The bonding conductor or grounding electrode conductor shall be copper or **other corrosion-resistant conductive material**, stranded or solid.

810.21(A) Material.

The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, copper-clad aluminum, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

250.102(A) Material.

Bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper, aluminum, copper-clad aluminum, or the items as permitted in 250.68(C). The material selected shall be resistant to any corrosive condition existing at the installation or shall be protected against corrosion. Conductors of the wire type shall be solid or stranded, insulated, covered, or bare.

2. Termination of CCS 40%:

Standard means of termination for CCS 40% grounding wire and strand currently exist in the market, such as exothermic welding and by mechanical termination with connectors. All major manufacturers of exothermic welding supplies recognize CCS 40% as suitable for exothermic welding. In fact, the exothermic welding of CCS 40% is a daily occurrence in the utility industry. Finally, research has proven that connectors listed to UL 467 for use with both CCS and copper are currently available in the market. The list of manufacturers with CCS/Cu dual listed connectors will continue to grow, as copper-theft escalates over this decade. The free market will push manufacturers for solutions to the growing theft problem.

3. Delamination Not Permitted by the Industry Standard.

Per the standard, ASTM B910 Annealed Copper Clad Steel Wire, the copper is not permitted to delaminate from the steel core. A metallurgical bond is created during the cladding process, an element that defines bimetals. Therefore, when bent or torsion-twisted by hand to make an electrical termination, the two metals will remain as one. To meet ASTM B910, the bimetal CCS 40% is subjected to a rigorous torsion test, much more severe than the standard bend test of a copper

coated grounding electrode (ground rod). Ground rods are not bimetals. Below are the appropriate sections of ASTM B910 mandating delamination testing.

ASTM B910:

7.4 Torsion (Twist) Test—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.3 of this specification.

5.3 Adhesion and Surface Defects—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

4. CCS 40% NOT Too Stiff to Apply by Hand.

A CCS 40% GEC can be supplied solid or stranded, depending upon the flexibility requirements of a particular job. CCS 40% wire to ASTM B910, regardless of whether it is supplied solid or stranded, undergoes a “Process” annealing treatment. Copper electrical wire is also process annealed per its standard. See definition of annealing:

“Annealing is a generic term denoting a treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily to soften metallic materials. The purposes of such heat treatment are to:

- Homogenize metal structure after rod rolling operations
- Relieve strain hardening induced by cold working during wiredrawing
- Soften the metal
- Alter ductility, toughness, tensile strength, yield strength, elongation, and other physical properties
- Produce a desired microstructure

“Ferrous Wire Handbook,” Edited by Robert M. Shemenski, Ph.D. The Wire Association International, Inc. Chapter 19, Annealing.”

After Annealing, per ASTM B910, copper-clad steel wire must meet the prescribed conductivity of the standard, be it 21%, 30% or 40% grade. The conductivity is verified through routine resistivity testing as mandated by the standard.

In addition to annealing, wires can be stranded to add flexibility. Stranded sizes of 6 AWG and 4 AWG sizes are 3x more flexible than solid wires of the same size. The same applies to any size: stranding makes it more flexible compared to the same size in solid. Per Code, GEC's, GE's and Bonding conductors can be both single-end solid or stranded. Strand made with 40% CCS can be as many ends as desired -- more wires in a stand size, smaller single-end wires, more flexibility. A metallurgical engineer can make a conductor as flexible or rigid as required for the application.

Finally, in metals, there is not always a direct relationship between flexibility, hardness and strength. One metal of high hardness, tensile and shear strength can be made to be equally as flexible as another metal of a lower hardness, tensile and shear strength. As discussed, this is accomplished by degrees of annealing and/or stranding. In short, when designing wire and cable products, the application drives the design. A GEC, for example, must be adequately conductive, hand-bendable and difficult to shear. These characteristics were all achieved when designing 40% CCS a century ago for use by the nation's utilities.

5. Will Elastic Memory of CCS 40% Damage Terminals?

By design, there is no spring-back memory remaining in CCS 40% wire after annealing. Because its core consists of annealed low-carbon steel, CCS 40% has no recoil force to dislodge or damage panel terminals once terminated. Low carbon steel (carbon range of 0.02 - 0.18%) is the grade used to make wire products such as soft rebar tie wire, wire hangers, soft bailing wire and CCS ground wire. Carbon is the main alloying agent used to strengthen steel: the higher the carbon, the more spring-back force a steel will have. Mechanical springs, for example, range in carbon content from 0.55% (bedsprings) and 0.65%

(basic mechanical springs) to 0.80% (high strength automotive springs) and 0.90% (oil tempered valve springs). Prestressed concrete strand, a high carbon cable designed to put dynamic load into concrete I beams and double tees for buildings and bridges, maintains a carbon level of 0.80% for strength and elasticity. In contrast, when first designing CCS grounding wire and strand in the early 1920s, low carbon steel with 0.06% carbon (AISI 1006) was chosen for the application. It was chosen for two qualities found in its cold drawn form: its lack of recoil memory and for its flexibility. Annealing further removed the stress within the material by changing the shape and position of the metallic grains, eliminating any stress risers that might have existed in the metal's original grain structure. The resulting product was strong, flexible, and contained no memory (spring-back force) due to the annealing.

6. Is CCS 40% Harder to Cut than Copper?

40% CCS has a significantly higher shear strength value than copper. Shear strength is defined as a material's ability to resist forces that cause its internal structure to slide against itself. It can be measured in either the vertical or horizontal direction. See the attached test report from Applied Technical Solutions (ATS) comparing the shear strength of copper to that of CCS 40%. The typical shear strength of a copper GEC, for example, would be +/- 23,000 PSI. CCS 40% would be 37,000 PSI. The ability to shear-cut, snip or dismember 40% CCS by mechanical means is exponentially more difficult than it would be for copper of the same diameter. A material's having a higher shear strength will not only better protect it from thieves, but also from accidental damage.

For perspective, the force of a nail tip being driven by a hammer blow could be as high as 10,000 PSI due to the small area of the nail's tip in relation to the force of the blow. A hammer blow itself could apply as much as 120 lb. of force. Further, the blade of a machete could easily deliver 15,000 PSI to a wire or strand surface given the torque of the blow and the tightly focused contact area. Due to its material softness, a few machete blows (if not one) can easily sever a # 4 GEC wire made from copper.

Shear Strength Comparison						
Sample ID	AWG Size	Material	Shear Strength (psi)	Ult. Load (lbf)	Diameter (in)	Area (Double Shear) (in ²)
A1	#6	Copper clad steel	38644	1603	0.1625	0.0415
A2	#6	Copper clad steel	37032	1533	0.1624	0.0414
B1	#6	Solid copper	23842	960	0.1601	0.0403
B2	#6	Solid copper	24565	992	0.1604	0.0404
C1	#4	Copper clad steel	36518	2374	0.2035	0.065
C2	#4	Copper clad steel	38506	2504	0.2035	0.065
D1	#4	Solid copper	24611	1602	0.2036	0.0651
D2	#4	Solid copper	24914	1618	0.2034	0.065

Source: Applied Technical Solutions (ATS) Metallurgical Lab, Marietta, Ga.

Additionally, CCS 40% has a significantly higher break load than copper. Break load measures the force required to stretch the material lengthwise to its breaking point. The following chart compares the tensile strengths of #4 and #6 CCS 40% to # 4 and # 6 Copper.

AWG size	material	Diameter	Break load (lbs.)	% elongation	Tensile (psi)
#6	Copper clad steel	0.1617"	1067	32.1	51958
#6	Copper clad steel	0.1617"	1091	36.4	53127
#6	Solid copper	0.1599"	725	44.5	36103
#6	Solid copper	0.1599"	723	44.7	36004
#4	Copper clad steel	0.2032"	1648	34.2	50818
#4	Copper clad steel	0.2032"	1659	35.6	51157
#4	Solid copper	0.2032"	1160	43.9	35770
#4	Solid copper	0.2032"	1168	44.2	36062

Source: Copperweld Metallurgical Lab Comparative Testing of Solid Annealed CCS 40% vs. Annealed ETP Copper (building wire grade copper)

Finally, material hardness has more to do with keeping a grounding conductor from being cut than even break load and shear strength. In metallurgical terms, hardness is described as a material's ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as cutting, abrasion, penetration or scratching. Low carbon steel has a material hardness (measured on both the Brinell and Rockwell scales) of 3 – 4 X higher than that of copper. Hardness aids CCS 40% greatly. It impedes localized deformation from occurring at the hands of cutting tools such as pliers, machetes and hammers.

Material	Brinell Hardness Number - HB
Lead	5.0
Pure Aluminium	15
Copper	35
Soft brass	60
Hardened Aluminium	75
Mild steel	130
Annealed chissel steel	235
White cast iron	415
Nitrided surface	750
Glass	1550
Rhenium diboride	4600

Brinell Hardness of Copper: 35. Brinell Hardness of Mild Steel (low carbon): 130. U.S. Department of Energy, Material Science. DOE Fundamentals Handbook, Volume 1 and 2. January 1993.

The benefits of a Mechanically Robust GEC, GE, or Bonding Conductor Include:

- Less Likely to Accidental Sever or Be Damaged by yard equipment, forklifts, automobiles, etc.
- Less Likely to be Removed by Tools Typically Used by Thieves.

Common sense is a tool that many times goes underemployed in daily life. In highly technical fields, common sense is often lost altogether. In the case of GEC, GE and bonding conductors, having a proven conductor material that is harder,

stronger and more resistant to cutting than the current alternative makes common sense, especially in today's economy of high-priced copper.

7. The Strength of Steel Requires No Oversizing

“One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128. The GEC is not required to be particularly conductive in practice, as “Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions.” SOARES 13th Edition, Page 128. The oversizing requirement of the GEC (derating) is largely due to the relatively weak mechanical characteristics of the three conductor materials currently permitted by Article 250 (copper, aluminum and copper-clad aluminum), which, due to their lack of core strength, are not particularly ideal for the job of carrying intense high-frequency current for millisecond durations. Those soft materials (copper-clad aluminum, aluminum and copper), albethey more conductive than CCS 40% at low frequencies, are more likely to fuse under such conditions. The logic behind oversizing copper, aluminum and copper-clad aluminum for use in grounding is to make them mechanically stronger against electrical and mechanical abuse. Increased diameter of wire = more mass = more mechanical strength.

The Technical Benefits of a Steel Core: Because CCS 40% is supported by a carbon steel core, derating the size is not necessary. CCS 40% has been proven by third party testing to withstand massive currents at high frequencies without breaking connection (Please consult the associated Public Inputs of this Public Comment for Power Tech's report on Fusing Current, Withstand Current, Peak and Short-time Current and EMF Tests). Utilities have understood this concept for decades. The conductive copper cladding (40% of the total mass of the wire) deals excellently with fault current at high Hz, as the skin effect comes into play. The

steel core helps keep the wire from fusing or exploding under high-frequency, short-cycle surge events.

Again, a steel core is not easily severed. And CCS bimetal has 1/10th the scrap value of copper of the street.

Because Aluminum and Copper-Clad Aluminum GECs cannot be installed within 18 in. of the ground, these materials are largely not feasible for the application of grounding, which leaves copper as the electrical contractor's only choice.

Permitting a GEC to be Copper Clad Steel 40%, on the other hand, grants users of Code a second alternative. Although CCS 40% is pliable and bendable by hand, cutting it is noticeably different (exponentially more difficult to due its hardness, break load and shear strength) than cutting copper, giving thieves ample time to recognize it and move on.

8. CMP5 Request: Listing Requirement for CCS 40%.

The submitter of this Public Comment agrees. A listing requirement was requested in First Revision. In the original set of Public Inputs covering CCS 40% which are listed in this PC, a listing was requested in the *Statement of Problem and Substantiation for Public Input*.

9. A GEC is not an Equipment Grounding Conductor (EGC)

The GEC is not an EGC. Other than sharing the same letters in their acronyms, there is little likeness in function between a GEC and EGC. They function in sync, however. The EGC provides a path to ground (earth) when connected to the GEC at the service or separately derived system. When not connected, the path to ground is broken, a condition which should be avoided. Nevertheless, one similarity between the GEC and EGC is that they only carry current during abnormal events. The type of current carried by one, however, is different than the other. In ground-fault conditions, an EGC may be required to carry low-frequency current of a short duration – a few cycles or seconds maximum. Accordingly, it must be sized to endure the event until an OCPD is activated. A

GEC, on the other hand, will never see powerful low frequency current of such a long duration. It will see short-cycle high frequency current lasting fractions of milliseconds and mostly from lightning strikes. Reclosers and auto-switches have mitigated the threat from utility-side abnormalities from power lines and transformers. Load side OCPD's are also in place for backup/redundancy to protect the GEC and GE system.

An EGC must be conductive enough to send ground fault current some distance to a grounded panel bus. A GEC need not be as conductive as an EGC, and it need only be long enough to span the short distance between the system's service equipment and the grounding electrode system. "The main purpose of the grounding electrode is to establish and maintain an earth reference for the system and non-current-carrying parts of the system but not to clear ground faults. SOARES 13th Edition, Page 128." In short, the GEC acts as the bridge between the two systems.

Therefore, a GEC should not be held to the same standard as an EGC in terms of its ability to carry continuous low-frequency current, for the GEC performs a completely different function than an EGC. They work together as a unit, and one certainly needs the other to provide safety from shock or electrocution, but the two are asked to perform different functions. Therefore, the conductor material appropriate for an EGC is not always the best for a GEC.

The single most important job of the GEC is to stay place. It must endure the life of the installation to maintain the connection to the electrical system's earth reference, the EC. This requires that the GEC be both corrosive resistant and mechanically strong. The GEC is not required to be particularly conductive in practice, as "Ground-fault currents through the GEC are not likely to attain a value anywhere near the continuous rating of the conductor even under fault conditions." SOARES 13th Edition, Page 128. However, the GEC should have the fortitude to withstand high-frequency intense current lasting a millisecond. "One of the reasons for requiring the grounding electrode conductors to be larger than the normal system current they might carry is because grounding electrode conductors also carry current from other events on the system, such as lightning

strikes or from accidentally being energized from high-voltage sources such as transformers or overhead lines.” SOARES 13th Edition, Page 128.

Globally, utilities invest billions of dollars per year in protection devices that serve to keep short-circuit current from destroying their distribution lines and equipment, namely via microprocessor-based feeder and recloser relay technologies. Because of decades of advances on the distribution side, a building’s electrical system will never experience surges of 1000 amps of continuous current lasting longer than a few milliseconds, not to mention 4, 6 or 9 seconds. Preventing such events, reclosers and breakers reside along every major step-down of the distribution system to keep safe not only the utility’s investments but also their customers – the public. In modern times, damaging a GEC or GE system with fault current, other than by a direct lightning strike, is too remote to be considered a threat.

Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]

(2) Material.

The bonding conductor or grounding electrode conductor shall be copper-clad steel, copper or other corrosion-resistant conductive material, stranded or solid.

Additional Proposed Changes

<u>File Name</u>	<u>Description</u>	<u>Approved</u>
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Copper Clad Steel Wire for Substation Grounding Mats	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Copper Clad Steel	
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	

Statement of Problem and Substantiation for Public Input

Grounding Electrode Conductor Purpose: The purpose of the grounding electrode system, grounding electrode(s) and grounding electrode conductor(s) is to provide a connection to earth for the electrical system and equipment. The grounding electrode system functions to limit errant voltages caused by lightning, transients and high voltage line clashes. For grounded systems it stabilizes the voltage of the electrical system during normal operations and keeps the voltage to ground at predictable limits. A grounding electrode conductor must be both strong and conductive. It should be strong enough mechanically to withstand high current/frequency (A/Hz) lightning strikes as well as any damage from normal use. Where terminated in or near ground level, it must be corrosion resistant. Finally, a grounding electrode conductor must be able to be connected with standard industry-accepted connectors that are used within the grounding electrode system. Grounding Electrode Conductor Materials: The present materials permitted for grounding electrode conductors are copper, aluminum and copper-clad aluminum. The aluminum and copper-clad aluminum are limited in use by 250.64(A) where the bare conductor is in or near the ground or concrete at grade level. Grade 40 Copper-Clad Steel (40CCS), a copper bimetal, is another alternative designed for use as a grounding electrode conductor (GEC) and should be added to the NEC®. It is governed by ASTM B910/B910M-2007, the Standard Specification for Annealed Copper-Clad Steel Wire. The standard's scope states the following: This specification covers bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications. Per the standard, the minimum tensile strength for all wire diameters must be higher than 40,000 PSI, which would elevate the strength of GEC materials currently provided in Article 250. The shear modulus of Grade 40CCS is 11,600 KSI. Because ASTM B910 requires 40CCS to be annealed (softened), the material is sufficiently pliable to allow for traditional installation practices for GEC's. Increased mechanical strength of a GEC elevates the protection of an electrical installation in two ways: 1) the GEC can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC is noticeably more difficult to cut without proper tools, which aids as a theft deterrent when thieves attempt to remove it. Additionally, Copper Clad Steel has no scrap value, which also disincentives theft. Terminations and Connectors: Grade 40CCS conductors have successfully passed UL 467 Short Circuit Testing for standard connectors available in the market. 40CCS conductors also successfully passed UL 486A and 486B for Mechanical

Sequence Testing. Attached to this Public Input, please reference Test Report TD002391, Burndy, UL 467 Short Circuit & UL 486A – 486B Mechanical Sequence Tests with Copperweld 40% Copper Clad Steel. These results offer clear evidence that 40CCS performs satisfactorily with grounding connector hardware standard for grounding systems. Corrosion Resistance: Corrosion can cause GEC connections to fail in the grounding system. As a copper bimetal, Grade 40CCS maintains the corrosion resistance characteristics required to keep grounding systems intact. Copper Clad Steel was invented in 1915 by the Copperweld Company in Rankin, PA, for use as both a grounding electrode and GEC. One of grade 40 CCS's traditional applications is as a buried grounding electrode for utility substations meeting IEEE Standard 80, IEEE Guide for Safety in AC Substation Grounding. For substantiation of the corrosion resistance of Grade 40CCS, please refer to the white paper attached to this Public Input: CCS_Corrosion_Paper_Rev2. Corrosion on Buried Copper Clad Steel, by Syarif and Hale. The paper describes the condition of grade 40CCS after 50 years of use as part of a ground grid under a substation in Kentucky. Resistance to Fusing at High Currents: The GEC must also have the integrity to hold up to high-current forces such as lightning. Fusing and withstand testing was conducted to judge the suitability of Grade 40CCS as a GEC. For reference, like-sized copper conductors were tested alongside CCS conductors. The results prove that grade 40CCS performs equal to or better than the same size copper conductor. Attached to this Public Input, please review test report PL-03027_REP1 "Copper and CCS Wire Withstand Current and Fusing Current Testing." Testing conducted at the Powertech Test Lab of Surrey, BC, Canada. Conductivity: Although not required to carry current continuously, the GEC must be conductive. The attached test report by Bill Lewey and Mike Rozer proves Grade 40CCS's conductivity. See CEL-13 Grounding Current Conductor Test. Current NEC® Applications: Copper Clad Steel as a GEC material is currently referenced in section 810.21(A) of the NEC®. . In addition to the substantiation information provided above for correlation purposes 40CCS should be included in applicable Articles, such as Article 250, and sections that specify grounding electrode conductor material. Public inputs have been submitted for this action in a number of sections. Listing: There are other grades of copper-clad steel available and this change is to be specific to Grade 40CCS conductor material. To ensure that the conductor material being installed is Grade 40CCS, the conductor material should be listed to the applicable ASTM standards. In addition to ensuring there is 40 percent copper cladding on the steel core, suitable tensile strength, and other factors the listing also ensures the critical aspect of the corrosion resistant properties of 40CCS, a copper bimetal, are provided through the metallurgical bond between the steel and the copper. A listing would guarantee the metallurgical bond, the hallmark of a true bimetal. The listing and suitable markings on tags or packaging also provides the installer and inspector the information needed to make and approve the installation.

Related Public Comments for This Document

<u>Related Comment</u>	<u>Relationship</u>
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	CCS Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	CCS Bonding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	CCS Grounding Conductors

Submitter Information Verification

Submitter Full Name: Peter Graser

Organization: Copperweld

Affiliation: American Bimetallic Association

Street Address:

City:

State:

Zip:

Submittal Date: Sun Aug 23 15:22:11 EDT 2020

Committee: NEC-P16

Committee Statement

Resolution: The existing text states "or equivalent" which is inclusive of copper-clad steel. The addition of "copper-clad steel" provides no additional clarity.

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



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Public Comment No. 906-NFPA 70-2021 [Section No. 250.191]

250.191 Grounding System at Alternating-Current Substations.

For ac substations, the grounding system shall be in accordance with Part III of Article 00250.

Informational Note: For further information on outdoor ac substation grounding, see IEEE 80-2013, *IEEE Guide for Safety in AC Substation Grounding*.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
CN_144.pdf	70_CN144

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 144 appeared in the First Draft Report.

The Correlating Committee directs that the reference to "Part III of Article 00250" be corrected to "Part III of this article". In addition, the Informational Note to this section shall be revised in accordance with 4.1.3 of the Style Manual.

Related Item

- Correlating Note No. 144

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 04 16:13:35 EDT 2021
Committee: NEC-P05

Committee Statement

Committee Action: Rejected but see related SR
Resolution: SR-8075-NFPA 70-2021
Statement: Revisions to text are made to comply with NEC Style Manual Section.

**Correlating Committee Note No. 144-NFPA 70-2021 [Section No. 250.191]****Submitter Information Verification**

Committee: NEC-AAC

Submittal Date: Tue May 04 17:11:53 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee directs that the reference to "Part III of Article 00250" be corrected to "Part III of this article". In addition, the Informational Note to this section shall be revised in accordance with 4.1.3 of the Style Manual.

Ballot Results

✓ **This item has passed ballot**

12 Eligible Voters

0 Not Returned

12 Affirmative All

0 Affirmative with Comments

0 Negative with Comments

0 Abstention

Affirmative All

Ayer, Lawrence S.

Gallo, Ernest J.

Hickman, Palmer L.

Holub, Richard A.

Hunter, Dean C.

Johnston, Michael J.

Kendall, David H.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Porter, Christine T.

Williams, David A.

**Public Comment No. 762-NFPA 70-2021 [Section No. 250.194]****250.194** Grounding and Bonding of Fences and Other Metal Structures.

Metallic fences enclosing, and other metal structures in or surrounding, a substation with exposed electrical conductors and equipment shall be grounded and bonded to limit step, touch, and transfer voltages.

(A) Metal Fences.

If metal fences are located within 5 m (16 ft) of the exposed electrical conductors or equipment, the fence shall be bonded to the grounding electrode system with wire-type bonding jumpers as follows:

- (1) Bonding jumpers shall be installed at each fence corner and at maximum 50 m (160 ft) intervals along the fence.
- (2) If bare overhead conductors cross the fence, bonding jumpers shall be installed on each side of the crossing.
- (3) Gates shall be bonded to the gate support post, and each gate support post shall be bonded to the grounding electrode system.
- (4) Any gate or other opening in the fence shall be bonded across the opening by a buried bonding jumper.
- (5) The grounding grid or grounding electrode systems shall be extended to cover the swing of all gates.
- (6) The barbed wire strands above the fence shall be bonded to the grounding electrode system.

Alternate designs performed under engineering supervision shall be permitted for grounding or bonding of metal fences.

Informational Note No. 1: A nonconducting fence or section may provide isolation for transfer of voltage to other areas.

Informational Note No. 2: See IEEE 80-2013, *IEEE Guide for Safety In AC Substation Grounding*, for design and installation of fence grounding.

(B) Metal Structures.

All exposed conductive metal structures, including guy wires within 2.5 m (8 ft) vertically or 5 m (16 ft) horizontally of exposed conductors or equipment and subject to contact by persons, shall be bonded to the grounding electrode systems in the area.

Additional Proposed Changes

<u>File Name</u>	<u>Description Approved</u>
5_CN_145.pdf	5 CN145

Statement of Problem and Substantiation for Public Comment

NOTE: The following CC Note No. 145 appeared in the First Draft Report on First Revision No. 8273.

The Correlating Committee asks that the Panel review the use of the term "metallic" vs. "metal" in regards to 3.2.4 and the use of "Standard Terms" in the document.

Related Item

- First Revision No. 8273

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 04 09:28:43 EDT 2021

Committee: NEC-P05

Committee Statement

Committee Rejected but see related SR

Action:

Resolution: SR-8076-NFPA 70-2021

Statement: Revisions to text are made to comply with NEC Style Manual and the use of "Standard Terms" in Annex A of the NEC Style Manual.

**Correlating Committee Note No. 145-NFPA 70-2021 [Section No. 250.194]****Submitter Information Verification**

Committee: NEC-P05

Submittal Date: Tue May 04 17:14:58 EDT 2021

Committee Statement

Committee Statement: The Correlating Committee asks that the Panel review the use of the term "metallic" vs. "metal" in regards to 3.2.4 and the use of "Standard Terms" in the document.

First Revision No. 8273-NFPA 70-2020 [Section No. 250.194]

Ballot Results

✓ **This item has passed ballot**

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

Affirmative All

Ayer, Lawrence S.
Gallo, Ernest J.
Hickman, Palmer L.
Holub, Richard A.
Hunter, Dean C.
Johnston, Michael J.
Kendall, David H.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Porter, Christine T.
Williams, David A.